“Not this, but that.”
Exploring disambiguation in the context of multilingual word learning.

Katharina Maria Repnik

Doctor of Philosophy

Linguistics and English Language

School of Philosophy, Psychology and Language Sciences

The University of Edinburgh

2021

Abstract

Growing up and living with more than one language modulates new language learning in a variety of ways. Similarities and differences to monolinguals with regards to languages learning in all its aspects were found. These range from phonology to pragmatics. However, non-linguistic domains, such as cognition, can also be affected by the multilingual experience.

The acquisition of words is an indispensable step in learning a language, be that one's first or subsequent languages. To learn a word, its word form must be correctly mapped onto its meaning and then remembered. One 'strategy' children and adults implicitly employ to map a new label to a new item or concept is referred to as *disambiguation*. This mental process is analogous to the common process-of-elimination and based on the Disjunctive Syllogism. The idea is that a new label refers to a novel object in the presence of familiar items creating the support for one-to-one mappings between a word and its referent. Attaching a new label to a new label-unknown object rather than a familiar label-known object expedites vocabulary growth, especially in children. Although this mental process can be found in adults too, it was predominantly studied in the context of word learning in children, and more recently multilingual children.

The interest in researching disambiguation in multilingual contexts arose as researchers began to wonder if people, who grew up and were exposed to more than one language, would exhibit the so-called *disambiguation effect* at all given that they know multiple labels for the same objects. The formulation of many-to-one mappings stands in opposition to one-to-one mappings mentioned above. However, does this mean that multilingual children and adults never disambiguate? The answer to this question cannot be binary, considering the myriad of direct and indirect effects multilingualism has on word learning.

In this thesis, I explore the use of disambiguation in various multilingual contexts:

1. Disambiguation studies on children are usually conducted under the scope of word learning, which consists of mapping and retention of words; however,

only very few studies explicitly explore the relationship between the mapping of a new word and the ability to retain it. In this first study, I explored whether and how monolingual and multilingual children's use of disambiguation as a fast mapping constraint boosted their ability to retain this new mapping within the same experiment. For this, I designed and adapted a looking-while-listening eye-tracking paradigm to allow for data collection within a young population (aged 18 to 30 months old). I found that children from monolingual and multilingual backgrounds are able to use disambiguation as mapping strategy; however, they differ with regards to how disambiguation modulated their ability to retain the new word. Whilst the use of disambiguation positively affected monolingual children's retention performance, children from multilingual backgrounds did not display this boosting effect. Thus, it can be said that disambiguation starts out as default mapping strategy that in some, but not other, cases develops into a more consolidated learning/retention strategy.

2. In a second study, I examined whether disambiguation as a mapping strategy is prevalent in multilingual adults and how their multilingual experience may modulate the processing speed of this process-of-elimination. Multilingualism does affect a person's learning not only directly but also indirectly. An accumulating amount of research is currently being conducted on the mutual effects of multilingualism and executive functioning with findings addressing cognitive domains such as working memory and cognitive control. As these findings allude to differences in cognitive processing, any task requiring the contribution of these skills, such as the one in this study, one must control for these variations. In this study, I explored the individual contributions of multilingualism and executive functioning to a fast mapping and retention task. Language experience variables strongly modulated the accuracy and processing times of disambiguation and retention conditions, whereby speed-accuracy trade-offs were found. Furthermore, working memory and cognitive control impacted the accuracy and reaction times. Those with better scores on the working memory task also performed faster. Results highlight the

requirement for regarding multilingualism as a multivariate spectrum in future research rather than in dichotomous categories.

3. In a third study, I extended the context of disambiguation by not only examining its use on mappings between words and objects but also on mappings between factual information and objects. Factual information about items in this study are, for instance, *"this is the one I keep in the living room"*. Studies with young children have shown their tendency to transfer the use of disambiguation onto other domains of language learning, such as assigning new factual information to an unfamiliar object rather than a familiar name-known object. However, it is self-evident that adults may not show this transfer of disambiguation due to their ability to draw from other forms of knowledge, such as their cognitive, semantic, and pragmatic abilities, and life experience in general. In this study, I examined how multilinguals adults' linguistic experience impacts on the use of disambiguation in factual contexts by looking at eye-gaze data. Furthermore, I probed participants' underlying decision-making processes by questioning their choices after specific trials. The results showed that adults do not extend disambiguation to contexts other than labels, but that language background did modulate those instances in which disambiguation took place based on contrast.

In conclusion, it can be said that disambiguation is a sound strategy for making fast decisions about labels and how they attach to meaning. However, the investigations in this thesis also show that the context in which disambiguation is to be used is paramount to its success or someone's implicit decision to rely upon it. Lastly, this thesis and its findings contribute to the modern view that multilingualism is a continuum and should be researched and regarded from a holistic angle.

Lay Summary

Growing up and living with more than one language influence the learning of a new language in a variety of ways. Researchers found similarities and differences between people who speak one or more languages in many areas of language research. These findings could range from how sounds are learned to how language is used in social situations. However, other domains, such as cognition, can also be affected by the multilingual experience.

Learning new words is an indispensable step in learning a language, be that one's first or subsequent languages. To learn a word, its word form must be correctly linked to its meaning and then remembered. One 'strategy' children and adults implicitly employ to map a new label to a new item or concept is referred to as *disambiguation*. This mental process is analogous to the common process-of-elimination. The idea is that a new name relates to a novel object in the presence of familiar items creating the support for one-to-one mappings between a word and its referent. Attaching a new label to a new label-unknown object rather than a familiar label-known object facilitates vocabulary growth, especially in children. Although this mental process can be found in adults too, researchers have mostly studied it in the context of word learning in children, and more recently multilingual children.

The interest in researching disambiguation in multilingual contexts arose as researchers began to wonder if people, who spoke more than one language, would exhibit the so-called *disambiguation effect* at all. This was because they already know many labels for the same objects. The creation of many-to-one mappings stands in opposition to one-to-one mappings mentioned above. However, does this mean that multilingual children and adults never disambiguate? The answer to this question cannot be black or white, considering the many direct and indirect effects multilingualism has on word learning.

In this thesis, I explored the use of disambiguation in various multilingual contexts:

1. Disambiguation studies on children are usually conducted under the scope of word learning, which consists of mapping and retention of words. However,

only very few studies explicitly explore the relationship between the mapping of a new word and the ability to retain it. In this first study, I explored whether and how monolingual and multilingual children's use of disambiguation as a fast mapping strategy helped them to retain this new mapping within the same experiment. For this, I designed and adapted an eye-tracking design to allow for data collection within a young population. I found that children from monolingual and multilingual backgrounds are able to use disambiguation as mapping strategy; however, they differ with regards to how disambiguation modulated their ability to retain the new word. Using disambiguation positively affected monolingual children's retention performance, but not that of multilingual children. Thus, disambiguation starts out as default mapping strategy that in some, but not other, cases develops into a more consolidated learning/retention strategy.

2. In a second study, I examined whether disambiguation as a mapping strategy exists in multilingual adults and how their multilingual experience may affect the processing speed of this process-of-elimination. Multilingualism does affect a person's learning not only directly but also indirectly. A growing amount of research is currently being conducted on the mutual effects of multilingualism and cognitive functioning with findings addressing cognitive domains such as working memory and cognitive control. As these findings mention differences in cognitive processing, any task requiring these skills, such as the one in this study, one should aim to control for these variations. In this study, I explored the individual contributions of multilingualism and cognitive functioning to a fast mapping and retention task. Language experience variables strongly affected the accuracy and processing times of disambiguation and retention conditions. Furthermore, cognitive abilities also impacted participants' performance.
3. In a third study, I extended the context of disambiguation by not only examining its use on mappings between words and objects but also on mappings between objects and factual information about the objects. Factual information about an object would be saying *"this is the one I keep in the living room"*, for example. Studies with young children have shown their tendency

to transfer the use of disambiguation onto other domains of language learning, such as assigning new factual information to an unfamiliar object rather than a familiar name-known object. In this study, I examined how multilinguals adults' language experience impacts on the use of disambiguation in factual contexts by looking at eye-tracking data. Furthermore, I explored people's underlying decision-making processes by questioning their choices at specific times. Results showed that adults, unlike children, do not transfer the use of disambiguation on to facts.

In conclusion, one can say that disambiguation is a sound strategy for making fast decisions about labels and how they attach to meaning. However, the investigations in this thesis also show that the context in which one uses disambiguation is paramount to its success or someone's implicit decision to rely upon it. Lastly, this thesis and its findings contribute to the modern view that multilingualism is a sliding scale, and it should be regarded from a holistic angle.

Kurzzusammenfassung

Mehrsprachig aufzuwachsen und zu leben kann den Erwerb neuer Sprachen auf verschiedenste Art und Weise beeinflussen. Sowohl Gemeinsamkeiten als auch Unterschiede zum einsprachigen Spracherwerb wurden in all seinen Facetten gefunden. Diese können von der Phonologie bis hin zur Pragmatik reichen. Darüber hinaus sind auch außersprachliche Bereiche betroffen, wie etwa die Kognition.

Die Aneignung neuer Worte ist ein unabdingbarer Schritt des Erlernens einer Sprache, sei dies im Erwerb der ersten, zweiten oder weiterer Sprachen. Um ein Wort zu erlernen muss zunächst die Form des Wortes, also die Buchstabenfolge, mit dessen Bedeutung korrekt verknüpft und anschließend abgespeichert werden. Eine „Strategie", die Kinder und Erwachsene implizit dazu nutzen nennt man *Disambiguierung*, welche analog zum Prozess der Eliminierung funktioniert und auf dem Disjunktiven Syllogismus beruht. Die Idee ist dabei, dass ein neu auftauchende Bezeichnung einem neuen und unbekannten Objekt oder Konzept zugeordnet wird sollte jenes im Beisein bekannter Objekte erscheinen. Dies hilft eins-zu-eins Assoziationen zwischen einem neuen Wort und dessen Referent zu schaffen, anstatt einem bereits bekannten Objekt eine weitere Bezeichnung zu geben. Das Erschaffen solcher Assoziationen fördert das Wachstum des Vokabulars, vor allem bei Kindern. Obwohl dieser Prozess auch bei Erwachsenen stattfindet, wurde er vermehrt im Kontext der Sprachentwicklung bei Kindern und seit kurzem auch bei mehrsprachig aufwachsenden Kindern erforscht.

Das Interesse an der Erforschung von Disambiguierung im Zusammenhang mit der Mehrsprachigkeit wuchs, als Forscher sich die Frage stellten, ob mehrsprachige Menschen ebenfalls den in der einschlägigen Literatur genannten *disambiguation effect* zeigen, zumal diese Menschen von Grund auf mehrere Bezeichnungen für dasselbe Objekt kennen. Diese Bildung solcher mehrgliedrigen Assoziationen steht im Gegensatz zu den obengenannten Einzelverbindungen. Bedeutet dies jedoch, dass mehrsprachige Kinder und Erwachsene niemals disambiguieren? Diese Frage kann nicht mit einem kategorischen Ja oder Nein beantwortet werden, wenn man die vielen direkten und indirekten Einflussfaktoren der Mehrsprachigkeit auf den Worterwerb berücksichtigt.

In der folgenden Doktorarbeit untersuchte ich die Verwendung der Disambiguierung in verschiedenen mehrsprachigen Zusammenhängen:

1. Studien über Disambiguierung werden oftmals im Zuge des kindlichen Worterwerbs, welcher aus *fast mapping* und *retention* besteht, formuliert. Dennoch gibt es bis jetzt nur wenige Studien die den expliziten Zusammenhang zwischen des Assoziierens des Wortes mit dem Objekt (*fast mapping*) und der Fähigkeit diese Verbindung im Gedächtnis zu behalten (*retention*) erläutern. In dieser ersten empirischen Studie mit ein- und mehrsprachigen Kinder untersuchte ich, ob und inwiefern die Verwendung der Disambiguierung als Methode schnelle Assoziationen zu bilden auch ihre Fähigkeit jene mental abzuspeichern begünstigen würde. Dazu entwickelte ich ein Eye-Tracking Paradigma, um Daten bei einer jungen Bevölkerung (im Alter von 18 bis 30 Monaten) zu erheben.
2. In einer zweiten Studie untersuchte ich, ob Disambiguierung als *Mapping*-Strategie auch in mehrsprachigen Erwachsenen vorzufinden war und inwiefern sich deren Mehrsprachigkeit auf die Geschwindigkeit des Eliminierungsprozesses auswirkte. Die Mehrsprachigkeit kann das Lernen nicht nur direkt, sondern auch indirekt beeinflussen. Immer mehr Forschung wird momentan betrieben welche die gegenseitigen Einflüsse von Mehrsprachigkeit und kognitiven Funktionen adressiert. Dabei werden kognitive Domänen, wie etwa das Arbeitsgedächtnis (working memory) und die Kontrolle kognitiver Unterprozesse (cognitive control) in Betracht gezogen. Da diese Studien Unterschiede zwischen ein- und mehrsprachigen Menschen erwähnen, sollten diese Variierungen mit einbezogen werden bei einer Studie wie hier. In dieser Studie erforschte ich die gegenseitige Mitwirkung von Mehrsprachigkeit und mancher kognitiven Prozesse, welche auch als *executive functioning* bekannt sind, auf ein *fast mapping* und *retention* Experiment. Die Ergebnisse heben hervor, dass sich die Forschung zukünftig mit der Mehrsprachigkeit als variables Spektrum auseinandersetzen sollte, anstatt diese kategorisch abzuhandeln.

3. In einer dritten Studie untersuchte ich die Disambiguierung auch in anderen Zusammenhängen. Dabei wurde nicht nur der Zusammenhang zwischen einem Wort und dessen Referenzobjekt, sondern auch zwischen einem Objekt und einer sachlichen Information genauer betrachtet. Studien mit jungen Kindern zeigten, dass diese dazu tendierten Disambiguierung als *Mapping*-Strategie auch auf andere Domänen des Spracherwerbs anzuwenden, wie etwa die Assoziation von einer Information mit einem unbekannten anstatt einem bekannten Objekt. Es wird jedoch schnell klar, dass Erwachsene aufgrund sowohl ihrer kognitiven, semantischen und pragmatischen Fähigkeiten also auch ihrer allgemeinen Lebenserfahrung dieses Verhalten eher nicht zeigen. In dieser Studie mit mehrsprachigen Erwachsenen untersuchte ich die Verwendung von Disambiguierung im Kontext von Fakten mittels einer Eye-Tracking Studie. Ferner prüfte ich den Entscheidungsprozess mittels stichprobenartiger Fragen während des Experiments.

Zusammenfassend kann festgehalten werden, dass die Disambiguierung eine solide Strategie ist, um neuen Dingen und Konzepten eine Bezeichnung zuzuschreiben. Dennoch haben die Investigationen in dieser These auch gezeigt, dass der Kontext in welchem disambiguiert werden soll maßgeblich dafür entscheidend ist darüber, ob sich eine Person implizit dazu entschließt diesen Prozess anzuwenden. Zuletzt trägt diese empirische Abfassung dem zeitgenössischem Blickwinkel bei, dass Mehrsprachigkeit ein Spektrum ist und auch als solches ganzheitlich betrachtet und erforscht werden sollte.

when all of this is over, I…

love me like there ain’t another day

lead with the heart, ain’t that the only way?

keep thinkin’ ‘bout how much I changed today.

- *Dermot Kennedy*

Acknowledgements

My time in Edinburgh and pursuing this degree have been transformational on so many levels that I could comfortably write another dissertation about those. I still remember the first night I had arrived here years ago. I was walking over North Bridge and thinking to myself that I was right where I was meant to be. It was here that I fell in love with life. This would not have been possible were it not for some seriously important people in my life.

I want to thank Dr Jürg Strässler whom I met during my undergraduate in Zurich. It was due to his incredible support and faith in me that I had been able to embark upon this journey. *Lieber Jürg, Ich danke dir aus tiefstem Herzen für all Deine Unterstützung. Ich bin froh in Dir einen so herzensguten Menschen als Freund zu haben. Merci!*

Furthermore, I thank my supervisors, Prof Antonella Sorace and Dr Vicky Chondrogianni, for their guidance.

Of course, my research would have been impossible without the countless parents, children and adults, many of whom were fellow PhD students, who participated in my sometimes quite amusing studies. We shared some good laughs in the eye-tracking room, and I felt pure joy getting out those Lego Duplo stones to play with the children.

I want to thank my friends, who helped me through some really rough times and followed me along this rollercoaster ride.

Namasté to the practice of Yoga for keeping me healthy, physically and more importantly emotionally and mentally. I cannot wait to study the Philosophy of Yoga further in the years to come.

Liebe Mamsi, natürlich möchte ich auch Dir danken für deine Liebe, Vertrauen und Unterstützung auf jeglicher Ebene. Du hast immer an mich geglaubt und wusstest, *dass ich alles schaffen kann. Dennoch hast Du mein ganzes Leben lang Deine Liebe nie an irgendeine Bedingung geknüpft und dieses Urvertrauen, das du in mich hast, spüre ich jeden Tag. Ich bin so unendlich dankbar, dass das Universum unsere Energien zusammengeführt hat. Ich hab Dich lieb.*

Finally, I want to thank myself for being such a legend. For having pulled through like an absolute boss even at times when all I wanted was to give up. I learnt how to prioritise my mental health, realised where my values lie and how to find love and peace within myself. I feel nothing but gratitude for my journey.

Contents

List of Figures

List of Tables

1 Introduction

Being born into and living in an increasingly connected world means that people from all around the globe can come in contact with people of different cultures. To successfully communicate with those from other places, speaking one language no longer suffices, and in fact, more than half of the global population speaks more than one language. One might say that being bilingual or multilingual represents the majority of the population; yet linguistic research has only recently been catching up studying bilingual people. The standard, in many cases, has been to examine language acquisition and processing within monolinguals. Drawing conclusions about bilinguals from theories based on monolingual research is problematic, as a bilingual is not merely two monolinguals in one person. Thus, these conclusions would not adequately describe the multifaceted experience of being bilingual. Manoeuvring between multiple languages, using them skilfully, and learning them in the first place requires a lot of flexibility and adaptability, and, therefore, challenges many traditional theories and models which tend to be more static. At the same time, it is precisely this challenge that can further our understanding of languages. This is because multilingualism renders it possible to test various theoretical models in different circumstances, and by doing so, we can further fine-grain and iterate these models. In this thesis, I explore how one mechanism, which is based on the well-known process-of-elimination, interacts with multilingualism, and what we can learn from doing so.

Whenever we encounter new objects for which we do not the name, we will have to engage in a mapping process that links the label to an object or referent. This initial mapping is the first step of learning the meaning of a new word. Upon hearing a new name, there may be many potential candidates of referents available that could be attached to the new label, which is termed referential ambiguity. To resolve referential ambiguity, research from the past 30 years has revealed that people, children and adults alike, exhibited the so-called *disambiguation effect* when they face one novel and one familiar object and hear a new label at the same time. In other words, once people hear a new label, they tend to attach it onto a new and unfamiliar referent instead of an object they already know. One might also say that they eliminate competing referents based on prior knowledge about words, which is akin to a process-of-elimination as we find them in non-linguistic domains.

This thesis aims to investigate how disambiguation behaves or changes if one keeps the multifariousness of speaking and learning two or more languages in mind. The multilingual experience can vary due to different amounts of exposure to each language, the age of acquisition, language proficiency and dominance, the number of languages spoken, or whether we examine children or adults to name but a few. All these differences render multilingualism incredibly complex and provide ways of testing theories in different ways since not all these variables show the same type of variety within monolinguals.

Moreover, another critical aspect that can impact on the language processing of multilinguals is that they must juggle two or more languages which inevitably leads to co-activation of languages. In order to manoeuvre this co-activation, one is required to suppress the language currently not in use. This suppression of language seems to relate to cognitive processes unspecific to language processing, such as inhibitory skills and attention. Although the focus of this thesis remains on how disambiguation is affected by multilingualism, it is essential to account for potential individual differences in these cognitive abilities whenever possible and required by the task.

In order to investigate in which ways multilingualism can be modulated, I highlight the multifariousness of being raised and living with multiple languages (chapter 2). I describe various types of bilingualism showing that bilingualism is more than solely speaking two languages. Multilingualism is an experience with many changing variables, and it is essential to consider these dimensions wherever possible. Furthermore, I evaluate various models on executive functioning and working memory, as multilingualism is not only affected by the various linguistic variables but also effects in non-linguistic cognitive domains. Hence, it is also crucial to account for implied differences in these non-linguistic cognitive domains wherever feasible.

In order to examine how disambiguation changes from childhood to adulthood, I present an overview of bilingual language acquisition and lexical access in chapter 3. I describe the fundamental developmental stages involved in language acquisition that should have happened before word learning commences. It is imperative to note this because multilingualism can influence any of the linguistic domains, be that the level of speech recognition and segmentation or grammar. Despite the focus of this thesis being on a process involved in word mapping and learning and how multilingualism might affect those, one should recognise that the effects of the multilingual experience are much wider. Learning an entirely new language has an impact on accessing words in adulthood; therefore, I interpret several models on bilingual lexical access that help to grasp what the most striking challenges are when multilinguals retrieve words from their lexicon. Accessing words is a vital process when recalling a word from memory, which was required in one of the studies testing adult participants.

In order to link disambiguation to word learning, I introduce specific concepts on word learning, namely *fast mapping*, and *slow learning* or retention, and how these two relate to each other (chapter 4). Furthermore, I explain the *disambiguation effect* in-depth together with its computational processes and underlying theoretical motivations according to different schools of thought. I introduce three significant studies of which the first tested disambiguation within young children (Halberda, 2003). The second tested monolingual, bilingual, and trilingual children on the same paradigm that lead to claims of multilingualism being a modulating factor in the use of disambiguation (Byers-Heinlein & Werker, 2009). The third tested (monolingual) children at the same age on how well they retained a word after having just learnt it (Bion, Borovsky, & Fernald, 2013). I follow with a review of more current studies on how disambiguation is affected by multilingualism in children and adults. Finally, I approach the applicability of disambiguation in contexts that do not involve mapping a word to an object, but rather associating factual expressions to an object.

Based on the reviewed literature, I formulate the following three research questions:

- How do monolingual and multilingual children use disambiguation as a mapping and retention strategy over the ages from 18 – 30 months (study 1)?
- How do multilingualism and executive functioning affect how multilingual adults engage in the process-of-elimination during fast mapping and retention (study 2)?

- Is disambiguation adopted in other referential contexts, such as facts, by multilingual adults? If not, what other strategies may they rely upon to form a conclusion (study 3)?

To address these questions, I designed three experimental studies.

In this first study, I explore whether and how monolingual, and multilingual children's use of disambiguation as a fast-mapping constraint boosts their ability to retain this new mapping within the same experiment. For this, I adopt a looking-while-listening eye-tracking paradigm to allow for data collection within a young population (aged 18 to 30 months old).

In a second study, I examine whether disambiguation as a mapping strategy is prevailing in multilingual adults and how their multilingual experience may change the processing speed of this process-of-elimination. Multilingualism influences a person's learning not only directly but also indirectly. An accumulating amount of research is currently being conducted on the mutual effects of multilingualism and cognitive functioning with findings addressing cognitive domains such as working memory and cognitive control. In this study, I explore the mutual contributions of multilingualism and cognitive functioning to a fast mapping and retention task.

In a third study, I widen the context of disambiguation by not only testing its use on mappings between words and objects but also on mappings between factual information and objects. Studies in young children have shown their bias to transfer the use of disambiguation onto other domains of language learning, such as designating new factual information to an unknown object rather than a familiar name-known object. However, adults may not do so due to the full development of their cognitive, semantic, and pragmatic abilities and life experience. In this study, I examine how multilinguals adults' linguistic experience influences the use of disambiguation in factual contexts by looking at eye-gaze data. Furthermore, I explore their underlying decision-making processes by questioning participants' choices.

This thesis shows that exploring a mechanism, such as disambiguation, under the magnifying glass of multilingualism furthers our understanding of the theoretical underpinnings of word mapping and learning. Disambiguation is not a static process, and factoring in the varied experience of bilinguals and multilinguals prevents us from making sweeping generalisations. More generally, this thesis challenges future research to incorporate the multilingual experience as a means to reassess existing theoretical models.

2 Multilingualism: A multi-faceted experience

This chapter first discusses the multifariousness of growing up and living with two or more languages by reviewing the different types of multilingualism and highlighting how problematic finding one universal definition for bilingualism and multilingualism is (2.1). Then a discussion of the language experience variables, such as language exposure or proficiency, impacting directly on the multilingual experience follows (2.2). Lastly, I examine accounts of executive functioning (2.3), including cognitive control and working memory, as well as long-term memory relating to multilingualism.

2.1 Definition and types of bilingualism and multilingualism

With ever-evolving technological advancements and people travelling all corners of the globe, defining bilingualism has become increasingly complex. The problem starts with the terms ‘bilingualism’ and ‘multilingualism’, which are often used synonymously but are also regarded as different experiences, especially in the field of language acquisition. Depending on the context, being multilingual can mean the ability to express oneself in more than one language; however, what about a ‘monolingual’ person who understands another language, but does not speak it? This is a case often found in people who have moved to a new country at a young age where they then acquired the new local language, but may no longer receive enough opportunities to speak the native language. Would these not be considered bilingual to some extent? What about someone who learned a second language at an older age who is perfectly capable of communicating in this language? While they might have a foreign language accent, would we not consider them bilingual? In everyday language, people often assume that people only fall into the bilingual category if they speak two languages to equal professional ability and have grown up with two languages. However, in language research, this narrow definition does not encompass the multifariousness of bilingualism or multilingualism. With increasing research in the field of bilingualism (henceforth used interchangeably with multilingualism) carried out over the past decades, a variety of different types of bilingualism have emerged. The most widely known, perhaps, is referred to as 'simultaneous bilingualism' whereby a child is exposed to two or more languages directly from birth on usually through their caregivers.

Further to that, developmental linguists distinguish between 'early' and 'late' sequential bilingualism. The former describes a population of bilinguals who started exposure to the first language from birth followed by another language during childhood; the latter includes bilinguals who began their second language later, often in the context of formal schooling. In the sphere of adult bilingualism, the term 'late bilinguals' is widely encountered. A late bilingual is usually someone who only spoke their first language well into adulthood, and later on learns an additional language. At first, these definitions seem very neat and clear cut; however, one should be aware that a bilingual can also fall into multiple of these categories, and the reality is often more complicated. Someone could, for instance, have grown up with German and Greek simultaneously from birth on, and then learnt English and French in school, and some basic Italian during university. This simple example illustrates that while the different definitions are helpful to describe certain features of bilinguals, the individual experience a bilingual undergoes is more far more complex. The opposite side of the same coin is displayed in the phenomenon of decreasing monolingualism, as fewer and fewer 'pure' monolinguals under a certain age can be located. Thus, rather than categorising people as monolingual or bilingual, researchers have started to describe the bilingual experience in the context of a bilingual spectrum or continuum. A variety of factors affect where a multilingual person finds themselves on the spectrum. These factors will be discussed in the next section.

2.2 Multilingual Experience factors

On a fundamental level, communicating using language requires a certain degree of comprehension and production of the language. In language development, be it in children or adults, improving comprehension precedes production (Clark & Hecht, 1983). It is when these skills are being moulded that specific factors can fundamentally shape the experience of bilingualism. In order to form rules, infer meaning, and establish patterns about the new language being learnt, a person needs to receive language input or exposure. The first input-related factor is quantity, as only with a sufficient amount of language input will a learner be able to internalise the language.

From a practical point of view, it can be challenging for parents who are raising their child with two or more languages to provide enough input in each language, as a day only has 24 hours, and children are also required to sleep and parents to work should it be the case that both parents work. The remaining waking contact hours with the child have to be divided by the respective number of languages if one aims for an even spread of input. In reality, this is often impossible, as children also attend nursery where the staff might speak a language that is not spoken at home. Looking at foreign language teaching at secondary schools presents another example of quantity as a decisive factor. Students who attend two hours versus six hours of French class do not share the same amount of exposure which can have a direct effect on students' French proficiency. Having to study other subjects at school in addition to languages does not leave much room for increasing language learning contact hours. Generally, it can be said that the more input or exposure a bilingual has received in their languages, the higher the likelihood will be that they can use these languages at a proficient level.

Concerning the quantity of input, another related factor is the differing language patterns that a bilingual will have been exposed to in their lifetime. Someone who grew up with two languages from birth has a different language profile than someone who was exposed to two initially and then three more in adulthood, for example. Especially for parents, it can be difficult to manoeuvre this tricky subject-matter. Some parents decide to employ a one-parent-one-language strategy which is a sensible decision if each of them speaks one language they wish to impart onto their child. Not every circumstance, however, warrants this to be the best strategy. In a seminal study by De Houwer (2007), over 1.500 bilingual families (with at least one child) were asked to complete a detailed questionnaire about their language input patterns. At least one parent spoke another language X that was not the majority language of the community, Dutch. De Houwer measured the effect of language input patterns in the parent pair on the children's use of the other language X.

Unsurprisingly, in cases where both parents spoke the other language X, at least one child spoke said language 96.3% of the time. When parents used a one-parent-one-language pattern (i.e., one parent spoke Dutch, the other language X), the use of language X dropped to 74.2% for the child. The most revealing result of this study, however, is presented in families where both parents used language X, and only one of them used Dutch. Here, at least one child of the family spoke the minority language 93.42% of the time. Compared to families where both parents spoke the minority language, but not Dutch, the difference in children's language use is negligible. By far the least successful language input pattern in terms of language transmission was found in families where both parents used Dutch, and only one of them spoke the minority language X. The transmission rate of the minority language for children dropped to 35.7%, or in other words, the chance of having a child who uses language X was one in three[1].

Parents deciding to speak a non-native (to themselves) language to their child also raises the question of language quality, and whether poor quality input has adverse effects on the child's bilingualism. Studies found that bilingual children possessed more comprehensive language knowledge when more input was received by a native rather than a non-native speaker of this language (Place & Hoff, 2011). The number of speakers a child actively encounters also impacts second language learning, with a higher number having boosting effects (Gollan, Starr, & Ferreira, 2014). Social live interaction, as opposed to instruction via video, also revealed to be a mattering factor modulating input quality. English-learning children who were exposed to Mandarin over several sessions demonstrated learning effects only if they had been exposed to the live speaker (Kuhl, Tsao, & Liu, 2003). Research has also demonstrated that language exposure, which is quality and quantity of linguistic input combined, shape the distribution of language dominance for each of a bilingual's language (Unsworth, 2015, 2016; Unsworth et al., 2014). Furthermore, neuroimaging studies revealed that cortical activity during lexical retrieval changes based on the amount of exposure (Perani et al., 2003).

---

[1] In families with more than one child, the majority of children (93.5% of 1.520 families) within the same family exhibited the same pattern of language use (DeHouwer, 2007, p. 414).

Whilst the notion that one cannot learn a language later in life is no longer entertained, the age of acquisition is an essential factor and has been prevalent since 1959 when Penfield and Roberts first proposed the Critical Period Hypothesis (CPH) which was later popularised by Lenneberg (1967). The CPH is formulated on the idea that there is a time window in which sensitivity to language learning is increased due to higher brain plasticity (Birdsong, 2005). However, no consensus has been reached as to what constitutes the upper limit of that period, and whether it exists. Nonetheless, studies demonstrated a significant modulation in the attainment of a second language based on the age of acquisition (Abrahamsson & Hyltenstam, 2009; DeKeyser, 2000; Johnson & Newport, 1989). From a neurological perspective, we know that the age of acquisition also impacts the brain structure with regards to language lateralisation (Hull & Vaid, 2007), and cortical thickness of the inferior frontal gyri (D. Klein, Mok, Chen, & Watkins, 2014).

Another dimension in which bilinguals vary is their degree of proficiency and if they are active or passive users of a language which addresses the previously mentioned idea of understanding, but not necessarily speaking another language. Passive language knowledge is often due to lack of exposure and reaching a certain level of proficiency, but can also be the result of language attrition. Language attrition can be defined in terms of first or second language attrition, whereby the former constitutes the case of natural, selective and predictable changes that take place in the first language of people who speak a second languages (Chamorro & Sorace, 2019). These changes could be, for instance, difficulty in retrieving the appropriate vocabulary or using untypical grammar. However, attrition can be reversed by re-exposure to the first language. The latter describes a case often found in people who have learnt a second language at some point in their life, often during secondary school, which they no longer or very seldomly use. Language use is directly related to language dominance, as bilinguals tend to use their most dominant language more often. Dominance in itself is modulated by their exposure to the language, their proficiency, confidence or preference to speak.

Fluent bilinguals often engage in code-switching if their interlocutor happens to know the same languages. Code-switching (CS) can occur within the same or consecutive conversational turn. Unlike often assumed by the general public or researchers outside the field of bilingualism, code-switching is neither a result of lack of proficiency, nor does it happen at random (Myers-Scotton, 2017). The degree of proficiency is often studied in the realm of switching between languages and associated cognitive switch costs. For example, asymmetric switch costs were observed when bilingual adults switched between their dominant and weaker language in that switching into the dominant language took longer than vice versa (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006). These results are often explained by the idea that more inhibitory control (see 2.3.1) is necessary to suppress the dominant language during access of the weaker language.

Another factor that can modulate the experience of bilinguals is the attitudes they hold towards specific languages, especially in the context of second language acquisition. Studies have shown that language attitudes can determine whether bilingual learners choose to engage in learning a specific language, especially in the context of schooling. Four key factors have been found to impact language attitudes, such as the instrumental value and status of the language, its perceived attainability, practical communication needs, and the learner's cultural identity (Chan, 2018). English, a language studied widely as *lingua franca*, is often favoured by learners over their native or other heritage languages, as it has been the case in studies testing Spanish-English bilinguals attending dual-language school (Babino & Stewart, 2017). However, a preference for English does not necessitate a negative attitude towards Spanish-speakers themselves (Miller, 2017).

Already this brief overview of factors impacting language dominance illustrates that the idea of a perfectly balanced bilingual is outdated. Linguistic exposure (quantity and quality), input patterns, age of acquisition, proficiency, and language attitudes, as well as differences between individuals all, contribute and shape the type of bilingualism and the placement on the bilingual continuum. In the studies part of this thesis, I specifically take into account the number of languages spoken, age of acquisition, language proficiency or vocabulary size (in the case of children), current language exposure, as well as English as L1.

2.3 Non-linguistic, cognitive abilities in multilinguals

The term *executive functioning (EF)* entails a variety of cognitive skills and mechanisms that the brain relies on to successfully master everyday tasks such as planning a trip to the grocery store. For this task, one needs to plan what food to buy there, change these plans to account for new and incoming information, shift between remembering the grocery list and focussing on driving the car to the shop, and inhibit distracting noises from traffic, for example. In laboratory settings, many tasks require EF for their successful completion, and specific tasks, such as the Flanker or Simon task, were created to measure different components of EF. One well-known model describes EF as entailing three core abilities: *inhibiting* prior stimuli or incoming interferences; *shifting* or switching between mental sets or tasks; and the *working memory*, which involves updating and monitoring of information and keeping it active and accessible (Miyake et al., 2000). Within working memory, the phonological loop is of utmost importance for language processing. It comprises a verbal short-term storage buffer that refreshes and maintains phonological information active for a short period (Montgomery, 2003). That is to say: the phonological loop keeps spoken language input stored long enough for it to be further processed by other faculties (Baddeley, Gathercole, & Papagno, 1998).

2.3.1 Inhibition and working memory

Inhibitory or cognitive control is a term used to describe inhibiting information or shifting between sets of tasks or information. Human cognition comprises a set of mechanisms that enable the regulation, coordination, and sequencing of thoughts and action in order to achieve behavioural goals. Of course, everybody regardless of their language background relies on these mechanisms to accomplish tasks such as learning to play the piano (e.g. Bialystok & DePape, 2009). Studies have shown that how someone is raised may shape how individuals perform on non-verbal tasks testing specific processes of cognitive (executive) control (e.g. Hedden, Ketay, Aron, Markus, & Gabrieli, 2008). An extensive discussion of executive function models is beyond the scope of this thesis; however, this section focusses on cognitive control models that are critical to studying bilinguals. These models have one crucial core element in common, namely inhibition. Seminal to the development of these models was Green's

Inhibitory Control Model (Green, 1998), which is solely based on inhibitory control and places focus on the local level, i.e. the linguistic representation. The following models incorporate further control processes to reduce some of the limitations posited in Green's model, such as the impact of individual differences (see DMC), additional layers of control mechanisms and the interaction amongst them (see Adaptive control hypothesis, Green & Abutalebi, 2013).

2.3.1.1 Inhibitory Control Model

The perhaps most impactful model of bilingual language control is the Inhibitory Control Model (ICM) developed by Green (1998). The ICM operates under these two crucial assumptions: (1) the requirement for higher-level task schemas, and (2) top-down control over the non-target word representations. To illustrate the first, consider tasks where a bilingual is asked to read in silence, read aloud, classify objects as animate or inanimate, translate, or the like. As these tasks are quite different from each other, they require different task schemas according to the ICM. A task schema is a mental rule or set of rules required to complete a task successfully. Interestingly, the 'winning' task schema is selected based on competition of different task schemas. Consider the Stroop task, for instance, which comprises a list of colour terms printed in mismatched ink, such as the term "blue" in red ink. The task is to name the colour of the ink, whilst inhibiting the urge to read the actual word, as doing so would lead to errors. The required schema would be "name-the-colour, which gets increasingly difficult for experienced readers, as the "read-the-word" schema is robust and will have to be inhibited (Paap, 2018). The second shared assumption is that representations of non-target items are controlled in a top-down manner; however, the ICM defines this assumption by stating that actual inhibitory control is not triggered until competitors for word production are being considered for processing. If in a picture-naming task, for instance, a pre-cue is given as to which language the target item has to be produced in, then a new task schema must be selected each time a language switch occurs. On a global inhibition level, every lexical item for the non-target language is inhibited. However, the foregoing specification indicates that actual inhibition is triggered only once the picture appears, the speaker plans to respond, and the processor traces competition between possible responses.

In summary, the ICM works under the assumption that task schemas function as global inhibitors of non-target words by blocking all lemmas under the non-target node that possess the non-target language tag, which enables quick filtering of unsuitable competitors. However, effects such as the Cumulative Semantic Interference (CSI) challenges this global inhibition assumption (Runnqvist, Strijkers, Alario, & Costa, 2012). This interference was found when bilinguals were asked to label a long sequence of images that belonged to varying categories in meaning (e.g., animals or clothes). Categories were not shown in blocks; however, each new item in the same category added 20ms to participants' response time. The authors explained that a named item was left more active after its naming (compared to its baseline activity), which in turn makes it a good competitor against the next item to be labelled in the same semantic category leading to interference. In other words, the activation of the previous item and the new item of the same category can lead to additive effects. In the critical condition, bilingual participants were asked to alternate between Spanish and Catalan. If the global inhibition assumption were appropriate, then no CSI effect should be found in the switch-trial condition, as switching to the other language is said to deactivate and inhibit the lemmas of the previous language node. What the authors found in this condition stands in contrast to this global inhibition assumption, as their results showed that both conditions (switch and no-switch) showed the same slope of the CSI effect, indicating that the previous language is still active after the switch and can lead to semantic interference. These findings render bilingual language control more and more similar to monolingual word processing based on competition between word forms without the need for top-down inhibitory control.

2.3.1.2 Dual Mechanisms of Control Framework

Another vital model describing inhibitory control in conjunction with goal maintenance is the dual mechanisms of control framework (Braver, 2012; Braver, Gray, & Burgess, 2007; Braver, Paxton, Locke, & Barch, 2009). The dual mechanisms of control framework describes proactive control and reactive control as a way of approaching the problem of variability within and between individuals and groups. The two processes are regarded as distinct but interdependent mechanisms. Proactive control can be conceptualised as a form of early selection, whereby information relevant to the goal is actively maintained in a sustained way before the occurrence of the actual event in order to optimally focus attention, perception, and action systems on the goal. Proactive control is associated with the sustained activation of the lateral prefrontal cortex and operates in a top-down manner. Reactive control, on the other hand, is a form of late correction corresponding to Green's inhibitory control mechanism (1998). The mechanism is only triggered as needed and 'just-in-time'. Reactive control is the transient activation of the lateral prefrontal cortex together with a broader network of additional brain regions and operates in a bottom-up manner. Postulating two distinct mechanisms in the model allows for the representation of the computational trade-off that ensures processing optimisation in a flexible manner (Braver, 2012; Braver et al., 2007). Having these two mechanisms in place enables the model to explain individual variability by virtue of how each person combines the two. In other words, the better the overall cognitive control is, the more optimal is the combination of proactive and reactive control. The use of different strategies shows not only different behavioural performances but also different brain activation profiles.

Consider the example for the use of the strategies during grocery shopping again. If a person decides at 3pm that they need to do some grocery shopping, they have basically two options for strategies that they could use. If they choose the proactive control strategy, it will mean to continually keep the goal of grocery shopping active in mind until the goal is completed. Reactive control strategy would mean that after the initial intention was set, the plan would then be dropped, and cognitive resources are available for other tasks. Later that day, the goal will need to be re-activated in order to complete the goal; otherwise, it would be forgotten. The decision between those two strategies is impacted by a variety of factors, such as the delay between the initial intention and the actual fulfilment of the goal, how cognitively demanding the goal is, the situation, or other factors that are interfering or distracting. Recent research on bilingual adults explored the effect that language experience variables, such as not only proficiency, but also the age of acquisition, and language exposure, may have on bilingual language control (Bonfieni, Branigan, Pickering, & Sorace, 2019), and found mutual effects between the language and cognitive variables. Due to these mutual effects, it is necessary to factor in differences and similarities of inhibitory control abilities when testing a multilingual sample.

In a study testing language learning, or word mapping and retention more specifically, both types of cognitive control would be required. During the word mapping phase, a new label needs to be attached to a new/foreign object. Depending on the number of competing objects available, and how high each contender ranks, a decision might not be reached immediately until more decision-qualifying information is presented. Whilst the decision is still pending, many competing objects have to be kept active and sustained, which requires attention or pro-active control. Reactive control plays an important role in integrating incoming new information. Hereby, one may need to shift between different new elements of incoming information, and inhibit those that are not relevant to reaching a decision, i.e., deciding on which referent to attach to the new label. The shifting and inhibiting between different bits of information needs to happen relatively fast in order to be efficient, but also not to increase the cognitive load whilst the proactive control is still keeping certain competing elements active. In order to reach a final decision, competitors must eventually be rejected, which is a mechanism described by the *Disjunctive Syllogism* that is also operative in the process of disambiguation. When it comes to retention, the competition between possible outcomes usually stems from words stored in long-term memory, and is further discussed in the next subchapter.

2.3.1.3 Adaptive Control Hypothesis

Like the previous models, the adaptive control hypothesis (Abutalebi & Green, 2016; Green & Abutalebi, 2013) assumes a direct relationship between how bilingual speakers process language and what the control processes that govern cognition. The speciality here is the inclusion of interactional contexts in which bilinguals communicate and the computational demands these contexts have on the control processes. According to this hypothesis, control mechanisms require adaptation to the speaker's context of which the authors describe three: single language (one language is spoken in one environment, the other in another, distinct environment; hereby, both languages compete), dual language (both languages are used but with different speakers; language task schemas compete), and dense code-switching (speakers systematically code-switch; thus, the co-operation of the two languages rather than competition). Each of these contexts increases or decreases the cognitive load on the control processes in a different way (Table 2.3.1). There are eight control processes (goal maintenance, conflict monitoring, interference suppression, salient cue detection, selective response inhibition, task disengagement, task engagement, opportunistic planning). The authors predict adaptive changes in the neural circuits that are in association with specific control processes. This is achieved by changing the parameters in terms of neural capacity, efficiency, or connectedness with other control processes. The adaptive control hypothesis, however, is difficult to test as the specific nature of each these eight control mechanisms remains fuzzy. Furthermore, it is unclear how they specifically interact and how they impact linguistic processing at different levels. For these complicating reasons, Braver's DMC model is the more elegant solution for the research questions posed in this thesis.

	Interactional contexts		
Control processes	*Single language*	*Dual language*	*Dense code-switching*
Goal maintenance	+	**+**	=
Interference control: conflict monitoring and interference suppression	+	**+**	=
Salient cue detection	=	+	=
Selective response inhibition	=	+	=
Task disengagement	=	+	=
Task engagement	=	+	=
Opportunistic planning	=	=	**+**

+indicates the context increases the demand on that control process (more so if bolded); =indicates that the context is neutral in its effects. Please see main text for explanation of the control processes.

Table 2.3.1: Demands on language control processes in bilinguals as a function of interactional context relative to demands on the processes in monolinguals in a monolingual context (taken from Green & Abutalebi, 2013)

2.3.2 Memory

Memory is a term that refers to the location of memory in the brain, the processes involved in storage and retrieval of information, and the stored information itself. Further separation is made between *long-term memory (LTM)* and *working memory (WM)*. The former stores, as the name suggests, knowledge for long periods, whereas the latter retrieves information from the LTM long enough to perform a mental operation, and is part of the previously mentioned executive functioning processes. Both faculties are necessary for word learning.

2.3.2.1 Working memory in multilinguals

Working memory, in particular, has been less researched, as more focus has been placed on studying the mutual effects of cognitive control and multilingualism. An early study (Papagno & Vallar, 1995) taking working memory into account compared multilingual (Italian plus two or three other languages) and bilingual adults (Italian plus one other language) on two Russian word learning tasks. One task required forming a new association between two know words in Italian, whereas the other task required learning Italian translation of Russian (transliterated into Italian) words. Results indicated that multilinguals performed significantly better on the word-learning task, but not the association task. This difference was ascribed to the superior phonological memory of multilinguals which was, firstly, supported by significant higher performances on non-word repetition and digit span tasks; and secondly by a positive correlation between these two memory tasks and participants' performance on learning the novel, Russian words.

To date, few studies investigated the components of working memory as a function of multilingual experience (Calvo, Ibáñez, & García, 2016; de Bruin, Treccani, & Della Sala, 2015; Dong & Li, 2015; Paap & Greenberg, 2013). It is noteworthy that most studies investigating these cognitive aspects recruited bilingual speakers, as in people speaking only two languages, and it is still unclear whether testing speakers of three or more languages may affect working memory differently. An exception is a recent study by Cockcroft, Wigdorowitz, & Liversage (2019) which investigated working memory ability of multilingual (speaking three or more languages) and monolingual adults on four memory components (verbal and visuospatial processing, verbal and visuospatial storage). They found supporting evidence for a multilingual advantage in all four components. Additionally, the authors examined the background factors that influenced this working memory advantage. These linguistic experience variables included language proficiency, age of (L2) acquisition, frequency of language use, as well as socio-economic variables. These results are analogous to those found in bilinguals, namely that cognitive advantages go beyond inhibitory control, and lead to the conclusion that multilingualism in general impacts on the executive control mechanism more generally, which is currently a focal point in the discussion around effects of multilingualism on EF.

2.3.2.2 Long-term memory

The focus of this section lies with the LTM which is split further into two systems referred to as declarative (explicit) and procedural (implicit) memory (Squire, Knowlton, & Musen, 1993). The declarative system can be subcategorised into semantic and episodic memory. Our mental lexicon, the words we know, shape a fundamental part of the semantic memory, whereas autobiographical memories are stored in the episodic memory. The declarative/procedural (DP) model was not posited initially to explain word learning per se, but some accounts have been developed that attempt to integrate the DP model with language learning. Before outlining how these neural memory structures relate to word learning, we briefly review a functional (Gupta & Tisdale, 2009), and a computational learning account (McClelland, McNaughton, & O'Reilly, 1995) for reference.

In order to relate the use of disambiguation, studied in this thesis, to the above memory systems, the functional word learning model by Gupta & Tisdale (2009) seems apt. As with other word learning models (e.g. Samuelson, Kucker, & Spencer, 2017), this model comprises a 'word learning' component that refers to learning one or a few new words within a short time frame, and a 'vocabulary acquisition' component, which refers to the cumulative outcome of acquiring words over multiple instances. Functionally, word learning entails learning the word form, its meaning and the link between them (de Saussure, 1914; de Saussure & Baskin, 2011). Thus, Gupta & Tisdale (2009) seek to answer (1) how meanings of new words are inferred – the creation of semantic representations; (2) how word-forms are learnt – the creation of phonological representations; how links between the two are formed through (3a) receptive word learning or knowing the 'meaning' and (3b) expressive word learning or producing the word form. Full mastery of a word entails all of those four core aspects. However, each of these core functions develops on their trajectory and require different mental operations and information which led to a considerable body of research investigating them separately (for a review see Gupta & Tisdale, 2009). One research stream, in particular, is relevant discussing here, as it ties in with the declarative/procedural memory system outlined below. Gupta & Dell (1999) proposed that learning the word form representation and semantic representation of a word are sub-served in different ways by the two memory systems. The first idea is that the creation of these two types of representations is based on distinctive mappings: systematic mappings vs arbitrary mapping (Gupta & Cohen, 2002; Gupta & Dell, 1999). A systematic mapping can be described as employing a mathematical formula whereby a specific input will always lead to a corresponding output. In terms of language function, mapping a heard phonological form (input) to a spoken output (as found in the immediate serial recall) is rather systematic. In contrast, an arbitrary mapping's change in the input does not lead to a similar output that can be interpreted logically. In terms of language function, mapping from a phonological word form to its semantic representation is almost always arbitrary.

Connectionist computational models, such as the complementary learning systems (CLS) framework (McClelland et al., 1995) can be seen as devices that enable such mappings. The CLS uses distributed representations on the input and output level. Hence, a stimulus activates a pattern of sub-units, for example, phonemes, distributed across as a pool. If a unit in the input is changed, then for systematic mappings, it will lead to a correct corresponding response without the need for adjustment. However, if the mapping is arbitrary, changing a unit in the input will unlikely lead to the production of a correct response, and previous learning does not help because it cannot be transferred systematically onto this new learning episode (Gupta & Tisdale, 2009). Thus, learning an arbitrary mapping needs to happen gradually over repeated presentations. Mapping labels to a referent, as tested in tasks of referential ambiguity, are arbitrary and should take longer to acquire than systematic associations. Nonetheless, adults have no difficulties in mapping a new word to a novel referent, and they do so very accurately (e.g. Halberda, 2003). How come learners can fast-map if the learning of arbitrary associations is gradual? A distributed connectionist network alone would not be able to account for such episodes of learning. It is for this reason that the CLS also fulfils the functional requirement for the second type of network that operates on a faster learning rate (McClelland et al., 1995).

In terms of resolving referential ambiguity, a task requiring the use of disambiguation, this account predicts that immediate effects of learning will exist after fast mapping (via the hippocampal route). However, that learning via the neocortical route will be delayed (Gaskell & Ellis, 2009). It is important to note that the CLS does not prescribe one or the other route of learning for incoming information. Instead, declarative information should be processed by both, the hippocampal (declarative) as well as the neocortical (procedural) route, taking into account that depending on the information, neocortical learning might be curtailed owing to its gradual properties (Davis & Gaskell, 2009). Disambiguation viewed as a mapping constraint supports the creation of arbitrary mappings required in semantic representations and receptive word learning, which is about knowing the meaning of a word. Other aspects of word leaning, such as being able to produce the word-form (expressive word learning), are part of the procedural system and would likely not be available yet after one instance of fast-mapping a label to its referent.

Chapter summary

In this chapter, I discussed the different types of bilingualism, such as simultaneous, early and late sequential, and late bilingualism. We explored how multi-faceted the bilingual experience can be and how language exposure, that is quantity and quality of input, language proficiency, age of acquisition, language input patterns, code-switching, and language attitudes modulate the language profile of a multilingual speaker. Furthermore, we briefly outlined other cognitive faculties required for language learning and affected by multilingualism. The cognitive abilities included executive functioning and memory systems. The linguistic variables, as well as the cognitive variables, are profoundly impacted by someone's multilingual upbringing and experience and has been found to have direct and indirect effects on all domains of language learning and discourse, whereby this thesis focusses on word learning.

3 Bilingual word recognition and access: Children and adults

In order to better understand the main research focus of this thesis, i.e. the investigation of a specific word learning ‘strategy’, this brief chapter aims to provide the theoretical framework that underpins bilingual language acquisition and lexical access. First, I introduce and clarify the steps involved in word recognition, a crucial step during word learning in children (**Error! Reference source not found.**). Second, I briefly introduce models and concepts of how bilingual adults access words in their two languages (**Error! Reference source not found.**).

3.1 Word recognition in two languages

The sections aim to discuss spoken word recognition, by which I mean the isolation of words from fluent speech, mapping the phonemes of a word to its meaning, and the final recognition of familiar words in real-time. Word recognition is crucial to word learning. Naturally, any child will have to hone and develop these skills, regardless of how many languages they speak and hear.

Depending on the language input situation, a child growing up in a bilingual environment might resort to different strategies or heuristics than a monolingual child. Just like monolinguals, bilinguals must develop skills to segment the speech stream they hear into words and recognise the relevant word boundaries, and that for each language. Language-specific approaches, such as relying on the stress pattern, work well if a language uses stress as cues for speech segmentation. However, if a bilingual child learns two languages where only one language does make use of stress while the other does not, then they will only be able to use that strategy to some extent. Language-general cues can also pose some difficulty. One of them is relying on the statistical properties of the speech stream, and learning which sounds co-occur to make inferences about word boundaries, but for bilinguals, this is more difficult, as they need to track these statistical properties separately for each of their languages which creates a higher cognitive demand. They cannot simply collapse all the information about their two languages into one category, as this would cause errors in their speech segmentation. Learning two sets of statistical information and keeping them separate leads to a higher cognitive load, and raises the question of whether bilingual children's speech segmentation skills might develop later than those of monolingual children. Saffran, Aslin, & Newport (1996) tested 8-month-old monolinguals who were able to reliably track which syllables appear next to each other in English.

Vihman, Thierry, Lum, Keren-Portnoy, & Martin (2007) tested how well 11-month-old Welsh-English bilinguals recognised familiar words. They created lists of words children know at this age, such as *apple* or *bottle* for both languages, and lists with unfamiliar words (at this age), such as *nettle*. This study also adopted, with slight adaptations, the head-turn preference procedure by having flashing light bulbs attracting children's attention rather than just a small indicator light. The hypothesis here was that if children had successfully segmented the familiar words and added to their lexicon, they would prefer the listening to the stream of familiar words. Results, indeed, showed that children at the age of ten months exhibited longer looking times towards the flashing light bulb whilst the familiar words were played (for both languages).

Bosch, Figueras, Teixidó, & Ramon-Casas (2013) went a step further and tested even younger bilinguals at the ages of six and eight months who were exposed to Spanish and Catalan. Adopting the head-turn preference procedure, the researchers familiarised the children with excerpts of fluent speech, and during the test, they heard monosyllabic words that either had or had not been part of the familiarisation excerpts. The authors concluded that bilinguals at both ages were able to segment the words in the dominant language, but that this ability was implemented in different ways: while the six-month-olds showed longer looking times to the familiar words, the 8-month-olds were more attracted by the novel words. This symptomatic difference might be due to processing differences, as the task might be more challenging for the younger infants, which could cause them to show a greater tendency towards familiar words (Hunter & Ames, 1988). However, the fact that both groups treated familiar and novel items distinctly indicates that they were able to segment speech at the very early age of six months.

The previous study looked at the bilinguals' dominant language, but a recent study investigated if children would also be able to segment speech in their non-dominant language (Polka, Orena, Sundara, & Worrall, 2017). They recruited French-English bilinguals, aged eight months, using the same procedure as Bosch et al. (2013) and implemented it for both, rather than one language. Thus, children had to complete two familiarisation and two test phases. Interestingly, the results here show that children successfully segmented the French words (by looking longer at the light when familiar French words were played), but did not show the same behaviour for English familiar words (English having been their non-dominant language).

A follow-up study by the same authors showed that the same bilinguals were indeed able to segment English, but only when it was the only language being tested. Polka et al. (2017) explain that the task was potentially too difficult for young bilingual children to test their speech segmentation skills. From these results, it can be concluded that the onset of speech segmentation skills for bilingual children happens around the same time as for monolinguals, especially with regards to their dominant language.

Segmenting words in fluent speech is the first step within spoken word recognition. The next step is to link these segmented words with their respective meaning, and also strengthen those links to be able to retain those words. As the focus of this thesis lies in the mapping and retention of novel word-object pairings, the following sections review some of the studies on children's mapping and retention without going into detail about the theoretical underpinnings, as a thorough theoretical discussion will be covered in Chapter 4.

Byers-Heinlein, Fennell, & Werker (2013) tested monolinguals and bilinguals at 12 and 14 months to investigate word mappings. Using a Switch task, an adaptation of the looking-time procedure, the authors compared monolingual and bilingual children's behaviour on associating a label with its referent. Monolinguals were learners of English, and bilinguals were simultaneous bilingual learners of English and one other language. Children were familiarised with two novel object-word pairings. Each object was presented in isolation with an auditory cue labelling the object as, e.g. *neem* while the object was moving across the screen for 20 seconds to attract the children’s attention. During testing, children were presented with two types of trials: a ‘same’ and a ‘switch’ trial. A ‘same’ trial contained a pairing congruent to the ones shown during the familiarisation phase; a switch trial presented them with an object paired with the opposite label compared to the familiarisation phase. If, during familiarisation, children did create links or mappings between the object and its label, then being presented with a contradicting mapping during the switch trial should cause some surprise. In other words, they were expected to look longer during the switch than the same trial.

Results showed that language experience did not impact the children’s basic word learning, as both monolingual and bilingual children noticed the change in the switch trial at 14 months, but not at 12 months old. After having mapped a word to its referent, or potentially referents, children are required to access the information on this link to recognise it in real-time fluent speech. To assess this, researchers make use of the LWL paradigm, such as Marchman, Fernald, & Hurtado (2010) who tested Spanish-English bilinguals aged 30 months. Children were presented with two objects on the screen: one target and one distractor item. After hearing an auditory cue in each of their languages, such as “Where is the dog?”, the authors measured how long it took for the child to direct their gaze to the target item using said time as an indication for processing speed. Through a parental report, they also used vocabulary size as one independent variable. The results showed that children with the largest English vocabulary also responded the fastest on English trials. The same was true for children with larger Spanish vocabularies and their speed on Spanish trials. However, there was no effect across languages, i.e. children with a large English vocabulary were not faster on Spanish trials and vice versa. From these findings, it can be concluded that language processing and vocabulary within each language develop interactively.

Another study (Hurtado, Grüter, Marchman, & Fernald, 2014) examined a bilingual population that was more balanced in their exposure, and thus, should have a more balanced vocabulary. From 30 - 36 months, the bilingual children in this study responded equally fast in both of their languages (again English and Spanish). Together, these two studies contribute to the idea that language processing, language exposure, and vocabulary size are linked and impact each other.

3.2 Lexical access

Once words are learned and consolidated, they need to be accessed in the future if one wants to communicate. Although this thesis does not directly address lexical access, I would like to provide a brief overview of the research conducted on bilingual children and adults.

Lexical access is impacted by the development of expressive and receptive vocabulary in both monolingual and bilingual children. Especially the link between vocabulary size, the production of translational equivalents, and lexical access is of investigative value. Many studies show differences in vocabulary size and access between monolingual and multilingual children and adults. For instance, during primary school, a consistent gap is found between monolingual and bilingual with respect to their expressive and receptive vocabulary size (Bialystok, Luk, Peets, & Yang, 2010; Eilers, Pearson, & Cobo-Lewis, 2006). Bilingual children and adults also show poorer accuracy and slower reaction times in picture naming tasks (Kohnert & Bates, 2002). Bilingual adults tend to have a smaller vocabulary in size in each of their spoken languages (Perani et al., 2003; Portocarrero, Burright, & Donovick, 2007). Lexical retrieval poses a challenge for bilinguals as they show deficits in verbal fluency tasks and struggle with interference in lexical decision tasks (LTDs).

The differences in vocabulary size and access may be linked with bilinguals' different experiences when acquiring and using their languages. Where monolinguals will encounter all the relevant words in each context, bilinguals are sometimes faced with contexts where they use only one of their languages, thus leading to a smaller context-specific vocabulary in the other language. Two main hypotheses have been devised to explain lasting deficits in lexical access within bilinguals. The Weaker Links Hypothesis attributes the differences in access to the frequency differences in which word-object links in the associative network are activated. Monolinguals are exposed to a higher frequency of word-object mappings compared to bilinguals in a particular language, and are, thus, faster in accessing those links (Gollan, Montoya, Cera, & Sandoval, 2008). The Competition Hypothesis suggests that bilinguals require more laborious processing to retrieve words in each language because they are required to inhibit the interfering competitors from their non-target language (Dijkstra, 2005; Green, 1998). Research on lexical retrieval comparing monolingual with bilingual children has led to mixed results depending on the age of the child and whether receptive or expressive vocabulary was being used for analyses. For example, in bilingual children younger than 36 months, the total of receptive and expressive vocabularies was reported to be similar in size to those of their monolingual peers (Junker & Stockman, 2002). However, school-aged bilinguals possessed a smaller receptive vocabulary size in their first language compared to monolinguals (Bialystok, Luk, et al., 2010).

Growing up with two or more languages will impact the cognitive structure that renders language processing possible, and those impacts may also influence extra-linguistic cognitive processes. For example, a speaker of two languages on average has more lexical entries than a monolingual, and for any given entry knows whether it is known in language A, B, or both (Paap, 2018). Following from that, a bilingual can comprehend and produce utterances in language A, B, or both, and must thus develop skills that enable them to identify, select, and switch to their target language. These skills are specific to bilingual language processing, as monolingual speakers have only one default language eliminating the need to select or switch. The main question that arises here is how bilinguals manage their two languages. On a broad level, researchers have proposed two different ways of how bilinguals might resolve this problem. On the one hand, it could be assumed that there are two separate, functionally independent lexicons and a superimposed control mechanism that allows for selective access to either language A or B. On the other hand, there is growing evidence that co-activation of the non-target language is taking place whenever a bilingual is reading, listening, or speaking. In other words, language access is non-selective, which creates conflicts when both languages are being activated.

Chapter summary

The first half of this chapter reviewed the word recognition involved in language acquisition in bilingual children. This provided the foundation for Chapter 4, where I discuss word learning in more detail but also illustrated the bigger picture in which word learning is embedded. The second half of this chapter briefly discussed research on lexical access in bilingual children and adults.

4 Learning novel words: Mapping & Retention

In this chapter, I begin with definitions of word learning, word mapping, disambiguation, and retention (4.1). It discusses the historical origin of the *disambiguation effect* with classic word learning accounts (4.2). I then discuss the Disjunctive Syllogism as the underlying mental computation of disambiguation together with four important theoretical motivations for disambiguation (4.3). I then review a more contemporary account of word learning, which regards word mapping and retention as interactive processes, and links disambiguation to retention (4.4). A summary of three critical studies that motivated me to examine disambiguation in a multilingual population (4.5) precedes the discussion of disambiguation in multilingual children and adults (4.6). Lastly, the chapter addresses the potential use of disambiguation with other referential expressions that are not labels, such as factual information about an item (4.7). At this point, it is essential to mention that the majority of disambiguation research to date has been carried out with young children; however, the chapter aims to include adult disambiguation research where appropriate.

4.1 Definitions

Word learning, or lexical acquisition, is a broad term used to describe the processes involved from the first encounter of a new word, assigning meaning or a referent to this word, and remembering this label-meaning link. This term includes word learning in children and adults from monolingual as well as multilingual backgrounds

Word mapping is the specific process of correctly mapping a new label to its corresponding object or concept to establish a word-object association. The initial mapping process is the first step of the word learning trajectory. Word mapping can be challenging in situations where many potential referents might be present.

Disambiguation is a mental process based on the process-of-elimination that helps learners establish word-object mappings. It is one specific mechanism that promotes the reduction of referential ambiguity by eliminating incorrect referents in favour of the correct referent. Disambiguation can be found in children and adults but is subject to modulation based on linguistic experience (see discussion below)

Retention is often a problematic term within the scope of word learning, as it is often used to refer to success on retention trials within an experiment (often with only a short delay). However, in the memory literature, retention refers more often to long term consolidation. Since the focus of this thesis is rooted in word learning, I will use retention in a way that includes the success on retention trials and will make it explicit if I refer to long-term consolidation/fully-fledged learning.

4.2 The beginnings of disambiguation and classic word learning accounts

The classic approaches to word learning were based on the acquisition of lexical knowledge in order to resolve the problem of referential ambiguity - an obstacle famously described by Quine (1960). With this, a new label can be associated with any object, its properties, the speaker's intentions or feelings for it, and action, or something else, and this, in any given naming situation. Considering all the potential referents, attaching the label to the correct referent is a daunting task.

Most traditional theories proposed for solving this problem of referential ambiguity fall under the constraint approach, which can be regarded as a metatheory. Under this metatheory, children possess constraints or biases which help them make inferences towards a label's meaning by supplying them with additional knowledge not available in the situation (Golinkoff et al., 1994; Woodward & Markman, 1991). Some of the constraints function on an elementary level by restricting the possible interpretations of a new word (Markman, 1990) suggesting that novel words tend to refer to a whole object (not parts) or basic-level categories. Notably relevant for my thesis and the conducted experiments is the mutual exclusivity constraint, as well as the novel name-nameless category principle (see 4.3). They describe how toddlers infer the correct word-object mapping based on with which other objects' labels they are already familiar. In other words, they tend to associate novel labels with novel objects, rather than attaching a novel label to an object for which they already know the name. This observable behaviour has become known as the *disambiguation effect.*

The exact form of this inference has been a hot topic (Grassmann & Tomasello, 2010; Halberda, 2006; Jaswal & Hansen, 2006; Markman & Wachtel, 1988; Mervis & Bertrand, 1994), but a child can infer meaning by integrating the current situation of referential ambiguity with the contents of his or her lexicon. In the constraint approach, the ability to make inferences becomes synonymous with learning, a development that has been challenged for various theoretical and empirical reasons. Research in these four areas has contested the fundamental ideas of the constraint approach: the vocabulary spurt, fast mapping, familiar word recognition, and cross-situational learning.

The well-documented vocabulary spurt happens around the age of 24 months and has been regarded as implicit support for constraints. Constraint theorists argued that the sudden shift in vocabulary size provides evidence that constraints are now available and facilitate this vocabulary growth (McMurray, Horst, & Samuelson, 2012). If that were indeed the case, then the acquisition pace of words in children should exhibit a sudden change in slope. Ganger & Brent (2004) looked at velocity profiles of 38 children and found that for 33 of those such a sudden change was not to be found, and instead, a smoothly growing function described the acquisition pace better. Another line of argumentation follows the idea that constraints such as mutual exclusivity are always available (Markman, Wasow, & Hansen, 2003; Tomasello, 2001), but children do not possess enough linguistic knowledge or a large enough vocabulary to use them (Elman et al., 1996; Van Geert, 1991). This notion has also been questioned by more recent studies (McMurray, 2007; Mitchell & McMurray, 2009), which reported that such an increase in vocabulary acquisition was also possible without disambiguation. They explained that if learning of easy and hard words happened in parallel and those words were evenly distributed, acceleration was present. These findings show that while constraints might contribute to the acceleration of vocabulary acquisition, the mere existence of the vocabulary spurt is not sufficient evidence thereof.

In 1978, Carey discussed the concept that word learning was composed of two sequential steps. She contrasted infants’ fast mapping of new words to a new object with a slower step of learning the word’s entire semantic meaning. However, it was not established whether fast mapping in her model referred to the early stages of learning or resolution of referential ambiguity in that specific moment. Nonetheless, if lexical acquisition can be attributed to fast mapping, then identifying the correct mapping should lead to some initial form of learning the label. Newer studies tested whether children mapped the new label its novel referent and whether they were able to retain said mapping a neutral context by juxtaposing the 'learnt' mapping with an entirely new object (Bion et al., 2013; Kalashnikova, Escudero, & Kidd, 2018).

4.3 The Disjunctive Syllogism and its theoretical motivations

Due to the focus of research having been on determining the timepoint when learners start to use disambiguation, little is known as to *how* they actually reach this conclusion. In 2006, Halberda designed a study whereby participants had to select the correct referent out of two possible images via disambiguation. The computational structure of this constraint is called *Disjunctive Syllogism*, or more commonly referred to as process-of-elimination, which can be described as:

(1) $A \vee B$

(2) $\neg A$

(3) $\therefore B$

Verbally, this is expressed as "A or B (1), not A (2), therefore B (3)". Note that in order to reach the logical conclusion (3), one must complete the essential step (2) which is the systematic rejection of *A*. Halberda (2006) tested adults on implicit and explicit versions of the Disjunctive Syllogism. For instance, prompting someone to "look at the *ball*" in the presence of a *chair* would be the logical opposite of (2), i.e. not the *ball*, thus making it implicit. Asking someone to "not select the *chair"* would logically correspond directly to (2) making it explicit. Halberda's results indicate that adults make use of the Disjunctive Syllogism in both cases and disambiguate to arrive at the correct answer.

Traditionally, four major accounts described the underlying motivations behind the disambiguation effect: Mutual Exclusivity (ME) (Markman & Wachtel, 1988), Contrast (Clark, 1993), the Pragmatic Account (Diesendruck & Markson, 2001), and the Novel-Name Nameless-Category (N3C) Principle (Golinkoff, Hirsh-

Pasek, Bailey, & Wenger, 1992). Each of these accounts makes similar behavioural predictions in a situation of referential ambiguity but does so for different reasons. The debate of these accounts has primarily focussed on the underlying motivations for why learners have this tendency to map new labels to novel objects. However, they mentioned little about the mental computations involved that would be required to support the use of the disambiguation principle at the time of conception. By suggesting that the Disjunctive Syllogism might be at the source for this mapping behaviour, Halberda (2006) was able to develop these accounts, as well as ways of revealing behavioural measures to help decide between them.

Under the ME account, the principle that every object has only one label prevails (Markman & Wachtel, 1988). Upon seeing a familiar, known object (e.g. a chair) in juxtaposition to a novel, unseen object, a word-learner who were asked to "look at the *dax*" would reason as follows: "The novel label *dax* can refer to either the chair or the novel physical item in this situation. It cannot refer to the chair, because that one already has a name (i.e. *chair*), and according to ME the chair cannot have another label. Thus, *dax* must refer to this new object". Thus, unless evidence is suggesting the contrary, the ME account assumes that a learner's first basic hypotheses with regards to the meaning of a new word are rooted in the principle that an object only has one label. The mental computation happening here is in line with the previously described Disjunctive Syllogism as it involves a step of rejection. In other words, under the ME account, the chair is rejected from the competition of potential referents, before the learner moves on to the novel object. The rejection stems from the knowledge that the chair already has a label and can only have one. Like ME, the advocates of Contrast and the Pragmatic Account also propose that rejection is a computational step required in their accounts.

Clark (1993, 1990) proposed the Principle of Contrast whereby all lexical representations contrast in meaning. If a word-learner were asked to "hand me the *dax*" after seeing the chair and the novel item, they would not view the label *dax* to be similar to the familiar label *chair*. If they were asked the same question while someone was pointing at a specific feature of the familiar item, then enough contrast would be present to assign the novel label to a part of the chair. However, under this account, a word-learner first assumes that a novel name refers to a basic-level-whole rather than part-of-a-whole. “When children hear new words, they assume that those words contrast with ones they already know and that they must therefore map onto hitherto unlabelled conceptual categories” (Clark, 1983). By applying contrast, many possibilities are immediately eliminated, which other principles would not eliminate. The Disjunctive Syllogism’s rejection step can also cover this elimination process. When deciding between *chair* and *dax*, a learner adhering to Contrast reasons that *dax* refers to an unnamed category, whereas *chair* belongs to the (basic-level) ‘chair’ category and cannot have another name; therefore, the *dax* must refer to the new object in an unnamed category. The decision to map *dax* onto to the novel object is performed via the rejection of the familiar object.

The Pragmatic Account follows the Gricean maxims of communication (Grice, 1975), especially the principle of cooperation, and postulates that speakers should use familiar terminology if possible. Diesendruck & Markson (2001) suggest that in a situation, as described under the two previous accounts, a word-learner would use pragmatic reasoning and reach a conclusion such as “if the speaker had wanted me to bring the chair, then they would have referred to it as *chair* and not by using a novel, unfamiliar label. Given they asked for the *dax* the speaker must mean the novel object”. Concluding that *dax* must refer to the novel referent is, again, performed by rejecting the familiar referent first. This again is a Disjunctive Syllogism. All of the three mentioned accounts satisfy the criteria of the Disjunctive Syllogism thus far, which explicitly relies on the rejection of one or more possible referents in order to reach the correct referent. It is worth noting, that while the above verbalisations of how the learner reasons are presented in a very explicit way, the Disjunctive Syllogism also operates in an implicit manner (Halberda, 2006), as it is an argument structure that can happen at any level of awareness and cognition.

The N3C account, however, denies that such rejection is necessary in order to successfully map a label to its referent (Mervis & Bertrand, 1994). The reasoning here is that word-learners are “positively” motivated to map new names to new objects from the start (Golinkoff et al., 1992). The fact that word-learners would find themselves in a situation where they are faced with unlabelled, novel objects is deemed sufficient motivation to map a new word to a new object. This account postulates that a learner using N3C would not need to reject other possible familiar referents, as the rejection step (2) or "not the chair" does not have a causal relationship with the mapping of novel words to novel referents.

To help decide between these different accounts, Halberda (2006) developed two preferential looking-while-listening experiments with adults, and then distilled the behaviours needed for each account. Learners should show if they engage in the process-of-elimination (in line with ME, Contrast, and a Pragmatic Account) or not (in line with N3C). In order to perform the rejection of a known label, a learner first needs to access, attend to, and evaluate it before rejecting it. Focussing attention and performing this evaluation on the familiar lexical entry will take time and is reflected in a learner's reaction time when ultimately selecting the novel item as the referent for the novel label. Halberda (2006) found that adults double-checked, i.e. evaluated and rejected, the known labels in 76% of the trials that juxtaposed a novel and a known item where the target item was the novel label/item. These results indicated that participants' decision was founded in the knowledge and information they possessed about the known distractors, and *not* about the novel object. These findings are in line with the accounts relying on a Disjunctive Syllogism.

4.4 The interactive relationship between mapping and retention

Research examining word learning is fundamentally concerned with answering the following questions: (1) do children know the word?, and if so (2) how do they acquire that word knowledge?, and (3) how many words do children know?

Upon addressing these questions, most articles begin by establishing why word learning is a daunting and challenging task by explaining that in any given situation of referential ambiguity, children must choose from an infinite number of referents for an unknown label. This is then proceeded by presenting ways in which children solve this problem. However, by approaching word learning from this angle, often an important question is omitted: what does it actually mean to *know* a word? We know that children comprehend more words than they produce (McMurray et al., 2012), which leads to the question of when to consider a word as learnt or known: is it at the point of understanding it or actually saying it?

Since quantifying when a word is known seems to be quite controversial, another way to frame word learning would be to consider how children *use* words, as this is something we can measure more directly. Using words not only refers to word production as such but can also refer to any moment that a word-object link is used to guide children's behaviour. This then includes processes like understanding familiar labels, as well as resolving referential ambiguity. In classic approaches of word learning, word usage is not part of the explanation for lexical acquisition, as they focus on the information required to for learning (and its amount), as well as the difficulties children are presented with when gathering said information. By focussing on this knowledge acquisition, these accounts have often neglected word use (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Mayor & Plunkett, 2010; Woodward & Markman, 1991; Xu & Tenenbaum, 2007).

Developing a lexicon is based on processes which enable children's real-time word usage in conjunction with those that consolidate into long-term learning. In other words, word learning can be summarised by two important questions: (1) what happens when a new word for a new object is mapped for the first time, and (2) what happens when said mapping is encountered repeatedly? Previously, word learning had been described as a sequence of events, whereby an initial *fast mapping* was followed by *slow learning*. A more advanced account in terms of using words was proposed by McMurray et al. (2012), who posited a computational model based on associative learning and dynamic competition between words. They describe two simple mechanisms that operate on distinct, but interactive timescales: (1) *fast mapping*, the dynamic competition entailing the processes that happen during referent selection at this specific moment in time, and (2) *slow learning*, the associative learning characterising the slower process of forming lasting mappings between labels and referents over a longer developmental-time.

Although the idea of these two processes is not new, their interaction is now regarded as dynamic interplay rather than a sequential process (Kucker, Mcmurray, & Samuelson, 2015) found that they do not manifest in a sequential manner but rather form a dynamic interplay. Thus, instead of viewing word learning as a two-step process, researchers should frame the two main word learning processes in terms of their time course and the behavioural, as well as functional goals they serve (Kucker et al., 2015). Coming back to the two questions posed above, one can define the time course in terms of *situation time* (4.4.1) and *developmental time* (4.4.2).

4.4.1 Behaviour in situation time

The child's behaviour during this time is vital, as it then when new words and new objects are encountered. Word learning, in general, is a problem of ambiguity, vagueness, and plenty of uncertainty. On the auditory side, acoustic cues to individual phonemes must be processed. On the visual, conceptual side, the visual properties of the object have to be parsed which is "extraordinarily difficult" and still not fully understood (Horst, Samuelson, Kucker, & McMurray, 2011, p. 234). Furthermore, children must decide between virtually an infinite number of interpretations for novel words and several possible referents. This problem was coined as *referential ambiguity*, and several biases impact the resolution of this conflict. The novelty of an item, for instance, plays a significant role for children, as their attention, eye-movements or pointing towards an object is naturally impacted in favour of the novel item (Fantz, 1963; Hunter & Ames, 1988; Quinn, Eimas, & Rosenkrantz, 1993; Shinskey & Munakata, 2005). Not only the child's familiarity with the novel object has an impact on referent selection, but also the relative novelty of an object to a speaker was found to act as a social pragmatic cue in naming contexts (Diesendruck, Markson, Akhtar, & Reudor, 2004). Not only does familiarity refer to a label, but also to the object itself, and these are not the same.

Of the 17.000 words that a child hears on any given day (Hart & Risley, 1995), they will hear many word forms for which they have not yet mapped the corresponding referents; and similarly, children will be surrounded by hundreds of objects for which they have yet to learn the labels. Learning for labels and objects is independent of each other, albeit interactive: a child can learn something about object categories without learning the name (Horst, Samuelson, et al., 2011). This is important since testing in laboratory settings usually involves confronting children with particular, novel objects and pseudo-names which constitutes a situation that has little chance of occurring in a child's real-world learning context (Horst, Samuelson, et al., 2011). Another factor that impacts the resolution of referential ambiguity is an object's location, as objects in closer proximity to the child make a more salient candidate than other competitors that are further away, due to children's short arm and stature (Kucker et al., 2015).

Children are susceptible to a change in the experimenter's excitement towards the object, which might have the capacity to override other factors (Horst, Samuelson, et al., 2011). Adults also limit possibilities for children by holding and naming single objects or labelling items children are playing with reducing referential ambiguity. All these different drivers mean that referent selection is prone to errors, and children determine a referent to support communication *at the moment* based on the confluence of mechanisms which can be observed as inference, constraint satisfaction, or problem-solving. However, a correct mapping in this stage is not synonymous with learning. One manifestation of fast-mapping that this thesis seeks to explore is the use of disambiguation to resolve referential ambiguity, mainly since multilingual children were found to rely less on the use thereof (Byers-Heinlein et al., 2013; Byers-Heinlein & Werker, 2009).

Children are required to discern what a speaker is referring to in any given moment in order to communicate. One major aspect of that is weighing the possible interpretations and choosing the best option in that moment, which is often seen as language-specific, rational, or language-specific mechanisms, especially by classic word-learning biases such as mutual exclusivity or N3C account (for a summary see 4.3). However, newer studies (McMurray et al., 2012; Samuelson, 2002) suggest that simpler mechanisms are at play when resolving referential ambiguity. In essence, they concluded, identifying the referent of a word is a matter of directing attention, and a child's attentional system is driven by external cues, such as salience, and internal cues, e.g. novelty biases (Roder, Bushnell, & Sasseville, 2000). Both of these change with time, developmentally speaking but also throughout the experiment, when children learn more about the stimuli in a task. In a real-world naming situation, a child's fast mapping process will often be facilitated by intelligent interlocutors through pointing towards the correct referent or repeating the label several times, for example.

4.4.2 Associative learning in developmental time

How do children go from the in-the-moment behaviour laid out above to a rich and robust lexicon? Smith & Yu (2008) argued that slow accumulation of small bits of learning happens during and after each situation-time behaviour, as shown in their cross-situation learning study in which children acquired robust links between novel words and referents. Albeit their study testing adults, it was one of the first research designs that explored cross-situational learning based on statistical learning of words, referents, and their co-occurrences at various moments. No information was given between words and their referents during any given trial. Through cross-trials statistical relations, adults learnt the word-object mappings over several trials. For infants, retention following the first presentation of a novel word-object mapping is minimal (Horst & Samuelson, 2008), but it rises systematically with repetition of said mappings (Mather & Plunkett, 2010) and vocabulary development (Bion et al., 2013). Strictly speaking, this type of learning is not purely lexical, as children also encode co-occurrences of non-target items (Wojcik & Saffran, 2013), context features (Goldenberg & Sandhofer, 2013), and where the object is located in space (Hoover & Richardson, 2008). Eventually, over a longer period, as objects are named in more diverse environments, the label will become less bound by the context and more closely linked to the right referential concept (E. Bates, Thal, & Marchman, 1991). Learning in developmental time is gradual that is built on initial word-object mappings and then refined via statistical learning and the slow accumulation of small bits of knowledge.

4.4.3 Re-framing Learning

Re-framing learning as a model that is based on the two independent, but interactive processes of fast mapping and slow learning away from the traditional two-step sequential idea of learning, consequentially leads to a redefinition of mapping constraints. This means that the biases used to resolve referential ambiguity are not synonymous with word learning. 24-month-old children were able to accomplish a standard fast-mapping exercise but were not able to retain the new name after a five-minute delay (Horst & Samuelson, 2008). Naturally, the ability to retain new information improves with neural maturation, and children aged 30 months were able to retain the novel mapping (Bion et al., 2013). Whether this success on retention is directly linked to the use of fast-mapping strategies is not clear, however. Through the lens of the associative network model, we gain insight into the relationships between the processes that facilitate word learning and use, and the model connects developments in word learning to language acquisition by relying on domain-general mechanisms (e.g. attention). These domain-general mechanisms (e.g. novelty, attention, and competition) have a direct impact on the associative learning rules. These rules are sensitive to how strong the links between words and their referents are, and said processes shape their strength. This strengthening mechanism shows how referent selection in situation time can modulate the associative network over its development. However, the functional consequences of forming these connections alter, based on the real-time processes that guide attention to an object as the child matures and gains more life experience. Behaviour in situation time vs. in developmental time is, therefore, strongly interactive even if they do not develop simultaneously. While the formation of correct word-object mappings is paramount to associative learning, children also strengthen incorrect non-links; or in other words, they prune links between words and incorrect referents (Regier, 2005). As unsupported links are pruned, correct mappings are chosen more rapidly (McMurray et al., 2012). Learning also speeds up as inappropriate connections are reduced, and remaining connections are supported by co-occurrences across different contexts (Horst, Parsons, & Bryan, 2011). Summarising, the associative network account puts simple, content-free processes like association and competition at the heart of word learning, rather than language-specific knowledge. Association and competition are separable mechanisms, and their occurring interactions are fundamental for building and using the lexicon. The dynamic interdependence of referent selection and gradual strengthening/pruning of previous mappings enables children to behave intelligently during situation time and cascades into improved retention. Retention itself leads to vocabulary learning and will improve future referent selection situations (Kucker et al., 2015). Notwithstanding that referent selection and retention are somehow linked, only a few studies (Kalashnikova, Escudero, et al., 2018) have investigated the direct link between fast-mapping and retention of novel word-object links.

4.5 Review of key studies motivating this research

Halberda (2003) sought to answer two main questions about word learning constraints: (1) Do they come into place right at the onset of the earliest word learning? (2) What are the underlying computations that provide constraints over time, from early to mature use? In pointing games, Mervis & Bertrand (1994) were able to show that 17.5-

month-olds could successfully map novel objects. However, looking time is a more sensitive way of measuring. Hence, Halberda (2003) adopted a version of the preferential looking-while-listening paradigm (henceforth: LWL paradigm) (Allopenna, Magnuson, & Tanenhaus, 1998), and tested 38 typically developing monolingual infants around 16 months old (range: 14;7 to 17;25).

Stimuli were computer-generated objects such as ball, car, cup, and a novel object (a phototube) which was referred to as *dax* (an English pseudo-word adhering to the phonotactic properties of English). Children had to identify the correct target picture in a pair after hearing an auditory cue like "Look at that ball! Ball". This study examined two conditions of which one juxtaposed two familiar objects (familiar word trials), and the other one juxtaposed a novel, unseen object with a familiar one (disambiguation trials). Before hearing the auditory cue, children were able to look at each picture pair for 3000 milliseconds, which allowed the author to assess a baseline preference. Looking times served as a measure for preference in the children's response and was coded from video, frame-by-frame, by coders who were blind to as which side the correct response was on. Newer studies use a similar design but would opt for eye-tracking technology since it not only provides a more accurate online measure but also tells us more about fixations in additions to looking times.

A first analysis revealed that results from familiar word trials differed to the ones from disambiguation trials (Halberda, 2003), which then led to another analysis with age as an independent variable. Linear regression showed that on disambiguation trials children differed in performance with regards to their age, which was not the case for familiar word trials. However, the decision to test for age differences was not made a priori, which meant that for a specific age range, there were varying numbers of subjects. In this case, it would have been more sensible to recruit more children and have them in age groups from the start in order to avoid an a-posteriori group allocation. Children of all age groups (14-, 16-, and 17-month-olds) performed as expected on familiar word trials, namely that they all increased looking at the labelled object (cup, ball, car). On disambiguation trials, however, an interesting pattern emerged. Compared to their baseline preference children were tested against chance level, which showed that 14-month-olds decreased looking towards the novel object ($p < .05$) compared to their baseline preference. 16-month-olds did not differ from chance, and 17-month-olds significantly increased their preference for the novel object. While the result of the oldest age group was anticipated, the results yielded for the youngest group came as a surprise. Were 14-month-old not capable of using disambiguation, they would simply perform at chance-level like the 16-month-olds. However, they show a consistent pattern of looking towards the familiar object.

For this reason, Halberda conducted a second experiment in which he sought to control for “all incidental aspects of the experiment which might have caused the 14-month-olds’ surprising performance” (Halberda, 2003, p. B29). The second experiment was identical to the first one with the exception that object labels were removed. By doing this, Halberda attempted to test two hypotheses. Firstly, they tested whether 14-month-olds performed as they did due to the possibility that the preference for the known object developed as the disambiguation trials unfolded; and Secondly, whether children failed to comprehend the novel object and simply wanted to comply with the order to “Look at [something]” (Schafer, Plunkett, & Harris, 1999). The results showed a main effect of experiment condition (labelled versus not labelled), but no other effects were found. This indicated that the reason why 14-month-olds increased looking to the familiar object was, in fact, solely due to the introduction of the object dax. This result also showed that neither of the two hypotheses could be confirmed. Even though the youngest infants in this study systematically increased their preference for the known object, this surprising failure of using disambiguation might open a way to understanding the underlying processes for later success (Halberda, 2003).

Byers-Heinlein & Werker (2009) focused on how language experience contributed to the use and development of disambiguation. Previous studies (Davidson & Tell, 2005; Frank & Poulin-Dubois, 2002) found that bilingual children showed a weaker tendency to use disambiguation during their years of pre-school and school. Byers-Heinlein & Werker (2009) compared mono-, bi-, and trilingual children around the age onset of disambiguation since this approach could disentangle whether previous results were due to the initial onset of disambiguation or increased social and linguistic experience. Their hypothesis was that if “disambiguation differs between monolinguals and multilinguals from the get-go, this would provide strong evidence that language experience influences the development of disambiguation, and not just its later use" (Byers-Heinlein & Werker, 2009, p. 816).

The authors similarly made use of a preferential LWL paradigm to test infants between 17 and 18 months old, which is the age where disambiguation was first attested for monolinguals (Halberda, 2003; Mervis & Bertrand, 1994). Monolingual subjects came from English-speaking homes, and bi- and trilinguals had been exposed to all their languages from birth. The bilingual group included a diversity of "English plus any other language" combinations, and the trilinguals followed a similar pattern of English plus two other languages. In total, the number of different languages spoken by all subjects combined counted 22. The vocabulary was measured with the Words and Gestures form from the MacArthur-Bates Communicative Development Inventories (L. Fenson et al., 1993). However, no data could be collected for the other languages, as many of them did not have a language-adapted version of the questionnaire available. The stimuli used were adapted from Halberda (2003), namely a *ball, shoe* and *car* for known objects, and a phototube which was labelled *nil* in this study (as opposed to *dax* in Halberda, 2003). Each label was presented in one of three carrier phrases, such as "Find the ball! Ball!". Data were collected using a Tobii 1750 eye tracker. Analyses on familiar word trials revealed that all children, regardless of the number of languages exposed to, increased looking to the target when hearing the label. On disambiguation trials, monolinguals showed a strong disambiguation effect with increased significant preferences for the novel object ($p=.0095$), whereas bilingual infants showed a similar but marginal effect ($p =.057$), and trilinguals showed no increase in looking towards the new object. To account for possible incidental aspects, Byers-Heinlein & Werker (2009) replaced the object label phrases with no-label attention phrases (such as "Look at that! That!") in a second study.

Results from this study showed that the children's failure to exhibit a systematic looking behaviour confirmed that incidental aspects of the experimental procedure did not account for their performance. These results demonstrated that the number of languages spoken modulates the development and use of disambiguation. Whilst the authors provided different possible explanations for their results, their point about within-language and between-language disambiguation struck me as very important. In their study, the Byers-Heinlein & Werker (2009) were only able to test between-language disambiguation for the multilingual children. However, little is known whether multilingual children deploy within-language disambiguation, i.e. when they are staying and learning within one language mode. Since many different language combinations were tested, it was unfeasible for them to test each child in their other languages. However, a paradigm investigating the potential existence of a distinction between within- versus between-language disambiguation would offer important insights as to whether multilinguals possess one mental lexicon entailing lexical entries of all languages, or whether their mental lexica are separated for each language. This new avenue for disambiguation research in multilingual children was part of the original plan for this thesis. However, due to difficulties recruiting enough bilingual infants of the same language combination at such a young age, I had to alter the research focus of the thesis.

The third critical study that is relevant for the present thesis was conducted by Bion, Borovsky, & Fernald (2013). They aimed to answer the following two questions with regards to disambiguation and word learning: (1) how is a child's skill in disambiguation related to word learning at the moment? (2) how is referent selection, as a measure of word learning at the moment, related to overall expressive vocabulary, as children develop? The authors compiled two experiments of which the first one sought to validate the method used to teach 18-month-olds that they could learn the associative link between a novel word and a novel object, at least when there is no ambiguity in the learning situation. Infants performed above chance on familiar word trials and showed evidence that they could map new words to novel objects. These results validated the experimental design for their second experiment, in which children (this time aged 18, 24, and 30 months) were presented with novel words in an ambiguous context.

As with the first experiment, infants in the second experiment had to identify a correct target picture adopting the LWL paradigm. The following three conditions were tested: familiar word trials, disambiguation trials, and novel word retention trials. The results suggest that overall children improved in all three conditions with increasing age. However, 18-month-olds did not reliably refer to new objects after hearing new labels, even though they performed consistently above chance for familiar words. 24-month-olds performed significantly above chance in the familiar and disambiguation trials; however, they could not yet retain the mappings after short delays. Only the 30-month-olds showed a retention rate slightly above chance which indicated that they are starting to retain the mapping within the scope of the experiment. The results regarding the relation between accuracy on disambiguation trials and retention trials yielded a correlation over all ages in which children who are more accurate on disambiguation trials also perform better on retention. This correlation has been confirmed by a linear regression that indicated that the ability to find the correct referent and remember that association is related and independent of age or vocabulary size.

Bion et al. (2013) were also interested in the links between vocabulary size and accuracy on retention trials, and between vocabulary size and accuracy on disambiguation trials. Results show that on disambiguation trials, children with higher vocabulary scores looked significantly more to the novel object. This link was attributable to each age group. Retention trials only showed a correlation for children aged 30 months. In sum, it can be said that only 30-month-olds started to retain the new word-object mappings over time. However, in this study, only monolingual children were tested, which opens up the question of whether a multilingual child's language experience might impact the retention in such an experimental setup.

4.6 Multilinguals and disambiguation

With ongoing research, it has become evident that disambiguation may be applied in some, but not other learning contexts, as has been the case in multilingual children (Byers-Heinlein et al., 2013; Byers-Heinlein & Werker, 2009). Here, it was indicated that multilingual children did not show the disambiguation effect to the same extent as their monolingual peers. The explanation for this finding was rooted in the idea that multilingual children by their very definition will eventually acquire more than one label for an object, i.e., at least one in each of their languages. Thus, they were said to override the assumption of one-to-one mappings between a referent and label, which has been interpreted as that disambiguation is not operational in multilingual children.

This leads to the question as to where the differences between monolingual and multilingual children's use of disambiguation lie. Byers-Heinlein & Werker (2009) concluded that the performance on disambiguation trials was impacted on their language background with monolinguals exhibiting the disambiguation effect, bilinguals performing at chance level, and trilinguals below chance. Houston-Price, Caloghiris, and Raviglione (2010) also tested monolingual and bilingual children aged 18 to 22 months and found that bilinguals did not exhibit disambiguation. These studies suggest that the emergence of disambiguation in multilingual children happens asynchronously to their monolingual peers, which is around 17 months (Halberda, 2003). A more recent study (Byers-Heinlein et al., 2013) indicated that it was not the language exposure per se that prevented multilingual children from applying disambiguation, but rather the composition of their lexicon. Testing 17- and 18-month-old bilinguals and using analyses of individual differences, they were able to show that children who knew fewer translational equivalents exhibited the disambiguation effect, whilst those with many translational equivalents did not. Although learning multiple languages does not preclude children from engaging in the disambiguation process, their multilingual experience does impact on the emergence of disambiguation. Studies with bilingual 2- to 4-year-olds found that they used the disambiguation in a similar way to their monolingual peers (Byers-Heinlein & Fennell, 2014; Davidson & Tell, 2005; Kalashnikova, Mattock, & Monaghan, 2015). In summary, it can be concluded that children's multilingual experience modulates impacts on their use of disambiguation and the developmental trajectory for the disambiguation effect. Knowing this, models such as the associative network model, which was formulated with monolingual children in mind, have to be updated or extended in order to account for these modulations and varying contexts in which fast-mapping via disambiguation may be used vs. not used. Whilst the associative network account mentions the strengthening and pruning of word-object links over time, it makes no predictions about these processes for the different languages in which a multilingual child receives input. Furthermore, it fails to include how prior lexical knowledge, i.e., accessing the lexicon, impacts the processes of fast-mapping and associative learning, which would be of special interest in children growing up with multiple languages. Due to underlying assumption that word learning is based on content-free processes like association and competition, rather than language-specific knowledge, it would be interesting to know how the original authors would incorporate more language-specific elements of word learning, such as lexical access. However, on the flipside of this coin, this domain-general approach towards learning makes it easier to account for modulations elicited by differences in executive functioning. Association and competition are separable mechanisms, and their occurring interactions are fundamental for building and using the lexicon, but they are also likely impacted by individual variations in cognitive control and working memory. Thus, it can be said that whilst the associative network model explicitly allows for domain-general processes to affect learning, it does not make any explicit predictions with respect to executive functions.

Although studies on multilingual children have shown that their multilingual background modulates their use of disambiguation, very little research has been conducted on adults and how their linguistic experience, and especially multilingualism, might impact on disambiguation. Multilingual adults are not oblivious to the fact that an object can have more than one label, and are likely to have a plethora of translational equivalents in the mental lexicon already. For them, the tendency to map a new name to a new, unknown object might not be as strong, as they are more likely to accept many labels for the same object. Using principles, such as mutual exclusivity, Contrast, a Pragmatic Account, or N3C, which operate under the assumption of one-to-one object-label mappings, would be counterintuitive and in some cases even counterproductive. Does this mean that multilingual adults do not disambiguate? As previously outlined, disambiguation is rooted in a process-of-elimination which finds applications outside word learning, even language, as well. Thus, it is not likely that multilingual adults would not rely on disambiguation if it were helpful in a specific context; however, their multilingualism may potentially affect the different mental processes involved when using disambiguation. Multilingual adults' language experience, such as language proficiency, age of acquisition, current language exposure, or the number of languages, might interact with disambiguation more subtly. At this point, I would like to revisit step (2) of the Disjunctive Syllogism, i.e. "not A" or the elimination step. Suppose the Disjunctive Syllogism is indeed the mental computation responsible for disambiguation. In that case, multilinguals will likely not only show differences during this rejection step due to the size of their lexicon and translation equivalents, the amount of exposure to the target language, or language proficiency, but also due to differences in cognitive functioning discussed in Chapter 2.3. The executive functioning research discussed earlier has found that multilinguals show advantages with regards to working memory performance which may lead to faster processing times during the rejection step. The process-of-elimination also requires successful inhibitory control and shifting for two reasons. First, learners keep shifting between the familiar and new item to engage in the double-checking process found by Halberda (2006). Second, they must keep goal-relevant information about the new item active until their decision has been finalised, whilst also shifting between the items. Because adult learners rely on disambiguation to form word associations, the extension of the associative network model would seem necessary, despite being originally proposed as a developmental model. However, the underlying fast-mapping and slow learning processes within the model are still taking place in adult language acquisition, whether in one's native or foreign languages. Since adults have forged much deeper connections over the years between a label and its referent, and thus, have engaged in the process of slow learning for longer, it would be insightful to see how the associative network model can be extended to explain the potential impact that language experience variables, such as proficiency, may have on the process of disambiguation.

In summary, the multilingual experience may modulate the disambiguation process, whereby these differences may manifest in faster processing speeds. Mapping a label to an object is just the first step of learning a word, and little is known with regards to retaining such mappings using disambiguation in adult multilinguals (see Chapter 7).

4.7 Disambiguation in other referential contexts

In 1997, Markson & Bloom tested adults and 3- and 4-year-old children on whether disambiguation was applied to expressions such as factual statements about the item (e.g. "This is the one I keep at work"). Both groups successfully fast-mapped the novel word (the *tulver*) and the new fact about another item to their novel referents. Diesendruck and Markson (2001) adapted and extended this study, and tested 3- and 4-year-old children, who were presented with two new objects, of which one was first introduced with a label (e.g. “this is a *tulver”*) or a referential fact (e.g. “my cat likes to play with this”). During the test, children were asked to find the referent of another new fact or a label. Although children portrayed the disambiguation effect in the label as well as fact condition, it has been questioned whether distinct underlying mechanisms were involved that resulted in a seemingly similar looking manifestation of disambiguation (Waxman & Booth, 2000).

A subsequent study (Scofield & Behrend, 2007) reported that children disambiguated not only words but also factual expressions. 49 two-, three-, and four-year-old monolingual toddlers were tested using the same preferential looking-while listening paradigm previous studies had used (Halberda, 2003). The study was adapted by adding more conditions to address if children extended the disambiguation ‘strategy’ from a pure word-learning scenario to other learning scenarios, such as factual information about objects which is more pragmatic. The non-target was introduced with a label (e.g. *koba)* or a fact (e.g. “This fell in the sink.”) and followed by a disambiguation probe, which could be a label or a fact. For one, the authors predicted that if children disambiguated in all of the four conditions, it would support the Pragmatic Account of disambiguation (Clark, 1990; Diesendruck & Markson, 2001) as children would employ disambiguation in contexts that are not purely semantic, but also in contexts of other linguistic domains such as socio-pragmatics. In contrast, if children only showed disambiguation in the condition where the item was introduced with a name, it would support the constraint accounts, such as mutual exclusivity and N3C (Golinkoff et al., 1994; Markman & Wachtel, 1988), because these view disambiguation as a constraint facilitating lexical acquisition only that are not applicable outside the lexical domain. They found that all children disambiguated in the word/word and fact/word conditions. However, results also showed that the two-year-old group disambiguated at above chance levels in the word/word condition, which was expected, but at below chance in the fact/fact condition. Due to disambiguation being affected by age and condition these findings challenge the pragmatic account.

A more recent study using a similar design (Kalashnikova, Mattock, & Monaghan, 2014) tested adults and children (aged 3;7 to 4;6 and 4;7 to 5;7). A linear contrast analysis revealed that the difference between disambiguation from labels versus facts increased as a function of age. During the initial stages of lexical acquisition, children extended reasoning by exclusion to other referential actions. As children mature and reach adulthood, their understanding of real-world communication grows, and this simple, default disambiguation strategy is limited to word learning. Due to the recruited sample being monolingual, the authors were not able to assess whether children or adults of a multilingual background who may have a more developed understanding about the communicative processes, would modulate their use of disambiguation from facts earlier than their monolingual peers. To ask further questions about adults' use of disambiguation in these differing referential contexts, Malone, Kalashnikova, & Davis (2016) adjusted Scofield & Behrend's (2007) design for adult use. They collected verbal reports from participants to grasp the reasoning behind adults' decision-making (for more see Chapter 8). Similar to the previous findings (Kalashnikova et al., 2014), adults did not rely on disambiguation from facts and only made use of the strategy when the target item was introduced with a label. This supports the idea that disambiguating facts versus labels operates and develops differently.

This research on referential expressions indicates that it is a worthwhile area to be examined further, especially since disambiguation has mostly been tested within children. In recent years, researchers have developed an interest in studying the use of disambiguation within a multilingual sample. However, no research thus far has focussed on the disambiguation of factual expressions in multilingual adults.

Chapter summary

The concept of disambiguation and the associated studies reviewed in this chapter show that multilingualism can have a profound impact on the development and use of disambiguation as a mapping 'strategy'. Disambiguation seems to be a useful mechanism in certain situations, such as resolving referential ambiguity. However, it does not automatically guarantee to long-term retention of a word since word learning itself comprises the two interactive processes, *fast mapping* and *slow learning*, that develop on different trajectories. It is still unclear as to how disambiguation and retention are linked, particularly if children's multilingual upbringing modulates disambiguation. How does this affect their retention? In chapter 6, I address these questions experimentally.

Not many studies thus far have examined the use of disambiguation in an adult population, or multilingual adults for that matter. We know that disambiguation is modulated by multilingualism in children; thus, it is not aliened to pose questions about how multilingualism may affect adults using this kind of process-of-elimination in word learning situations, whether their process is different to that of monolinguals, and how it relates to retention. I address these questions in Chapter 7. Moreover, this chapter reviewed other referential contexts in which disambiguation may find an application. These studies are relevant because whilst we can describe or measure an observable *disambiguation effect*, the thinking process behind people' reasoning can differ based on the referential situation. In Chapter 8, I address how people's multilingualism may shape their use of disambiguation in contexts using labels and facts, and interview them on their reasoning.

5 Summary of literature and research questions

In this brief chapter, I summarise the conclusions drawn from the literature reviewed in the previous chapters, I devise three main research questions and introduce the experimental studies which seek to answer them.

In chapter 2, I highlighted and discussed the multifariousness of being raised and living with multiple languages. I outlined different types of bilingualism and offered an array of descriptions which emphasised that bilingualism is more than solely speaking two languages. By doing so, it became more evident that multilingualism is an experience affected by many modulating variables. These variables included current language exposure, age of onset, language proficiency, or the number of languages spoken, but are not limited to just those. Due to this variability within multilingualism, people from multilingual backgrounds cannot merely be treated as one homogeneous group, as most of the research tended to do until very recently.

For this reason, it is essential to include these measures wherever possible. Furthermore, by reviewing various models on executive functioning and working memory, I showed that multilingualism is not only affected by the different linguistic variables mentioned above but also that the multilingual experience itself can have mutual effects on executive functioning and working memory. In other words, multilinguals may perform differently on particular, even non-linguistic, tasks due to these indirect effects. Thus, it is also necessary to account for potential differences in these non-linguistic cognitive domains wherever possible. Naturally, collecting these measures for children of a very young age, who are often the target sample population for disambiguation research, is challenging.

In chapter 3, I outlined word recognition and lexical access in order to give the reader an insight as to what phonological prerequisites have to be met in order to learn new words, but also to offer an overview of how consolidated, learned words may be accessed. Despite my thesis focussing on a process involved in word mapping and learning and how multilingualism might affect those, it has to be kept in mind that the effects of the multilingual experience are much greater. Accessing words is a vital process when recalling a word from memory, which was required by the adults tested in study 2 (chapter 7).

In chapter 4, I introduced specific concepts pertaining to word learning, namely *fast mapping*, and *slow learning* or retention, and how these two processes relate to each other. Furthermore, I defined and provided an in-depth review of the *disambiguation effect*, its computational processes, its underlying theoretical motivations according to different schools of thought, and its relationship to word mapping and retention. Specifically, I reviewed three key studies of which the first tested disambiguation within young children (Halberda, 2003). The second tested monolingual, bilingual, and trilingual children on the same paradigm that lead to claims of multilingualism being a modulating factor in the use of disambiguation (Byers-Heinlein & Werker, 2009). The third tested (monolingual) children at the same age on how well they retained a word after having just learnt it (Bion et al., 2013). Subsequently, I reviewed newer studies and how disambiguation was used in multilingual children and adults. Lastly, I addressed the applicability of disambiguation in contexts that did not involve mapping a word to an object, but rather linking factual expressions to an object.

Based on the reviewed literature, three research questions are formulated:

1. How do monolingual and multilingual children make use of disambiguation as a mapping and retention strategy over the ages from 18 – 30 months (study 1)?
2. How do multilingualism and executive functioning individually affect how multilingual adults engage in the process-of-elimination during fast mapping and retention (study 2)?
3. Is disambiguation used in other referential contexts, such as facts, by multilingual adults? If not, what other strategies may they rely upon to reach a conclusion (study 3)?

In order to answer these three questions, I now present three independent studies that explore various aspects relevant for the research on disambiguation and its sensitivity to multilingualism: disambiguation as a mapping and retention 'strategy' in multilingual children (study 1), the individual contribution of multilingualism and executive functions on the underlying computational process within multilingual adults (study 2), and the applicability of disambiguation in other referential contexts and the reasoning of multilingual adults behind the decision-making in situations of referential ambiguity (study 3). By doing so, I aim to provide a more holistic view of bilingualism research and why testing multilinguals is essential to understanding disambiguation better. In these three studies, I examine two populations: young infants around the age when disambiguation emerges, and adults. More specifically, I tested the following groups:

1. Monolingual English children (control), and multilingual English-plus other languages children who came from a variety of language backgrounds were tested. These children participated in study 1.
2. The adult group comprises proficient daily users of English, whereby there was a mix between native and non-native multilingual speakers, and monolingual speakers. All participants spoke English daily as they resided in Scotland at the time of testing. Adults participated in studies 2 and 3.

The first study (chapter 6) investigated whether monolingual and multilingual children disambiguated a novel word-object mapping, retained a trained, previously seen word-object mapping, retained the novel fast-mapped word-object mapping, and whether and how age, English vocabulary size, and language background modulated disambiguation and retention. I also tested whether children who disambiguated would also retain better. For this, I adapted a looking-while-listening paradigm for use with eye-tracking. I collected data from 18- to 30-month-old mono- and multilingual children. The data were analysed using binomial mixed-effects models. The analyses reveal that vocabulary size predicted the outcome of mapping and retention better than age. I find that monolinguals' accuracy on disambiguation trials is high from the start, whereas multilinguals start to disambiguate later as their vocabulary grows. On retention trials, only monolingual children perform above chance level. The most exciting finding is that the use of disambiguation improves retention for monolingual, but not for multilingual children. This study shows that disambiguation should first and foremost be treated as a default fast mapping mechanism rather than a fully-fledged learning strategy. Vocabulary growth leading to an increase in disambiguation supports the notion that the disambiguation effect stems from previous learning as postulated by the associative network account (see 4.4).

In the second study (chapter 7), I studied the role multilingual experience played on the accuracy and processing times in a word-learning task (similar to that in the first study) using English proficiency, age of acquisition of English, current English exposure, the number of languages, and English as the first language as modulating background variables. Then I assessed if multilinguals could retain fast-mapped word-object links from the disambiguation phase in three different retention conditions, and how the above variables modulated retention. In each analysis, I separately investigated how working memory and executive function may affect the results. These abilities were collected using a counting recall and the AX-CPT (Braver et al., 2009). The results indicated that multilinguals' performance and processing speed in disambiguation and retention trials are modulated by their linguistic background, whereby English proficiency plays the most influential role with regards to processing speeds, and English exposure with regard to accuracy. Furthermore, working memory positively impacted accuracy and processing speeds, whilst executive functioning measures showed a speed-accuracy trade-off.

In the third study (chapter 8), I explored multilingual adults' use of disambiguation on referential expressions other than labels. Previous studies had shown that adults, unlike children, did not extend reasoning by exclusivity to disambiguate other referential expressions, such as factual information about objects. This has led to an ongoing debate as to whether disambiguation is a process that is specific to word learning. In the second study (chapter 7), I found that multilingual experience variables modulated the use of disambiguation of words. If disambiguation were applicable in other referential contexts, such as facts, I would have expected these multilingual language variables to impact on the disambiguation of facts similarly. To further contribute to the debate of domain-specificity of disambiguation, this eye-tracking study tested multilingual adults on four conditions of a disambiguation task involving factual expressions and labels.

Furthermore, I interviewed participants about their reasoning strategy after selecting referents. Results indicated that adults disambiguate only in the label/label and fact/fact condition. Although this effect may seem similar at first, the analysis of the eye-gaze data revealed that looking patterns differed significantly. This can be explained by the use of significantly different strategies in these two conditions: in the label/label condition, adults used a contrast-based strategy resulting in direct looks to the target, whereas in the fact/fact condition they opted for a logic-based strategy resulting in a different gaze pattern. The linguistic background variables modulated the use of the contrast-based strategy, but not the logic-based, linguistic, or topic-based strategy. The results of this study are challenging both the domain-specific and domain-general view of disambiguation.

As I will discuss in chapter 9, jointly these studies show that disambiguation as a strategy undergoes a narrowing from a default mapping strategy in childhood or when no other information about a referent is available in adults to a more language-specific constraint facilitating word learning. Disambiguation is prone to modulation by someone's multilingual experience, be that in child- or adulthood, and this suggests that multilingualism expedites the narrowing for application.

6 Linking disambiguation and retention in a developmental eye-tracking study with monolingual and multilingual children

This chapter has been published as article (Repnik, Chondrogianni, & Sorace, 2021) in the *Journal of Experimental Child Psychology* on February 11, 2021. DOI: https://doi.org/10.1016/j.jecp.2020.105072. Repnik designed the study, ran the participants, analysed the data and wrote the original manuscript. Chondrogianni and Sorace acted as supervisors, gave feedback on each of these steps and contributed to the revision of the manuscript.

6.1 Introduction

Word learning starts in early childhood through an interplay between processes that enable children's in-the-moment behaviour with those creating long-term retention. To learn and retain a word correctly, one needs to map it to its referent. In any given word learning scenario, a child is exposed to many potential referents upon hearing a new label. To reduce the complexity of this task, a well-documented constraint that helps guide in-the-moment behaviour is called disambiguation. Disambiguation refers to children's ability to correctly assign a novel label to a new object in ambiguous word learning contexts with many other competing referents by eliminating referents that already have a name (Diesendruck & Markson, 2001; Markman, Wasow, & Hansen, 2003). By engaging in this process-of-elimination, children can resolve referential ambiguity and map a new label to a novel referent. However, mapping itself is a fast and short-lived process, and one instance of successful word-object mapping does not guarantee recall at a later stage, which indicates that disambiguation of a new word-object mapping does not result in fully-fledged learning. Thus, one must be careful about calling disambiguation a 'learning strategy' as such. For the child to successfully retain a word-object link, repeated mappings of this link must have occurred (Mather & Plunkett, 2010). However, the direct impact fast mapping has on subsequent recall is not well understood (Bion et al., 2013; Kalashnikova, Escudero, et al., 2018). Moreover, word learning and more specifically the use of disambiguation has been shown to be impacted by children's language experience, such as the size of their vocabulary or whether they are exposed to more than one language. The present study will address how multilingual children disambiguate and retain novel word-object mappings. More specifically, the contribution of the present study is the investigation of the direct impact the use of disambiguation may have on retention.

6.2 From traditional to dynamic approaches to word learning

Traditionally, the ability to map a label to its corresponding referent has been explained via various word-learning principles that children might rely on during the early stages of lexical development. Researchers have been predominantly interested in why children exhibited the use of disambiguation in the first place (Diesendruck & Markson, 2001; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1990). One of the earliest assumptions was put forward in the late 1980s (Markman, 1990; Markman & Wachtel, 1988) and became known as mutual exclusivity (ME). ME is a principle which assumes that new words tend to refer to novel objects, and that referents only have one label. In other words, if a child is already familiar with the name for an object, they would not assign another label to this object. Under the ME account, the familiar referent is rejected from the competition of potential referents, before the learner moves on to the novel object. The rejection stems from the knowledge that the familiar object already has a label and can only have one. In an early study by Merriman, Bowman, & MacWhinney (1989), ME was assessed using a preferential looking-while-listening (LWL) paradigm where children were presented with physical objects of familiar and novel referents and were asked to choose a target object in response to a new label. The idea was that if children relied on ME, they would prefer the novel over the familiar object by fixating longer on the novel object, as the latter already had a familiar label. In doing so, children exhibited the so-called disambiguation effect – of which the ME account offers one possible explanation. Other underlying motivations for disambiguation have been attributed to the principle of cooperation (Grice, 1975) and that speakers should use familiar terminology (Diesendruck & Markson, 2001), or to a child's motivation to map new referents to new objects from the start (Golinkoff et al., 1992). Another more lexical motivation was found in the notion that all lexical representations contrast in meaning (Clark, 1990). Thus, a child hearing a new label upon seeing a familiar name-known and a novel name-unknown object would assign the new name onto the new object, as new object warrants enough contrast to receiving a label.

Children’s ability to disambiguate has been widely studied (in various adaptations of the LWL paradigm) over the developmental trajectory, from young infants (Bion et al., 2013; Halberda, 2003; Kalashnikova, Mattock, & Monaghan, 2016), primary school children (Diesendruck & Markson, 2001; Halberda, 2006; Markman & Wachtel, 1988), to adults (Halberda, 2006; Kalashnikova et al., 2014; Malone et al., 2016). With more research on the topic in the past decades, it has become apparent that the use of disambiguation may only be useful in some, but not in other word learning contexts, such as when children grow up in an environment where they are exposed to more than one language (Byers-Heinlein et al., 2013; Byers-Heinlein & Werker, 2009). These studies have shown that multilingual children do not exhibit the disambiguation effect compared to their monolingual peers at the same age. This finding was explained by the notion that multilingual children by their very definition will eventually acquire translational equivalents (TEs) for most words in their lexicon, and thus override the assumption of a one-to-one mapping between a referent and its label, which has been interpreted as that disambiguation is not operational in multilingual children.

The emergence of disambiguation as a mapping constraint starts early at 17/18 months in monolingual children (Halberda, 2003). Whilst previously, the focus has been on investigating the underlying motivations for disambiguation, only recent studies have explored how it initially develops (e.g. Kucker, Mcmurray, & Samuelson, 2015). At the onset of disambiguation research (e.g. Markman and Wachtel 1988), the effect was described as a language-specific constraint that is exhibited during early word learning. This view has been challenged with more recent studies (Samuelson et al., 2017) on this topic supporting the idea that the disambiguation effect can be ascribed to more general attention biases not specific to language, as proposed by the associative network account (Horst, Samuelson, et al., 2011). For this account, disambiguation is first and foremost a mapping ‘strategy’, and its use does not guarantee the actual retention and learning of that word-object mapping. Furthermore, disambiguation is not responsible for a child's first word, such as mummy or daddy, which can already occur as early as six months (Tincoff & Jusczyk, 1999). This suggests that other driving factors initiate word learning before the onset of disambiguation.

Turning to multilingual children, the question that arises is whether or not they make use of disambiguation in the same way as their monolingual peers, and if they do not, does this mean that they have not yet engaged in a sufficient number of in-the-moment learning episodes to show the disambiguation effect? After testing monolingual, bilingual, and trilingual infants aged 17 months, Byers-Heinlein and Werker (2009) concluded that their performance on disambiguation trials depended on their language background with monolinguals exhibiting the disambiguation effect, bilinguals performing at chance level, and trilinguals below chance. Also, Houston-Price, Caloghiris, & Raviglione (2010) investigated monolingual and bilingual children from 18 to 22 months, and the bilinguals did not show any use of disambiguation. These studies suggest that the emergence of disambiguation in multilingual children happens asynchronously to their monolingual peers. However, a more recent study by Byers-Heinlein et al. (2013) concluded that it is not the language exposure as such that prevents multilingual children from using disambiguation, but rather the composition of their lexicon. They tested 17- and 18-month-old bilinguals and through an analysis of individual differences were able to show that those children who knew fewer TEs did show the disambiguation effect, whilst those who knew many TEs did not. However, learning two or more languages does not preclude them from engaging in disambiguation, but that the experience of growing up with more languages impacts on the emergence of disambiguation. Studies with bilingual 2- to 4-year-olds have shown that they similarly use disambiguation as their monolingual peers (Byers-Heinlein, Chen, & Xu, 2014; Davidson & Tell, 2005; Kalashnikova et al., 2015). With these research findings in mind, one can say that children's multilingual experience impacts on their use of disambiguation and modulates the developmental trajectory for the disambiguation effect. However, direct predictions have yet to be made why these differences shape the associative network in the multilinguals.

6.3 Disambiguation in the associative network

With recent studies supporting the idea that the disambiguation effect is not specific to language acquisition (e.g. Kalashnikova et al., 2018; Samuelson et al., 2017), fast-mapping has been described as the consequence of more general attentional processes coupled with the growth of a child's vocabulary (McMurray et al., 2012; Samuelson et al., 2017). A computational model by Kucker et al. (2015) suggests that the disambiguation effect could be purely derived from associative learning paired with competition, the salience of the object, attention, previous receptive vocabulary (Kalashnikova et al., 2016), and other environmental factors, such as object location or proximity. In other words, the associative network account explains successful disambiguation as the result of a sufficiently structured or pruned network which has direct implications on real-time referent selection.

The authors of this account argue that lexical development in children relies on processes that differ in terms of their time course. They describe these distinct, yet interactive time scales as situation time and developmental time. Situation time encapsulates behaviours and functions that support communication at the moment, and can result in inference, constraint satisfaction, or other in-the-moment problem-solving strategies. It is during this period that fast-mapping or disambiguation takes place. Disambiguation is one way of reducing referential ambiguity; however, it is not the only way. The associative network account also takes into consideration that adults often limit the possibility for other referents by holding and naming a single object to which a child is attending and that children, due to their stature and short arms, can see fewer items during the naming of objects, which also reduces referential ambiguity (Pereira, Smith, & Yu, 2014). Fundamentally, mapping a label onto its referent is a matter of directing attention to the correct referent. Children's attention is modulated by both external (such as object salience) and internal cues (such as object novelty), which both change over time, not only as the child is ageing but also as they learn more about the task and the stimuli within a task itself (Roder et al., 2000). During the developmental time, a network of mappings between words and concepts is created and updated as children encounter repeated uses of a word, and gradually over time, this learning process refines the network forming a stable vocabulary. During each situation time episode, small amounts of learning happen (Smith & Yu, 2008) which rises systematically with the repetition of mappings (Mather & Plunkett, 2010) and vocabulary development (Bion et al., 2013). Associative learning is not only forming correct word-referent links right away but also about pruning links between words and incorrect referents as the mental lexicon is faced with new evidence (Regier, 2005). With regards to the disambiguation effect, the associative network account describes its occurrence as evidence that prior learning has happened and is considered a consequence of a sufficiently structured network. This account approaches disambiguation in a top-down manner, postulating that domain-general mechanisms shape the network first, which make it then suitable for the language-specific use of disambiguation (Kucker et al., 2015). In other words, if children exhibit the disambiguation effect, they have successfully engaged in prior learning episodes.

One aspect pertinent to previous disambiguation research has not yet been addressed under the associative network account – namely how bilingual or multilingual children's trajectory of the disambiguation effect can be explained. Children who are exposed to two or more languages divide their waking hours over these languages. This means that for each language, the daily exposure time in which fast-mappings happen is also reduced, which in turn leads to fewer occasions of situation time learning episodes. In other words, the fast mappings multilingual children strengthen and prune during situation time will take longer to be solidified by slow learning processes of developmental time. Thus, the consolidation of a multilingual child's associative mental network may be at a different stage compared to their monolingual peers. If this is the case, then multilingual children will have had fewer prior learning episodes per language at the same age, which according to the associative network account, has direct implications on their use of disambiguation, and by extension also on retention.

6.4 Disambiguation and retention

Disambiguation and retention are linked insofar as they represent the two learning trajectories set out by associative network account, i.e. fast mapping in situation time, and slow learning in developmental time. If children's multilingual experience impacts on their use of disambiguation, as set out above, then the trajectory for slow learning or retention of new words is also altered, as the two processes are interactively linked and inform each other. If, as laid out in the previous section, multilingual children have fewer exposures to situation time mapping encounters, the solidification of word-object links over developmental time will take longer. Because most studies investigating disambiguation do not usually invite children for a follow-up on long-term retention, it should be noted that the term 'retention' in the subsequent studies refers to a trial type. Studies have shown that at 24 months old, relying on disambiguation to establish a novel word-object mapping did not result in successfully retaining this mapping after an only minimal delay (Bion et al., 2013; Horst & Samuelson, 2008). A study by Kalashnikova and colleagues (2018), however, found opposite results. They tested 18- and 24-month-olds and found that monolingual, as well as bilingual children, aged 18 months were already able to retain a word-object link mapped via fast mapping trials, but at 24 months old only the monolingual group was able to do the same. Moreover, this study tested the correlation between the use of disambiguation may have on retaining the object that was disambiguated, and they found no significant direct correlation between the two.

Although these results are somewhat inconclusive, the age of 24 months seems to be a vital timepoint during language development. At this age children successfully retained an object-word mapping when presented in an ostensive, non-ambiguous manner (Bion et al., 2013), or if children were exposed to the target objects before the experiment as a way to familiarise them with them (but not the label) (Horst & Samuelson, 2008; Kucker & Samuelson, 2012). Even though these studies describe children's accuracy or success on retention trials as 'retention', they do not assume long-term retention of the tested items. Although long-term consolidation cannot be determined by such retention trials, unless children were to be retested in a follow-up, the success on these trials furthers our understanding of the initial steps down the slow learning path posited by the associative network model (Kucker et al., 2015). Despite not to be taken as synonymous with fully-fledged retention, the developmental relationship between initial retention and full consolidation of a word warrants the use of the term 'retention' for either.

In summary, the picture that is drawn from research on disambiguation still leaves some gaps. Disambiguation is not available from the get-go of language acquisition, such as when children utter their first words around six months old, and that to make use of disambiguation means to draw on prior episodes of learning (McMurray et al., 2012; Samuelson et al., 2017). This dynamic associative view of the disambiguation effect suggests that to view things as mutually exclusive in tasks of referential ambiguity, as required under the ME account, is the result of general learning or attentional biases. Moreover, only with growing vocabulary and linguistic experience can the ME assumption develop into a reliable mapping and possibly retention strategy. Nevertheless, we do not know how this trajectory unfolds for multilingual children. One possibility with increasing evidence could be that the emergence of the disambiguation is simply delayed for multilingual children as they are establishing two or more lexicons in tandem, which reduces the exposure to each language and thus the in-the-moment learning episodes within a language, and thus, requires more time for establishing an associative network. Provided this is the case, there is little consensus on what they do use in the meantime if not disambiguation. The fact that multilinguals portray the disambiguation effect in some situations, but not in others, leads to the postulation of another possibility, namely that disambiguation is kept as a “default fast-mapping heuristic” (Kalashnikova, Escudero, et al., 2018). However, it is not adopted as a consistent word-learning strategy. The latter makes sense in the context of learning translational equivalents, as applying disambiguation under the ME assumption for one object would be counter-productive to the creation of a multilingual semantic network.

6.5 Present study

Given the interactive nature of fast mapping and slow learning processes and the documented differences in multilingual children with regards to disambiguation, our study contributes to filling the gaps of explicitly linking fast mapping and slow learning under the associative network account and how the multilingual experience modulates these trajectories. More specifically, we were interested in how monolingual and multilingual children’s performance on disambiguation and retention trials developed over time, and how performance on the former may impact the success in the latter. For this, we designed disambiguation trials, which juxtaposed a novel to a familiar item (either a ball or car), retention trials which juxtaposed the new item (from the disambiguation trials) to a trained item (seen in a prior training phase), and familiar word trials (car vs ball). Like the above research designs, we tested ‘retention’ by measuring the accuracy on selecting an item that was shown to children within an experiment, and we do not make claims about their ability to memorise this word-object mapping beyond the scope of the experiment.

First, we focussed on how the trajectory of disambiguation unfolds for multilingual children aged from 18 to 30 months, as previous studies (Byers-Heinlein & Werker, 2009) had indicated that disambiguation in this group might emerge later due to their multilingual background. However, Kalashnikova and colleagues (2018) found that bilinguals as young as 18 months showed the disambiguation effect. Differences in how the target window was defined for analysis may have contributed to these diverging results, as their post-target window was longer (i.e. 0 – 3000ms) than in other studies (e.g. 360 – 2000ms in Byers-Heinlein & Werker, 2009). In these studies, only children aged 18 months and 24 months were tested. In the present study, we aimed to gain better insight into the multilingual trajectory of disambiguation by extending the age range of interest.

Furthermore, researchers have not reached a consensus yet as to what constitutes disambiguation, as some studies defined disambiguation as the accuracy on disambiguation trials (accuracy on familiar and novel target item taken together) (e.g. Kalashnikova et al., 2018; Yow et al., 2017), which could conflate the success on the accuracy of the familiar item with the actual disambiguation of the new item. In the present study, we defined disambiguation as the successful mapping of the novel label, excluding familiar labels, during disambiguation trials. We predicted that multilingual children would disambiguate to a lesser extent than monolinguals for all ages with disambiguation emerging slightly later than in monolinguals, as was found in previous studies (e.g. Byers-Heinlein & Werker, 2009). In addition to age, we also predicted that vocabulary size would be a critical modulating factor with regards to the use of disambiguation, as found in previous studies (e.g. Kalashnikova et al., 2018). In the present study, we also examined the interplay between the two and which factor, age or vocabulary, is a more reliable predictor of the children's ability to disambiguate and retain new words.

The study also sought to answer if children growing up with more than one language were able to perform similarly on retention trials, and how performance on the different retention items unfolded from the ages of 18 to 30 months. For this, we designed one trial type (a novel vs a trained item) that allowed us to test retention performance on a previously, ostensively trained item, and a fast-mapped item seen during the disambiguation trials. Put simply; we investigated how children differed in their ability to retain a novel label that was mapped either during unambiguous teaching trials versus fast-mapped disambiguation trials. Bion, Borovsky, and Fernald (2013) showed that monolingual children as young as 17 months could retain object-word mappings after ostensive teaching trials. We predicted that the ability to retain the ostensively mapped word would be high in both mono- and multilingual children. For the retention of the fast-mapped item, we predicted that both groups would score lower than on ostensive retention, but that their performance would increase with age and vocabulary size. Moreover, for multilingual children, we predicted that even though they might exhibit the disambiguation effect, retention might not be guaranteed, as shown in Kalashnikova et al. (2018).

In the present study, we predicted that at least the monolingual children who perform well on disambiguation trials, and thus, make more use thereof, would be the ones retaining novel object-word links better. However, that effect was predicted to be present only when children had been confronted with a case of ambiguity between two or more possible referents. In a situation where there is no doubt what a new label refers to, the use of disambiguation is not necessary to make a correct mapping. The mapping of a novel target item, e.g. nil, presented in unambiguous teaching trials at the start of the experiment should not show the disambiguation effect as only one object could be the referent for the label. Hence, in this case, we did not expect that children's use of disambiguation impacts on the retention of this word-object mapping. However, the mapping of another novel target item, e.g. dax presented in an ambiguous context next to a familiar item, needed to be disambiguated before it could be mapped and retained. Here, we expected that children who disambiguate more would be more accurate at object-word mappings. Finally, we also examined how children's performance on disambiguation and retention trials was modulated by age and vocabulary size.

To summarise, we predicted that multilinguals would make use of disambiguation, albeit to a lesser extent and later on. For retention, we predicted that neither group would have difficulties retaining the trained item and that both groups would perform lower in the more effortful retention of the fast-mapped item. Here, we also predicted that multilingual children might not be able to retain the fast-mapped mapping despite the potential use of disambiguation. We also predicted that at least monolingual children would perform better on retention if they also performed well on disambiguation trials.

6.6 Material and methods

6.6.1 Participants

A total of 96 children participated in the study. Children belonged to the monolingual or multilingual group. Forty-three children belonged to the Monolingual group (19 female) and forty children to the Multilingual group (12 female, 28 bilingual, 12 trilingual). The age range for the monolinguals was from 17.56 to 32.15 months (M_{age} = 24.94) and for the multilinguals from 17.46 to 32.71 months (M_{age} = 23.92). The latter were raised in multilingual homes with English as one of their languages. The monolinguals did not differ from the multilinguals with regards to their socio-economic status (SES) based on the Scottish Index of Multiple Deprivation (SIMD). The SIMD is calculated with the postcode of their residence. The means of both groups lie in the top half of the calculated deciles (1 = contains 10 % of the most deprived areas in Scotland), with 7.42 for the monolingual (SD = 2.76, range = 1 to 10) and 6.65 for the multilingual group (SD = 2.61, range = 2 to 10). Thirteen children (of which five monolingual, four bilingual, four trilingual) were excluded from the final sample due to failure to calibrate or to capture sufficient gaze data for analyses (10), to complete the task due to extreme fussiness (2), or to comprehend the task (1).

6.6.2 Language Background

All participating families were asked to complete the 'The CDI: Words & Sentences (Toddler form)' (see Appendix D) part of the MacArthur-Bates Communicative

Development Inventories (Fenson et al., 1993; Fenson et al., 2007). This questionnaire is suitable for children aged from 16 to 30 months and assesses not only the size of children's expressive vocabulary, but also how they combine words into sentences. Since the focus of this comprehension study was the acquisition of words, the relevant metric used is the former, bearing in mind that children's comprehensive vocabulary size was likely larger. Parents were asked to mark the words that children understand and use, rather than just understand, as this is easier to assess for parents.

For monolingual children, the size of expressive vocabulary ranged from 0 to 628 words[2] ($M = 251.10, SD = 185.40$), and for multilingual children from 5 to 530 words ($M = 175.60, SD = 174.42$). Vocabulary size for the two groups did not differ significantly from each other ($W = 1051, p = .083$). A more detailed overview of the sample demographics can be found in Table 6.6.1.

All multilingual children had English as one of their first languages. Multilingual children received their languages either from both parents, or different parents, with children being exposed to three or more languages also receiving input through nurseries or ambient language. The additional languages were Arabic, Danish, French, Gaelic, German, Greek, Hungarian, Italian, Lithuanian, Mandarin, Norwegian, Polish, Portuguese, Russian, Slovenian, Spanish, and Valenciano. Parents of multilingual children were interviewed after the experimental session while children played in the play area. We assessed current exposure, cumulative exposure of English, and age of first exposure for English and all their other language by using the Bilingual Language Experience Calculator (see Appendix D, Unsworth, 2013). The amount of current exposure was ascertained by asking caregivers how much exposure their child received in each language using a percentage scale. Most parents had no difficulty answering this question. However, if at a later stage, they realised they might have forgotten about an element, we revised their previous statement. The cumulative length

---

[2]. One multilingual child had an expressive vocabulary of zero at testing. However, the caregiver detailed that the child was able to understand many of words detailed on the CDI questionnaire. Parents were instructed only to select the words that their child verbalises. Thus, the number of words understood by children was higher, which was also the case for this child. We explicitly checked if this child performed differently on familiar word trials (which depicted *car* and ball), and no difference compared to other participants was found indicating that this child understood the task at hand and could be included in further analyses.

of exposure the BiLEC gathers the following information for the child: a) how much each caregiver and other adults living with the child spoke the language(s) in the years before the study participation; b) if the child attended nursery or day care in this period, and if so, what the language of instruction was, and c) what languages were used on holidays. It was rather easy to ask about the period before they participated in this study as we tested children of a young age which meant parents had a good recollection of the language situation. From this data, cumulative exposure was calculated by averaging how much a child was exposed to English at home for each yearly period whilst also considering waking/sleep hours. The exact calculations can be found in the BiLEC Manual (v5, 2016).

	Monolingual		Bilingual		Trilingual	
N	43		28		12	
Age (in months)	24.62		24.38		22.58	
SES	7.32	(2.87)	6.75	(2.70)	6.92	(2.75)
CDI	236.31	(180.01)	219.54	(186.31)	71.00	(164.20)
Current English exposure (average % per week)			0.67	(0.19)	0.42	(0.16)
Cumulative English exposure (in years)			1.08	(0.48)	0.56	(0.50)
AfE English (m;d)	0;0	-	0;27	(3;3)	1;24	(3;18)
Current Other Language 1 exposure (average % per week)			0.34	(0.18)	0.37	(0.16)
Cumulative Other Language 1 exposure (in years)			0.70	(0.41)	0.42	(0.49)
AfE Other Language 1 (m;d)			0;20	(3;14)	0;13	(1;14)
Current Other Language 2 exposure (average & per week)					0.22	(0.10)
Cumulative Other Language 2 exposure (in years)					0.31	(0.36)

AfE Other Language 2 (m;d)			1;5	(2;26)

Table 6.6.1: Sample demographics. Means (and standard deviations). NB: In the main analysis bilingual and trilingual children were part of one group ("Multilingual"). Abbreviations: N = number of children; SES = Socioeconomic status; CDI = MacArthur-Bates Communicative Development Inventories ; AfE = Age of first exposure.

6.6.3 Stimuli

To investigate whether children's use of disambiguation and retention was modulated by their language background, as well as age and vocabulary size, we developed an eye-tracking task where children were presented with two juxtaposed images of objects. Stimuli were monosyllabic words in all four conditions. To account for accurate reaction time measurements, only words that began with a plosive or nasal were used as these allow for the word onset to be determined with the high precision (Moss, 1996). The familiar items and words used were ball and car. The stimuli used for the trained and novel condition, nil and dax[3] respectively, were pseudo-words that adhere to the phonotactic properties of English. The images for the ball, car and nil were coloured 3D drawings selected from the TarrLab Object DataBank (1996). The image representing the dax was a 3D-rendering of a green modern garlic press found through a simple Google search (Figure 6.1). All items were presented on a black background in consistent pairs, except in unambiguous teaching trials. Auditory stimuli were recorded by a female native Standard Scottish English speaker who was instructed to speak in an infant-directed manner. All items appeared with each of the three carrier phrases (Table 6.6.2).

The experiment was divided into four conditions, of which each had eight trials. Trials were pseudo-randomised by target item with a repeating order of familiar, familiar, trained, novel throughout the testing blocks. Trial types were:

◊ Familiar word trials (FF) which juxtaposed the ball with the car. This condition was included to ensure children understood the task

[3] During testing, it became apparent that *dax* was not an ideal label, as it could be confused with the plural of *duck*, as well as the homophonous German word *Dachs* for English *badger*.

◊ Disambiguation trials (FN) which juxtaposed the novel item dax with either one of the familiar items

◊ Novel word retention trials (TN) which juxtaposed the trained, familiarised item of the training phase (nil) with the novel item dax. This condition was split by target item to test two types of retention:
  - o if children were able to retain the ostensively familiarised word-object mapping from the training phase (trained item was the target)
  - o if children were able to retain the novel word-object mapping presented during disambiguation trials (novel item was the target)

◊ Familiarity trials juxtaposing the familiar and trained item (for future analysis)

Figure 6.1: Stimuli (from left to right: ball, car, nil and dax)

Carrier phrase	Label	Item
Look at the …! …!	Ball	Familiar (F)
Find the …! …!	Car	Familiar (F)
Where is the …? …?	Nil	Trained (T)
	Dax	Novel (N)

Table 6.6.2: Carrier phrases and items

6.6.4 Apparatus

The visual stimuli were presented on a 23-inch screen with auditory stimuli being played from one loudspeaker on either side of the monitor concealed behind a black curtain. Data were collected using a Tobii TX300 eye-tracker via E-Prime presentation software using extensions for Tobii. Recordings were sampled at a refresh rate of 60 Hz. For the duration of the experiment, children sat on their caregiver's lap approximately 60 cm away from the screen in a dimly lit room. Caregivers were instructed to keep their gaze low and remain behind their child to avoid the erroneous recording of their eye movements. They were also asked to refrain from prompting their child or reacting in any way to the stimuli. The experimenter remained next to the child and caregiver throughout the experiment monitoring the progress. At the beginning of the experiment, a 5-point infant calibration took place. After the experiment, children received stickers, and caregivers were compensated for their time.

6.6.5 Procedure

Before children participated in the study, they were invited to play in the laboratory in order to establish rapport between the experimenter. The experiment itself consisted of two phases, training and testing. The training phase comprised eight unambiguous, ostensive teaching trials (referred to as the OT condition) in which children were familiarised with the item nil. This new object-word mapping was modelled after Bion et al. (2013). The training phase was concluded with a short break and then followed by the testing phase, which consisted of two presentation blocks (each with 16 trials). The experiment had 40 trials in total. Each trial began with a fixation cross that was paired with an auditory cue (a ping sound) to attract children's attention to the screen. A baseline presentation of the images on the screen for 3000 ms followed before the auditory stimulus was presented. After the onset of the auditory stimulus, the images remained on screen for a further 6500 ms. In the testing phase of the experiment, each of the four items appeared as the target eight times, with the target item being presented on either side of the screen half of the time. The trials were pseudo-randomised, and no item could be the target for more than two consecutive trials. The testing phase always started with a familiar word trial, and trial order was by target item (cycling through familiar, trained, novel items in this order). Informed consent was given by children's caregivers before testing, and parents remained in their child's presence at all times.

6.6.6 Eye-tracking analyses

Looking duration and fixations were collected for the baseline phase of each trial, and the remaining 6500 ms after the onset of the auditory stimulus. The analysis window for the testing phase was defined from 360 to 2000 ms after the target word onset. This starting point has been taken to indicate the time needed to process the word and initiate eye movement (e.g. Dahan, Swingley, Tanenhaus, & Magnuson, 2000). Any reaction or eye movements beyond 2000 ms are less likely to be responses to the target word itself (Fernald, Perfors, & Marchman, 2006; Swingley & Fernald, 2002). In line with Byers-Heinlein and Werker (2009), we removed trials with more than 62.5% of track-loss from the pre-target window (0 to 2000ms after word onset); in other words, children had to have looked at the areas of interest at least 750ms during the first 2000ms after target onset. Looks towards the target item (TargetLook in models, tables, and figures) were coded as "1" and looks towards the competitor as "0". Accuracy was defined as proportions of looks towards the target item over looks towards target and competitor and was our dependent variable.

For the statistical analysis of each condition, we commenced with a null model, against which each built model was compared. We used a stepwise bottom-up approach and compared models via likelihood ratio tests. For the final models, ROC curve analyses were performed. The closer the calculated C-value reaches 1, the better the performance of the model. A value near 0.5 would mean that a model is not better than chance level. For the complete data analysis, we used R (R Core Team, 2019), and for mixed-effect modelling, in particular, the lme4 package (Bates, 2005; Bates & Sarkar, 2007).

To answer how children's development impacted on their performance on disambiguation and retention trials, we also checked whether and how predictor variables related to each other. As age and vocabulary size were naturally correlated (in our case $\rho = .78, p < .001$), we disentangled the individual contribution of impact each of these two variables had and created a new variable for residual age predicting age by vocabulary. Due to a high number of data points, continuous variables, namely children's age and their vocabulary size, were rescaled to allow for model convergence.

6.7 Results

Table 6.7.1 presents children's accuracy across the experimental conditions.

Group	Condition	Target	M	SD
Monolingual	Familiar (familiar vs familiar)	ball	0.60	0.49
		car	0.83	0.38
	Disambiguation (familiar vs novel)	ball	0.64	0.48
		car	0.75	0.43
		dax	0.66	0.47
	Ostensive Teaching	nil	0.98	0.12
	Familiarity (familiar vs trained)	ball	0.69	0.46
		car	0.79	0.41
		nil	0.76	0.43
	Retention (novel vs trained)	dax	0.55	0.50
		nil	0.63	0.48
Multilingual	Familiar (familiar vs familiar)	ball	0.57	0.50
		car	0.77	0.42
	Disambiguation (familiar vs novel)	ball	0.73	0.44
		car	0.74	0.44
		dax	0.58	0.49
	Ostensive Teaching	nil	0.99	0.09
	Familiarity (familiar vs trained)	ball	0.65	0.48
		car	0.66	0.47
		nil	0.62	0.48
	Retention (novel vs trained)	dax	0.48	0.50
		nil	0.67	0.47

Table 6.7.1: Accuracy (means and SDs) for each target in each condition by group

6.7.1 Familiar word trials

In order to ensure children had understood the task, we presented them with familiar word trials (FF) whereby a familiar word pair (ball vs car) was shown. We first assessed whether the performance accuracy (overall proportions) for each group was above chance level adopting one-sample t-tests. With an accuracy of .70 ($SD = .16$) on average, monolingual children performed significantly above chance ($t(40) =$

$8.05, p < .001, \mu = .5$). Similarly, multilingual children performed at .68 ($SD = .13$) accuracy, which was also significantly above chance level ($t(39) = 8.67, p < .001, \mu = .5$).

6.7.2 Disambiguation trials

To address whether children disambiguated, and how their age, vocabulary size, and language background modulated the use of disambiguation, we looked at the disambiguation condition (FN). In this condition, children were presented with pairs of images of which one was always one of the familiar ones, and the other was the novel item dax. For all subsequent analyses, we collapsed both familiar items into one variable. We defined disambiguation as the accuracy on trials where the novel item dax was the target during disambiguation trials. To see whether children performed above chance, and hence, were able to disambiguate, one-sample t-tests were performed on both groups, with monolingual children performing above chance at an accuracy of .67 ($SD = .20, t(41) = 5.47, p < .001, \mu = .5$), whereas multilingual children's accuracy was below at .58 ($SD = .27$) which did not reach significance, but yielded a trend ($t(38) = 1.78, p = .08, \mu = .5$). As children had a wide age range, the non-significance of the t-test can likely be traced back to younger children's lower accuracy cancelling out that of older children. As previously shown (Byers-Heinlein et al., 2014), multilingual children tend to be delayed in the emergence of disambiguation. Hence, we performed a binomial mixed-effect regression analysis for these trials to disentangle this potential conflation of age.

Our analysis for disambiguation trials resulted in two models, one describing the entire sample, the other describing the multilingual children. Both models regarded the individual variance as a given (accounting for with a by-target slope on the subject random intercept) and had a by-TrialId random intercept. The random effect structure was kept as maximal as possible (Baayen, Davidson, & Bates, 2008; Barr, 2013; Barr, Levy, Scheepers, & Tily, 2013; Bell, Fairbrother, & Jones, 2019; Jaeger, 2008; Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). Children's age was entered and directly compared; however, models with vocabulary size as predictor variable resulted in better models, and hence age as a covariate was removed.

6.7.2.1 Main analysis: Disambiguation mediated by Vocabulary size

Fixed effects for the optimal model were Target type (familiar, novel) and Language group (monolingual, multilingual) with vocabulary size as a covariate. The optimal model contained Vocabulary rather than Age as the predictor, as vocabulary increased the fit of the model significantly ($\chi^2\,(0)\ = 4.72, \mathrm{p}\ <\ .001$). The optimal model showed no significant main effects but yielded a significant two-way interaction between Target type and Language group ($e^{\beta} = .29, SE = 1.80, z = .12$). This result reflects that multilinguals behave differently than monolingual children on the disambiguation trials (Table 6.7.2). The interaction is visualised in Figure 6.2.

Through a confusion matrix, we assessed the accuracy of our model. Out of possible 42’574 observations, our model correctly predicted 74% of the cases making it a robust model. The C-index for this model was $C = 0.77$.

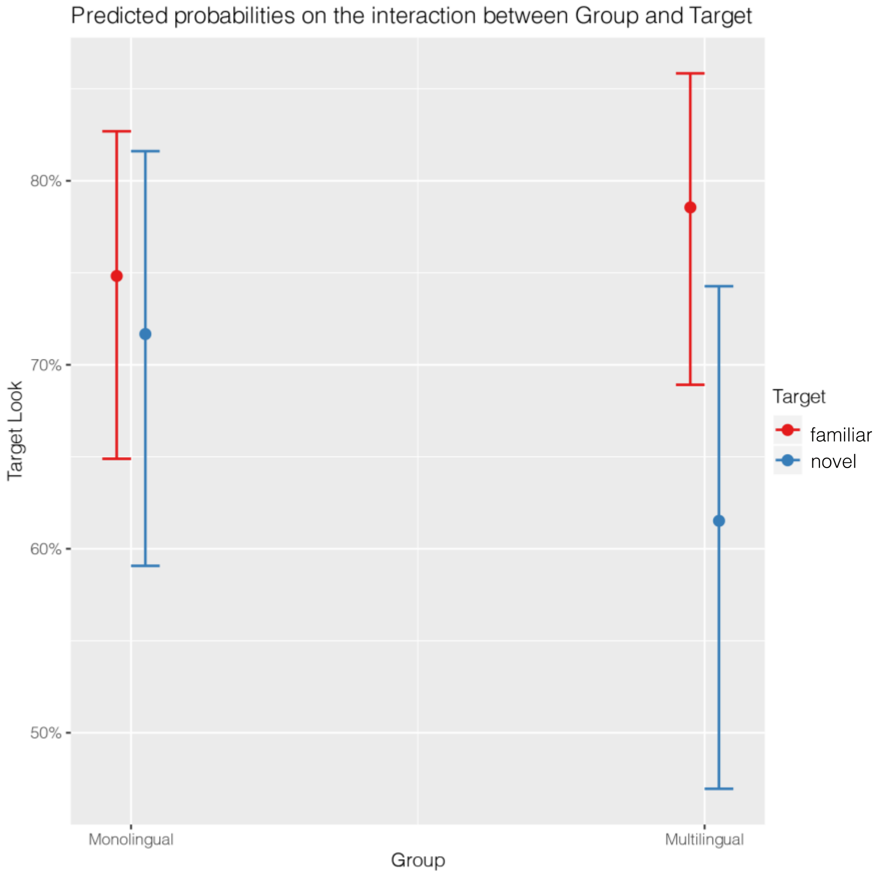


Figure 6.2: Interaction between target and language background (marginal effects) on disambiguation trials

	e^{β}	Std. Error	z value	p-values
(Intercept)	2.93	1.41	22.67	0.002**
Target (novel)	0.66	1.62	0.43	0.395
Vocabulary (scaled)	1.01	1.32	1.04	0.968
Group (multilingual)	1.50	1.51	2.67	0.325
Target (novel):Vocabulary (scaled)	1.38	1.50	2.22	0.425
Target (novel):Group (multilingual)	0.29	1.80	0.12	0.034*
Vocabulary(scaled):Group (multilingual)	0.79	1.51	0.56	0.562
Target(novel):Vocab(scaled): Group(multilingual)	2.14	1.82	3.55	0.206

Table 6.7.2: Model 1 – Formula: $\boldsymbol{TargetLook \sim Target * Vocabulary(scaled) * Group + (1|TrialId) + (1 + Target|Subject)}$

	e^{β}	Std. Error	z value	p-value
(Intercept)	4.99	1.42	94.69	<.001***
Target (novel)	0.16	1.73	0.04	<.001***
Vocabulary (scaled)	0.74	1.42	0.42	0.387
Target(novel):Vocabulary (scaled)	3.25	1.76	8.03	0.037*

Table 6.7.3: Model 2 – Formula: $\boldsymbol{TargetLook \sim Target * Vocabulary\ (scaled) + (1|TrialId) + (1 + Target|Subject)}$

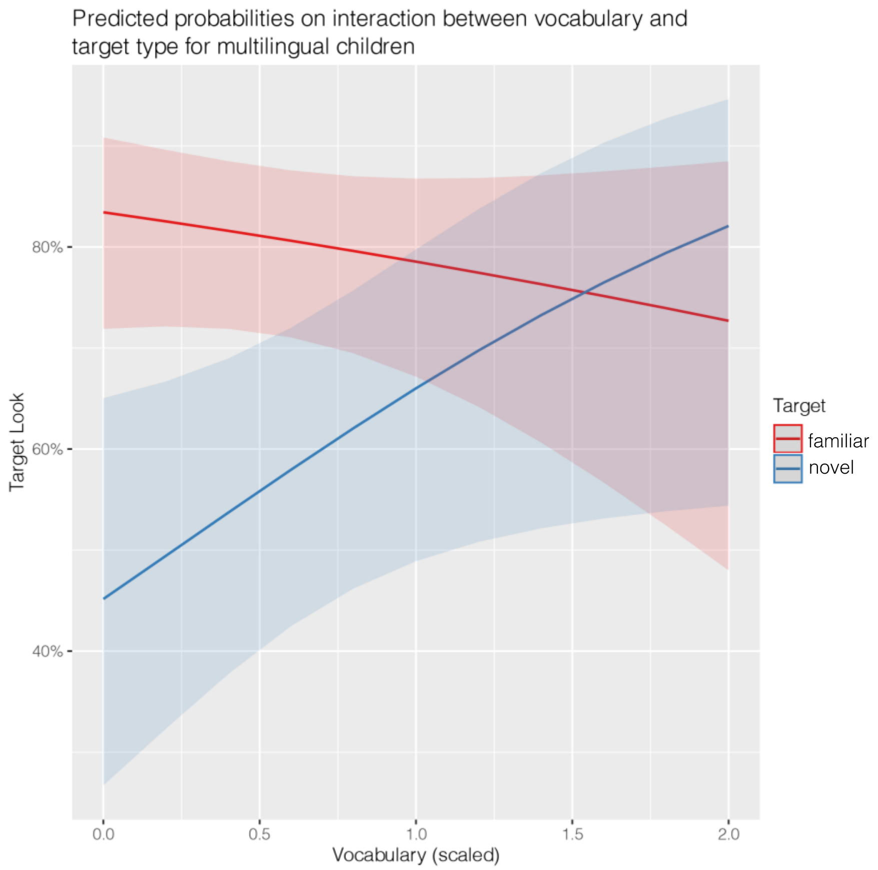


Figure 6.3: Interaction between target type and vocabulary size (marginal effects) on disambiguation trials for multilingual children

6.7.2.2 Sub-group analysis

To unpack the two-way interaction found in Model 1 (Table 6.7.2), we split the dataset by Group, and ran the same model removing the fixed effect for Group. For the monolingual group, no significant effects were found indicating that they treated the novel and familiar targets similarly, and in both conditions, accuracy was above chance. For multilingual children, we found a main effect of Target type ($e^{\beta} = .16, SE = 1.73, z = .04$), and a significant two-way interaction between Target type and Vocabulary size ($e^{\beta} = 3.25, SE = 1.76, z = 8.03$; Table 6.7.3). The interaction is visualised in Figure 6.3. This interaction indicates that with growing vocabulary size, multilingual children started to disambiguate[4].

[4] Although age as predictor did not improve our models significantly, we included an additional graph to show how age modulated multilingual children's performance in our supplementary material (see Appendix A). As we extended the age range from 24 to 30 months compared to previous studies looking at disambiguation in multilingual children, this might be of interest.

To answer the question of how children's language background, their age, and vocabulary size impacted on their ability to retain novel word-object mappings, we performed two analyses, as two types of retention were tested within the same trials (TN); firstly, ostensive retention and secondly, retention via fast mapping.

6.7.3 Ostensive retention

Ostensive retention was tested to address whether retention on a fundamental level was possible for these children. Neither monolingual nor multilingual children had difficulties in performing above chance ($\mu = .5$) on trials where the trained item nil was the target ($M_{mono} = .66, SD = .19, t(39) = 4.08, p < .001; M_{multi} = .66, SD = .25, t(37) = 4.04, p < .001$ respectively). These results also indicated that the two groups did not differ in their performance of retaining object-word mappings after unambiguous training. To test whether children had retained the label of the trained item and were not simply familiarised to its shape, we performed a sub-analysis for each group to compare infants' pre-naming and post-naming tendencies for the nil. We added "Part of Experiment" as predictor variable with the following levels: Baseline Duration (reference level), Pre Target Duration (time after baseline pre-naming of target), Target Duration (duration in which target label was auditorily presented), and Rep Duration (duration in which target label was repeated). Both the monolingual and multilingual children significantly increased their looks towards the target in the post-naming portions of the trial: Target Duration ($e^{\beta} = 1.34, SE = 1.01, z = 34542.54, p < 0.001;$ $and\ e^{\beta} = 1.22, SE = 1.03, z = 712.60, p < 0.001$); and Rep Duration ($e^{\beta} = 1.54, SE = 1.04, z = 47426.56, p < 0.001;$ $and\ e^{\beta} = 2.09, SE = 1.05, z = 7748628.70, p < 0.001$ respectively).

6.7.4 Retention via fast mapping

The picture for retaining the novel item dax mapped during disambiguation trials differed as expected. Monolingual children performed at an accuracy of .58 ($SD = .25$) almost reaching significance above chance ($t(37) = 1.96, p = .058$). As before, older children with larger vocabularies performed better, which cannot be assessed using a simple t-statistic. Multilingual children, however, performed at chance level ($M = .50, SD = .24, t(37) = .04, p = .965$). Subsequently, we ran a new set of logistic mixed-effect regression models to investigate how vocabulary size impacted on children's success in retention trials. The analysis of the retention condition was analogous to disambiguation trials.

Fixed effects for the optimal model were Target type (trained, novel) and Language group (monolingual, multilingual) with vocabulary size as a covariate. The analysis of retention accuracy showed a main effect of vocabulary size, as children with larger vocabularies performed better on these trials ($e^{\beta} = 2.14, SE = 1.38, z = 10.35$). The main effect of target type did not reach significance, nor did we find a group effect or significant interactions (Table 6.7.4). Visualisations of the main effect for vocabulary size can be found in Figure 6.4. The model had a prediction accuracy of 72.35% and a C-index of C = .78. The optimal model contained Vocabulary rather than Age as the predictor, as vocabulary increased the fit of the model significantly ($\chi^2\,(0) = 12.13, \mathrm{p} < .001$).

6.7.5 Disambiguation: Mapping or retention constraint?

To address the question of whether the use of disambiguation leads to better retention of object-word mappings, we calculated the proportional use thereof for each child and entered this as a prediction term in our optimal retention model. The proportional use of disambiguation was determined by calculating a mean accuracy score for the disambiguation condition for each child.

	e^{β}	Std. Error	z value	p-value
(Intercept)	0.74	1.47	0.47	0.447
Target (novel)	1.63	1.59	2.85	0.295
Group (multilingual)	1.03	1.59	1.07	0.943
Vocabulary (scaled)	2.13	1.38	10.27	0.020*
Target (novel): Group (multilingual)	1.30	1.70	1.63	0.625
Target (novel): Vocabulary (scaled)	0.92	1.44	0.78	0.808
Group: Vocabulary (scaled)	0.71	1.61	0.48	0.467
Target (novel): Group (multilingual): Vocabulary (scaled)	1.66	1.70	2.60	0.339

Table 6.7.4: Model 3 – Formula: $\boldsymbol{TargetLook} \sim \boldsymbol{Target} * \boldsymbol{Group} * \boldsymbol{Vocabulary}\ (\boldsymbol{scaled}) + (\mathbf{1}|\boldsymbol{TrialId}) + (\mathbf{1} + \boldsymbol{Target}|\boldsymbol{Subject})$

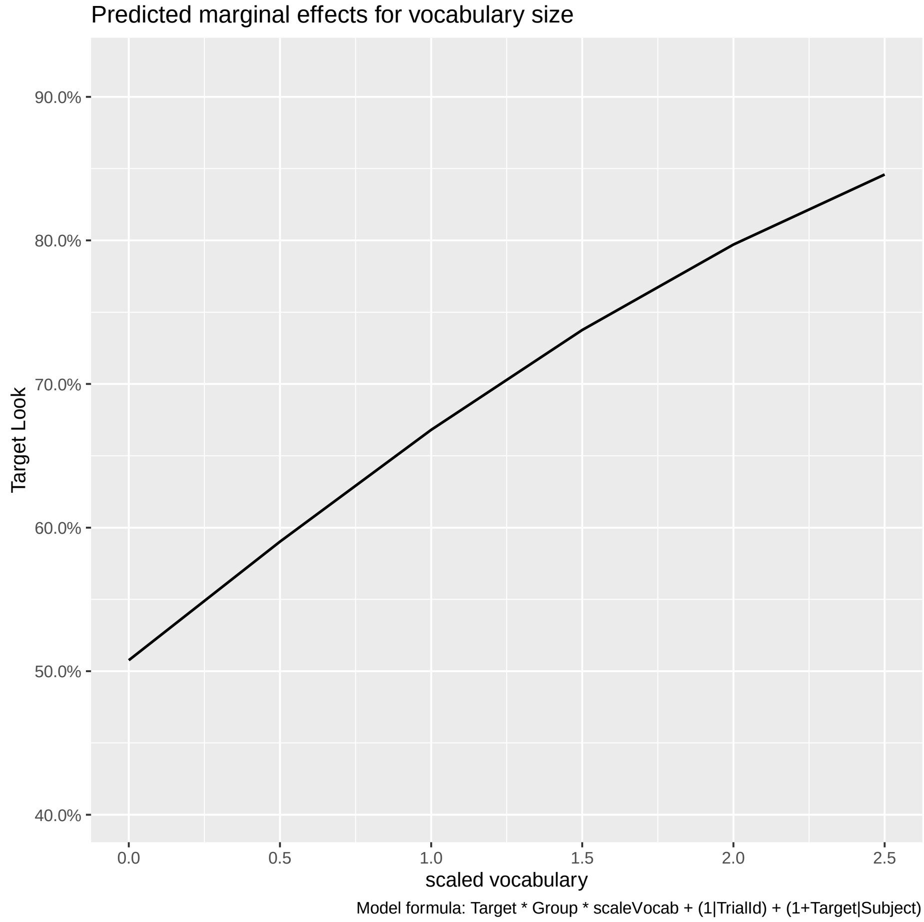


Figure 6.4: Main effect for vocabulary size (marginal effects) on retention via fast-mapping trials

6.7.5.1 Main analysis: Retention modulated by disambiguation

Fixed effects for the optimal model were Target type (trained, novel), Language group (monolingual, multilingual), and then for each individual calculated Disambiguation rate with vocabulary size as a covariate. The optimal model showed a main effect for Language group ($e^{\beta} = 15.20, SE = 1.75, z = 8129.22$), Disambiguation rate ($e^{\beta} = 37.37, SE = 1.96, z = 215.12$), target type ($e^{\beta} = 8.75, SE = 1.77, z = 45.17$), and Vocabulary size ($e^{\beta} = 1.87, SE = 1.18, z = 41.67$). The group effect reflects that multilinguals' performance differed from that of monolinguals. The effect on target type, again, reflects that the trained item yielded higher accuracies compared to the novel item. As before, the effect on vocabulary size indicates that performance improved for children with larger vocabularies. Also, our added variable of disambiguation rate resulted in a main effect, reflecting the fact that the use of disambiguation affected their retention performance. However, we also found a significant three-way interaction between Language group, Target item, and

Disambiguation rate ($e^{\beta} = 47.94, SE = 2.77, z = 44.54$; Table 6.7.5). The model had a prediction accuracy of 72.35% and a C-index of $C = .78.$ To check how age might modulate children's performance, we also ran the same model with age as a covariate instead of vocabulary. This model did not yield convergence.

6.7.5.2 Sub-group analysis

To gain further understanding of this interaction, we split the data by Group first. For the monolingual children, we found a significant main effect for Disambiguation rate ($e^{\beta} = 31.90, SE = 2.54, z = 41.15$), Target type ($e^{\beta} = 7.19, SE = 2.23, z = 11.73$), and Vocabulary size ($e^{\beta} = 1.73,\ SE = 1.20,\ z = 19.65$), as well as a significant two-way interaction between Target type and Disambiguation rate ($e^{\beta} = .08,\ SE = 2.98,\ z = .10$; Table 6.7.6). The visualisation of this interaction can be found in the left pane of Figure 6.5. The interaction illustrates that the use of disambiguation positively modulated monolingual's performance on retaining both the trained and novel item. Specifically, performance on retaining the novel item improved for the children who disambiguated more.

The results for multilingual children, however, differed. Here, the sub-group analysis only yielded a main effect of Vocabulary size ($e^{\beta} = 2.14,\ SE = 1.36,\ z = 11.82$), but no other main effects or interactions (Table 6.7.7). In other words, for multilingual children, no improvement on retention was found as even with high levels of disambiguation overall performance on retaining the novel item was at chance level.

	e^{β}	Std. Error	z value	p-value
(Intercept)	0.08	1.63	0.01	<.001***
Group (multilingual)	15.20	1.75	129.22	<.001***
Disambiguation rate	37.37	1.96	215.12	<.001***
Target (trained)	8.75	1.77	45.17	<.001***
Vocabulary (scaled)	1.87	1.18	41.67	<.001***
Group (multilingual):Disambiguation rate	0.01	2.29	0.00	<.001***
Group (multilingual):Target (trained)	0.16	2.00	0.07	0.010**
Disambiguation rate: Target (trained)	0.07	2.16	0.03	<.001***
Group (multilingual):Disambiguation rate: Target (trained)	47.94	2.77	44.54	<.001***

Table 6.7.5: Model 5 – Formula: $\boldsymbol{TargetLook} \sim \boldsymbol{Target} * \boldsymbol{Group} * \boldsymbol{Disambiguation\ rate} + \boldsymbol{Vocabulary}\ (\boldsymbol{scaled}) + (\mathbf{1}|\boldsymbol{TrialId}) + (\mathbf{1} + \boldsymbol{Target}|\boldsymbol{Subject})$

	e^{β}	Std. Error	z value	p-value
(Intercept)	0.09	1.96	0.03	<.001***
Disambiguation rate	31.90	2.54	41.15	<.001***
Target (trained)	7.19	2.23	11.73	0.014*
Vocabulary (scaled)	1.73	1.20	19.65	0.003**
Disambiguation rate: Target (trained)	0.08	2.98	0.10	0.024*

Table 6.7.6: Model 5 (monolingual children) – Formula: $\boldsymbol{TargetLook} \sim \boldsymbol{Target} * \boldsymbol{Disambiguationrate} + \boldsymbol{Vocabulary}(\boldsymbol{scaled}) + (\mathbf{1}|\boldsymbol{TrialId}) + (\mathbf{1} + \boldsymbol{Target}|\boldsymbol{Subject})$

	e^{β}	Std. Error	z value	p-value
(Intercept)	1.37	1.82	1.68	0.602
Disambiguation rate	0.30	2.46	0.26	0.180
Target (trained)	1.01	2.26	1.02	0.987
Vocabulary (scaled)	2.14	1.36	11.82	0.014*
Disambiguation rate: Target (trained)	5.79	3.16	4.60	0.127

Table 6.7.7: Model 6 (multilingual children) – Formula: $\boldsymbol{TargetLook} \sim \boldsymbol{Target} * \boldsymbol{Disambiguation\ rate} + \boldsymbol{Vocabulary}\ (\boldsymbol{scaled}) + (\mathbf{1}|\boldsymbol{TrialId}) + (\mathbf{1} + \boldsymbol{Target}|\boldsymbol{Subject})$

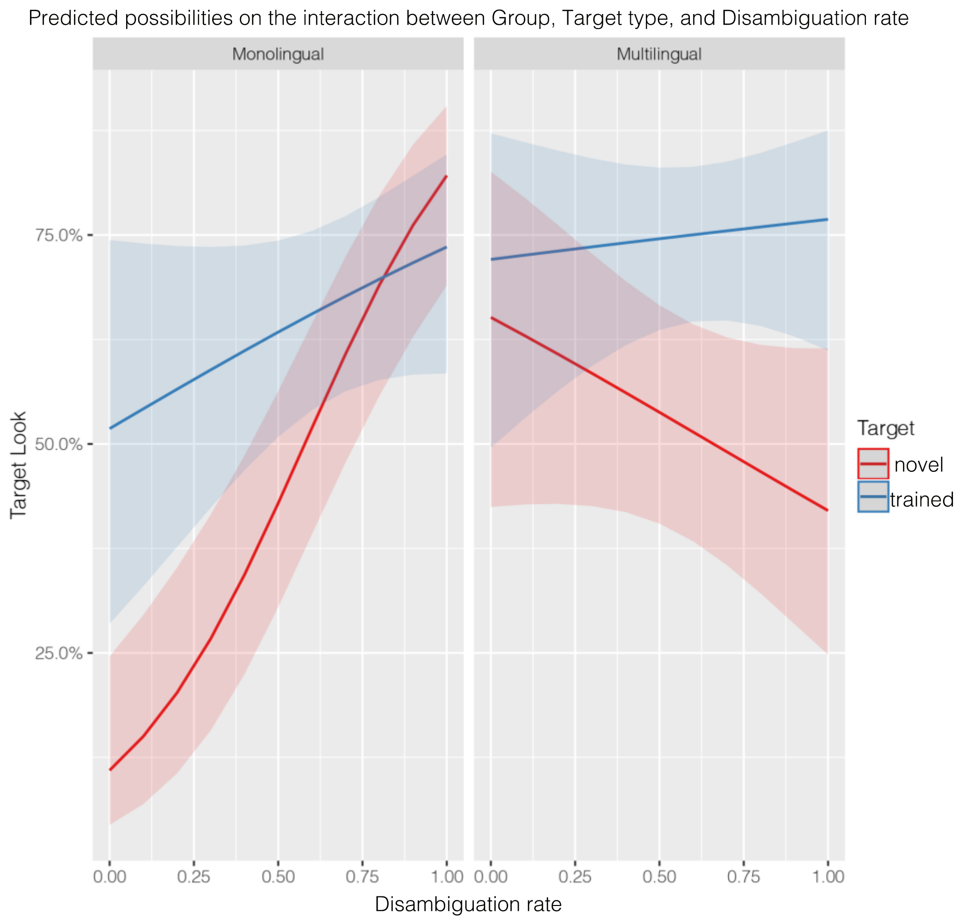


Figure 6.5: Interaction between proportional use of disambiguation, group and target item (marginal effects) on retention trials

6.8 Discussion

In a developmental eye-tracking study with mono- and multilingual aged from 18 to 30 months, the aim was to expose the role disambiguation plays with regards to retention, or rather a precursor thereof. We investigated children's success in disambiguation trials and how it was modulated by their language background, age, and vocabulary size. Furthermore, we explored whether the same children were able to retain word-object links presented to them in an unambiguous and ambiguous context, and how the aforementioned factors modulated their accuracy. Lastly, we shed light onto the link between mapping and retention by ascertaining whether children who disambiguated also showed better performance on retention.

We tested children's use of disambiguation; a constraint said to support word learning that has been only observed in some, but not other contexts, such as monolingual vs multilingual language backgrounds. Concurrently, the view that disambiguation is a language-specific word learning strategy was challenged, and newer approaches provide evidence that disambiguation is based on more domain-general attentional biases (Horst, Samuelson, et al., 2011; Samuelson et al., 2017). Under this account, disambiguation was concluded to be a default mapping strategy supporting word learning to some extent; however, word learning entails more than simply mapping the correct object to the corresponding label. In order to remember a word-object link, it must be reactivated consistently under the presence of other competitors until those are pruned. Hence, it becomes more apparent that a single instance of disambiguation or fast-mapping of a word-object link cannot lead to proper learning. Nevertheless, disambiguation being a first and foremost mapping strategy during situation time does not necessarily negate its supporting role in a precursor of retention, as it builds the first step down the slow learning path of developmental time. In other words, children who disambiguate might still have an advantage when remembering a fast-mapped word-object link. This supporting role of disambiguation in retention has not been widely tested yet, and so far, results have been somewhat inconclusive (Bion et al. 2013; Kalashnikova et al., 2018). Furthermore, our study contributes to the understanding of how fast mapping and slow learning unfold and interact in multilingual children, a missing aspect of the associative network model that has yet to receive more attention.

6.8.1 Disambiguation boosted by vocabulary size in monolingual and bilingual children.

Our analyses and results of the disambiguation trials showed that all children performed better with increasing vocabulary size in English. Thus, the emergence of disambiguation was modulated by children's English linguistic experience. By this, we mean not only the number of languages a child is exposed to, but also their English vocabulary. Multilingual children started to disambiguate and performed like their monolingual peers as their English vocabulary size grew indicating that the emergence of the disambiguation effect for multilingual children requires a richer vocabulary, and thus, in turn, more time. Bearing in mind that these children have to split the exposure to each of their languages over their waking hours, i.e. they had reduced exposure in English than their monolingual peers possessed at the same age. This means that their vocabularies in each language tend to be smaller, whereas their combined overall vocabulary size will likely approximate or surpass that of a monolingual child (Pearson, Fernandez, Lewedeg, & Oller, 1997). Our final model showed that English vocabulary size explained children's behaviour better than age in terms of disambiguation. This finding is in line with previous research which found that the composition of children's lexicon is more indicative of their use of disambiguation than age (Byers-Heinlein et al., 2013).

These results support an associative network account, as to make use of disambiguation, a child's lexicon must have a sufficient structure, or in other words a sufficient number of word-object links (Kalashnikova, Mattock, and Monaghan, 2016). Multilinguals make use of disambiguation once their vocabulary size has reached a specific size, meaning they need to have more words established in their English lexicon before they show the effect. This suggests that in the meantime children with a multilingual background may rely on other word-learning heuristics in order to establish a lexicon before they use disambiguation in certain situations. This also supports the idea that other word-learning strategies seem to be more prevalent and useful for multilinguals. Such strategies would notably support the idea of many-to-one mappings and might thus be favoured by multilinguals. This does not preclude multilingual children from making use of disambiguation per se, but they are likely to encounter more learning situations in which other, less restrictive heuristics lead to better word learning. Our results also answer the question as to whether multilinguals might have a differently structured lexicon: the fact that multilingual children are capable of using disambiguation as a mapping constraint shows that their mental lexicons do not differ structurally to those of their monolingual peers.

6.8.2 Do monolingual and bilingual children retain in the same way?

Before discussing the results on retention, we reiterate that children's performance was based on retaining the fast-mapped object-word link within the same session after a minimal delay. It is highly probable that children will have forgotten this link shortly after their study participation. Hence, when we talk about 'retention' here, we want to emphasise that the measured performance on retention trials highlights a precursory and initial form of retention, rather than fully-fledged learning and long-term retention. The analyses performed on retention trials indicated that retaining a novel word-object pairing mapped during referential ambiguity remains difficult for children of such a young age. These findings corroborate what previous literature found (Bion et al., 2013; Horst & Samuelson, 2008). Whereas retention of the trained item was done successfully in both the monolingual and multilingual group as early as 18 months, retaining a new mapping that had to be inferred via disambiguation posed a challenge.

Overall, children's retention abilities increased as the size of their vocabularies grew. Age was not entailed in our final model, as it did not make significant contributions to explaining the variance on their performance. In the retention analysis, there was a difference of retaining the new fast-mapped pairing between the two language groups, as only monolingual children performed above chance. This raises the question of whether these performance differences can be attributed to the use of disambiguation or not. One caveat in our experiment is that it could not fully disentangle whether the success on retaining the novel object was due to actual establishment of the mapping (during the disambiguation trials) or 'reverse' disambiguation triggered by recalling the trained item. Since the disambiguation process takes place regardless of item type, as in having to engage in the process-of-elimination, the 'reverse' disambiguation of the trained nil cannot be entirely ruled out. All children retained the trained object very well and treated it similarly to the familiar words. If children had shown an increased 'reverse' disambiguation effect on the trained nil, then the multilingual children should have performed much better on the novel word retention trials and portrayed similar disambiguation rates found in the disambiguation trials. However, future studies investigating the link between disambiguation and retention could address the above issue by including two novel items for children to disambiguate and juxtaposing these two during the retention trials. We decided not to do so as adding another new item might have overwhelmed children at a such a young age, and in fact, multilinguals' chance performance indicated that one novel item already posed a challenge.

6.8.3 Relationship between disambiguation and retention

The use of disambiguation did not constitute an advantage of retention for every child. Although the use of fast-mapping constraints in the ostensive teaching trails was not necessary, we found an effect for monolingual children, but not multilingual children. Learning words is made up of in-the-moment referent selection, where disambiguation can be helpful especially in situations of referential ambiguity (such as in our disambiguation trials), and long-term retention, which requires repeated activation of word-object links (Kucker et al., 2015). Thus, no guarantee can be given as to whether a label is successfully retained after only a few fast mappings. However, mapping a novel label to its referent employing disambiguation should, one would assume, at least facilitate retention. If a mapping is established, then it should, in theory, make future retention more accessible as the first link that will go onto the slow long-term learning has been made. Throughout our experiment, children were presented with at least four occasions to make the expected link. Four occasions might not have been enough to strengthen the word-object mapping. However, monolingual children who disambiguated did, in fact, show higher accuracy on retaining the fast-mapped item. The higher their individual success rate on the disambiguation condition, and thus mapping the novel word-object link correctly more often, the better was their performance during the retention condition. Interestingly, we did not find this in the multilingual group. In this group, it made no difference whether their rate of disambiguation was low or high, as they still performed at chance level. These findings show that disambiguation might be a suitable mapping strategy for multilinguals at a specific moment in time when they have to select a referent, but it does not lead to learning in the long run. This is although they can disambiguate and do so, as their performance on disambiguation trials showed. This could be due to several reasons.

Multilingual children may require more activations of the same object-word mapping before they consider the competition with other referents as settled. Due to their learning of translational equivalents, they are more likely to accept many-to-one mappings at this age, and thus, competing referents are not ruled out as quickly when forming semantic associations. Our results support this idea, as multilingual children performed at chance level with regards to retaining the fast-mapped item, as well as past research which suggested that multilingual children are more likely to suspend the ME assumption to accept overlapping names for the same referent (Kalashnikova et al., 2016; Kandhadai, Hall, & Werker, 2017). Monolingual children, on the other hand, are not yet required to build many-to-one mappings this early, as the acquisition of synonyms usually happens later in their development. Thus, their mapping process does not face as much competition from other possible referents, or at least it is resolved earlier in the process of linking fast mapping with long-term retention.

Moreover, mapping and retention are processes developing on distinct, yet interactive timescales. Previous research, as well as our results, have provided evidence that fast-mapping via disambiguation is delayed for multilingual children. Albeit developing independently, this delay might contribute to a delay in retention performance for children from multilingual backgrounds. The fact that both groups in our experiment disambiguated and the difference in retention performance inform that disambiguation starts as default mapping strategy for every child, albeit delayed for multilinguals, and later develops into a more reliable word-learning strategy for monolingual children. This means that disambiguation develops dynamically across the developmental trajectory and is impacted by factors such as language background, translational equivalents, vocabulary size, and exposure. Monolingual children refine their use of disambiguation from a pure mapping constraint to a more sustained strategy that facilitates the short-term precursory retention of the fast-mapped word-object link. Multilingual children employ disambiguation as default when no other information about the referents is available (Kalashnikova et al., 2018). Unlike Kalashnikova et al. (2018, p. 10), we would not go as far as calling disambiguation a “genuine word-learning strategy across linguistic development”, as neither ours nor their study investigated long-term retention of the fast-mapped word-object link. Nonetheless, our findings corroborate that monolingual children eventually use disambiguation differently. However, rather than regarding this as a lack of refinement in multilingual children, we see it as encouragement for the research community to investigate the possible other strategies upon which multilingual children rely. Multilingual children’s performance at chance level suggests that between the ages of 18 to 30 months old, these strategies have yet to emerge. Our findings could be complemented by studies investigating the relationship between disambiguation and long-term retention by using a longitudinal design that allows for retesting whether the previously fast-mapped word-object link would be retained at after a longer delay of days or weeks. However, such a design would need to recruit an older population of children, as even short-term retention within the present study still seems to be too challenging for children of 18 to 30 months.

In our study, we faced certain limitations because its trial order which was done by target item rather than condition. This meant that in some cases, retention trials preceded disambiguation trials. In turn, it was more difficult to infer whether children had retained the novel mapping upon encountering it during the retention trials, or whether they engaged in another round of disambiguation. A follow-up analysis revealed that children treated the novel item dax differently between the disambiguation and the retention trial leading us to conclude that children did indeed show different behavioural patterns depending in which context the dax was presented. Although future studies could address this issue by creating two separate experimental blocks for disambiguation vs retention trials, it has to be noted that as soon as more than one trial prompting the disambiguation of the same item is part of any experiment, a learning effect will take place. Hence, the complete disentanglement of disambiguation and retention is impossible, as long as researchers have to expose children to multiple rounds of the same word-object mapping due to children's maturational memory constraints.

6.9 Conclusion and future directions

In summary, we found that disambiguation can be found in children with multilingual language experience. Learning a new word consists of two different processes, namely fast mapping and slow learning, that are linked, but develop independently. It appears that children growing up in a multilingual environment rely on other constraints that help them hone these processes. Thus, disambiguation should be, first and foremost, considered a mapping strategy with a potential extension as 'retention' strategy for monolingual children. Eventually, further research needs to be carried to increase our understanding of multilingual word learning. Especially the investigation of the underlying mechanisms that drive retention and its developmental trajectory should receive more focus, as it is not yet clear how these constraints can be described.

Other directions to explore the difference in using disambiguation as ‘learning strategy’ include investigating real-time gaze data to determine patterns, as well as how variables such as cumulative length of exposure, current exposure, or quality of input impact on disambiguation and retention for multilingual children. Another aspect of the disambiguation effect that has not yet been researched is the possibility of different types of disambiguation upon which multilingual children might rely. In other words, it would be unhelpful to a multilingual child to rely on disambiguation in a cross-linguistic word learning situation as it would lead to prevention of many-to-one mappings. However, if multilingual children find themselves in a predominantly monolingual situation, they might be more likely to use disambiguation as it would satisfy the ME assumption that one referent possesses only one label. As the present study only involved one of the children’s languages, namely English, multilingual children were in a rather monolingual mode where they had to suppress their other first languages. This means they were tested on within-language disambiguation, which they do rely on albeit with a delay. Developing an experiment that includes language-switch mode trials will keep both languages active, and therefore, test between-language disambiguation. This co-activation of both languages in a bilingual might lead to less use of disambiguation in multilingual children.

7 Individual effects of multilingualism and executive functioning on fast mapping and retention in adults

The previous study investigated the use of disambiguation in multilingual children and found that the mapping via disambiguation per se did not positively affect multilingual children ability to **retain** a new word-object mapping while it did so for monolingual children. This may be regarded as a 'bilingual disadvantage'. However, this difference can also be viewed as disambiguation undergoing a specification/narrowing process that is applicable only to monolingual children, but not their multilingual peers. Thus, the often-posited questions of whether multilingual children are able to disambiguate can be answered as 'yes'. If we know that multilinguals are generally able to use disambiguation as a mapping constraint, it still raises questions around the impact of multilingualism on disambiguation in other ways. What I am referring to here are modulations that are subtler than a categorical 'yes' or 'no'. Multilingualism is a very rich and individual experience that potentially impacts the deeper underlying processes of disambiguation, such as the *Disjunctive Syllogism* outlined previously. This rich experience is composed of varying degrees of numbers of languages spoken, language proficiency and exposure, or age of acquisition to name but a few. Thus, whilst we now know that multilinguals do use disambiguation (as children, and consequently also as adults), we can now pose more nuanced questions about how specific aspects of multilingualism may impact on the processes of disambiguation. Since measuring these facets of multilingualism is more feasible in adults, but also due to their matured cognitive development, I decided to explore these more nuanced research questions with a multilingual adult population. I was specifically interested in how multilingual engage in the process-of-elimination in disambiguation and retention conditions. In the following study, I addressed how multilingualism on the one hand, and cognitive abilities on the other hand, impacted the use and processing speeds of disambiguation in multilingual adults during a word-mapping and retention task. I found that language-specific variables, such as language proficiency and exposure, predicted not only accuracy, but also processing speeds to varying and sometimes complimentary degrees. Furthermore, results also showed that those with better working memory abilities performed more accurately and faster throughout.

7.1 Introduction

By the time a person reaches adulthood, they typically know between 20.000 to 40.000 words, albeit only using a fraction of those daily. For people who speak more than one language, this figure increases accordingly, as they will have labels for one concept across all of their languages. But how do people come to learn words? And how do people from a multilingual background learn words? How does being multilingual affect their cognitive abilities, which may have consequences for learning, too? In this study, we explore the individual contribution of multilingualism and executive functioning on word learning and retention of novel word-object pairings in adults. We first give a brief overview of the direct and indirect effects of multilingualism on novel language learning with a focus on lexical acquisition, providing the theoretical framework that informed our study. We follow with a review of one particular phenomenon observed in word learning called the *disambiguation effect* or process-of-elimination and hypothesise that adults from a multilingual background experience an advantage when engaging in this process. We are specifically interested in how their multilingualism and cognitive functioning may contribute individually on their ability to disambiguate and retain novel word-object pairings.

7.2 Direct and indirect effects of multilingualism on word learning

Over the past two decades, an increasing body of work on multilingualism has emerged, investigating the multilingual experience from various angles. There are many possible avenues to look at potential differences between monolingual and multilingual populations. For example, some research findings indicate that multilinguals are better in the different linguistic aspects when learning a new language, be it at the level of vocabulary (Kalashnikova et al., 2015), phonology (e.g. Wang & Saffran, 2014), grammar (Klein, 1995; Sanz, 2000, 2007), or literacy (e.g. Kahn-Horwitz, Kuash, Ibrahim, & Schwartz, 2014). Another area of research focusses on identifying the cognitive mechanisms that may underlie these advantages

(Bartolotti & Marian, 2012; Bartolotti, Marian, Schroeder, & Shook, 2011; Wang & Saffran, 2014), while another area investigates how factors related to the participants' multilingual experience, such as the age of acquisition, learning context, number of languages, or proficiency, may modulate novel language learning. To highlight where our research is positioned, we draw on a theoretical framework (Figure 7.1) proposed by Hirosh & Degani (2018). They propose that multilingual differences can stem from two avenues: *direct* transfer of previous knowledge and skills, and *indirect* factors resulting from the multilingual background impacting on the non-linguistic system. The authors explain that direct effects transfer 'as is' from previous experiences to the task a person is currently performing, which includes the execution of existing learning strategies, and the transfer of knowledge from familiar languages. The impact of these direct factors is heavily modulated by the degree of similarity between the known and novel language and the transferability between previous learning strategies and the task at hand. Indirect influences may impact on the task at hand via mediating factors that were informed by prior experiences. This may be, for example, the change of a learner's social or cognitive abilities due to previous multilingual life experience. These changes may facilitate learning a new language. Because these factors were shaped by past experiences and thus may enhance learning but are not directly accessible by the learner to be applied to a new context, they can be regarded as having an indirect impact on learning. This is contrasted by explicit knowledge about a language which can be accessed and used, and thus, acts more directly. In other words, modulations of a learner's social or cognitive abilities due to multilingualism may be described as indirect. The authors further divide these indirect factors into linguistic and non-linguistic factors. Someone's multilingual experience shapes both direct and indirect effects, and therefore are highly variable; moreover, each of the effects may impact on the different aspects of language learning differently.

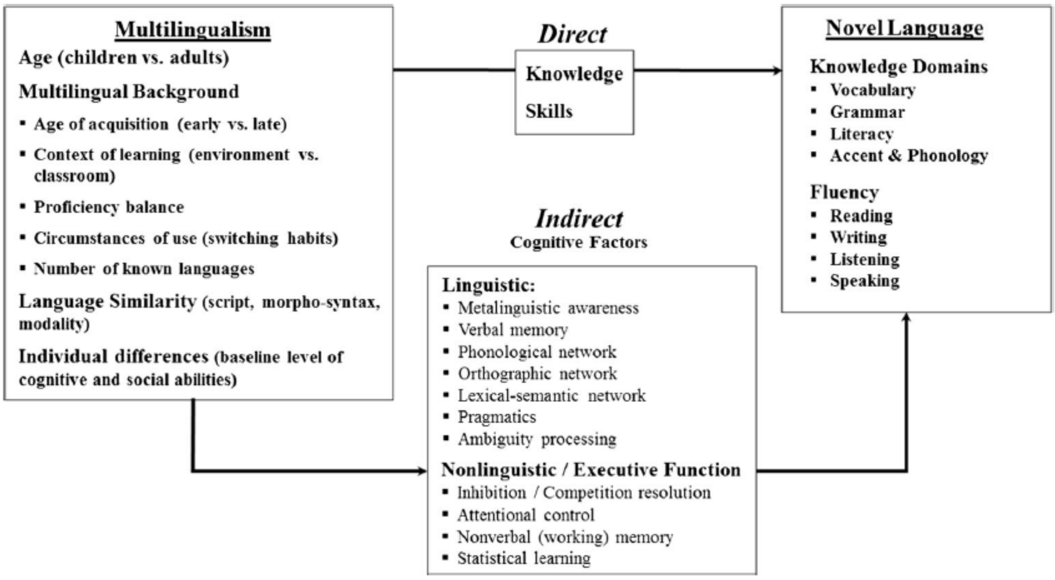


Figure 7.1: Theoretical framework for the influence of multilingualism on novel language learning (Hirosh & Degani, 2018)

7.3 Word learning: mapping & retention

Although multilingualism can have a direct and indirect impact on any domain of language learning, a large body of research has investigated how monolinguals and multilinguals may differ with regards to novel word learning. For a word to be learnt, it first needs to be associated with an object or concept, before this word-object link can be strengthened and eventually recalled. How are these mappings formed, and how does multilingual experience modulate them? The existing research has reported differences for multilingual over monolingual children (e.g. Kalashnikova, Mattock, & Monaghan, 2014; Kaushanskaya, Gross, & Buac, 2014), as well as adults (e.g. Bartolotti & Marian, 2012; Kaushanskaya, 2012; Kaushanskaya & Marian, 2009; Kaushanskaya & Rechtzigel, 2012; Kaushanskaya, Yoo, & Van Hecke, 2013; Papagno & Vallar, 1995; Wang & Saffran, 2014) as described below.

7.3.1 Mapping labels to referents

Research investigating lexical acquisition usually commences by stating that word learning is a challenging task whereby a learner has to consider an infinite number of meanings upon encountering a new word before finding the correct referent of a label. By diving straight into the potential processes involved in word learning, an important question is omitted: what does it actually mean to *know* a word? For example, we know that children understand more words than they can produce (McMurray et al., 2012), and similarly, adults comprehend more words than they use. This leads to the question of when we consider a word as learnt or known: is it at the point of recognising, understanding, or saying it? The entanglement of these processes is somewhat controversial, also because quantifying when someone understands a word mentally is methodologically more difficult than measuring word production. However, 'using' a word not only implies its vocal production but also refers to how such a word-object mapping might guide behaviour in other ways, such as using the knowledge about a word to make a decision about another word.

One such way can be found when learners encounter a situation of referential ambiguity. Referential ambiguity constitutes a situation whereby the referent of a label is not yet clear or decided, usually because the label is novel and unfamiliar to the learner. If a learner is exposed to two physical items such as a *ball* and another oddly shaped item with an unknown label and is then asked to "find the *dax*", the learner will implicitly recognise and understand *ball* as familiar without having to say it, before assigning the *dax* label to the novel object. If the learner has now successfully learnt the new word-object mapping for *dax*, they should be able to successfully 'use' that mapping in a follow-up round where they have to discern between the *dax* and another new item. In a real-world context, learners often encounter multiple possible referents for a new word. To break down the complexity of word learning, learners might use certain language constraints. These mechanisms can range from attentional biases like salience (Hollich, Hirsh-Pasek, & Golinkoff, 1998; Plunkett, 1997), the direction of a speaker's gaze (Baldwin et al., 1996), and directing of attention via pointing (Mervis & Bertrand, 1994), to more language-specific lexical constraints (Clark, 1983; Markman, 1990; Markman & Hutchinson, 1984), constraints via Theory of Mind (Bloom, 2002; Markson & Bloom, 1997) or pragmatic inference (Clark, 1990; Diesendruck & Markson, 2001; Tomasello & Barton, 1994).

Although these accounts come from different angles, they agree on the observable behaviour of learners as the manifestation of disambiguation. However, little is known yet about when and at which level this mechanism is operating. One such overt behaviour was the tendency to assign novel labels to unfamiliar, novel objects in moments of referential ambiguity. This was coined *disambiguation effect* which has been found in adults (Halberda, 2006) and children (Halberda, 2003; Markman, 1990; Merriman, Bowman, & MacWhinney, 1989) alike. The underlying process, called *disambiguation,* also known as process-of-elimination, is one of many biases that learners might use to limit the number of possible referents. For instance, monolingual children's acquisition of new words is said to be guided by the principle of disambiguation, or the assumption that new words tend to refer to new referents. This means that children assume that each concept or object only has one name or referent. This helps children to identify whether a label for a referent is already familiar or not and allows them to build up a vocabulary without overlapping meanings in the beginning. However, learning multiple names for the same object or class inclusion, such as cat/animal, are hard to acquire. With age they will eventually be able to override this constraint (Gathercole, 1989; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Liittschwager & Markman, 1994). Most of the current literature is concentrated around investigating the onset of disambiguation, especially by looking at children with a variety of multilingual linguistic experience and found that multilingual children exhibit the disambiguation effect to a lesser extent than age-matched monolingual children and that the effect emerges later in their linguistic development (Byers-Heinlein & Werker, 2009, 2013; Davidson & Tell, 2005). We return to why this might be the case after having introduced and discussed the Disjunctive Syllogism.

7.3.2 The Disjunctive Syllogism at the core of disambiguation

With the focus of research having been on determining the timepoint when learners start using disambiguation, little is known as to *how* they actually reach their final decision. In 2006, Halberda designed a study whereby participants had to select the correct referent out of two possible images via disambiguation. The computational structure of this constraint is called Disjunctive Syllogism, or more commonly referred to as process-of-elimination, which can be described as:

$$A \vee B$$
$$\neg A$$
$$\therefore B$$

Verbally, this is expressed as "A or B (1), not A (2), therefore B (3)". Note that in order to form a decision (3), one must complete the critical step (2) which is the systematic rejection of *A*. Halberda (2006) tested adults on implicit and explicit versions of the Disjunctive Syllogism. For instance, prompting someone to "look at the *ball*" in the presence of a *chair* would logically speaking be the opposite of (2), i.e. not the *ball*, thus making it implicit. Asking someone to "not select the *chair"* would logically correspond directly to (2) making it explicit. Halberda's results indicate that adults make use of the Disjunctive Syllogism in both cases and disambiguate to arrive at the correct answer.

Traditionally, four major accounts described the underlying motivations behind the disambiguation effect: Mutual Exclusivity (ME) (Markman & Wachtel, 1988), Contrast (Clark, 1993), the Pragmatic Account (Diesendruck & Markson, 2001), and the Novel-Name Nameless-Category (N3C) Principle (Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992). Each of these accounts makes similar behavioural predictions in a situation of referential ambiguity but do so for different reasons. The debate of these accounts has primarily focussed on the underlying motivations for why learners have the tendency to map novel labels to novel objects. However, little was mentioned about the mental computations involved that would be required to support the use of the disambiguation principle at the time of conception. By suggesting that the Disjunctive Syllogism might be at the source for this mapping behaviour, Halberda (2006) was able to develop these accounts, as well as ways of revealing behavioural measures to help decide between them. To do so, Halberda (2006) developed two experiments with adults and distilled the behaviours needed if learners should show if they engage in the process-of-elimination (in line with ME, Contrast, and a Pragmatic Account) or be absent (in line with N3C). In order to perform the rejection of a known label, a learner first needs to access, attend to, and evaluate it before rejecting it. Focussing attention and performing this evaluation on the familiar lexical entry will take time and is reflected in a learner's reaction time when ultimately selecting the new item as the referent for the new label. Halberda (2006) found that adults double-checked, i.e. evaluated and rejected, the known labels in 76% of the trials that juxtaposed a novel and a known item where the target item was the new label/item. These results indicated that participants' decision was founded in the knowledge and information they possessed about the known distractors, and *not* about the novel object. These findings are in line with the accounts relying on a Disjunctive Syllogism.

7.4 Multilinguals and disambiguation

From research with infants, we know that very young children also engage in disambiguation processes when resolving referential ambiguity. More importantly, studies on children have shown that their multilingual experience impacts their use of disambiguation. For example, children from multilingual backgrounds were found not to exhibit the disambiguation effect compared to their monolingual peers at the same age (Byers-Heinlein & Werker, 2009), and that this may be due to differences in their lexicon structure (Byers-Heinlein & Werker, 2013). Some studies have found a disambiguation effect for bilingual children, although they were significantly less inclined to adhere to the mutual exclusivity assumption (Davidson & Tell, 2005).

However, very little research has been carried out as to how adults' linguistic experience, and especially multilingualism, might impact on their use of disambiguation. Adult speakers of multiple languages are very aware that an object can have more than one label, and in fact, they will likely know at least one translational equivalent for an item in each of their languages. For them, the tendency to assign a novel label to a novel object might not be as strong, as they are more likely to accept many labels for the same object. Using principles, such as ME, Contrast, a Pragmatic Account, or N3C, which favour one-to-one object-label mappings would be counterintuitive or even counterproductive for multilingual adult learners. Does this mean that multilinguals do not make use of disambiguation at all? In short, no; however, their multilingualism might impact on the mental processes involved when using disambiguation. Adults with mature cognitive functions engage in various kinds of problem-solving processes, some of which are under the umbrella of process-of-elimination. The Disjunctive Syllogism is not bound to the realm of word learning alone and can occur in many non-linguistic and domain-general situations. Having more experience with these types of situations, one would not expect that multilingual adults do not make use of disambiguation at all. Thus, it is likely that multilingual adults would exhibit process-of-elimination strategies, also in word learning contexts.

Here, we suggest making the distinction between asking multilinguals to apply disambiguation in one of their specific languages or to disambiguate in an unspecified language. This is rooted in the idea that multilinguals may be able to access specific language modes (Grosjean, 1998, 2001), depending on the situation they face. For example, a multilingual speaker of English who is in a context where they are required to speak only English can be said to operate in a 'monolingual mode', which is akin to letting them perform a task in a laboratory setting that is conducted in English. Being within an 'English mode' already eliminates many potential competitors from a multilingual's other languages during referent selection, thus, reducing the likelihood of many-to-one mappings. In contrast, suppose a multilingual faces a situation where they hear many foreign languages, of which they knew none, then they are more likely to keep their language mode as 'wide open' as possible in the hope to grasp some aspects of these foreign languages. For example, they could be listening out for cognates. In a lab setting, this would be akin to asking multilinguals to disambiguate in a task administered in an unknown language to them. Due to their inability to narrow referents down to one specific language, they are likely to stay in a 'multilingual mode', and thus, may be more likely to entertain the idea of many-to-one mappings going against mutual exclusivity assumptions.

However, multilingual adults' language experience, such as proficiency in their languages, age of acquisition, current exposure to a language, or the number of languages, might impact on the use of disambiguation in a subtler, more *indirect* way as framed by Hirosh & Degani (2018). Recall step (2) of the Disjunctive Syllogism, i.e. "not A" or the *rejection step*. Suppose the Disjunctive Syllogism is the mental computation executed during referent solution. In that case, multilinguals will likely not only show differences during this rejection step that may depend on the size of their lexicon and translation equivalent, the amount of exposure to the target language, language proficiency, but also because of differences in cognitive functioning discussed below. To perform the rejection step, both the novel target and the familiar distractor have to be attended to. During the rejection step, a learner is focussed on the familiar item; however, they are still required to keep the information about both items active in their working memory (visual and verbal information that was cued). The research discussed below has found that multilinguals show advantages with regards to working memory performance which may lead to faster processing times during the rejection step. Moreover, the process-of-elimination requires skilful inhibitory control and shifting for two reasons. On the one hand, learners keep shifting back and forth between the familiar and novel object to engage in the double-checking found by Halberda (2006). On the other hand, they have to keep goal-relevant information about the novel item active until their decision is made, whilst also shifting between the items. Both of these can be measured using ‘proactive’ and ‘reactive’ control outlined in the Dual Mechanisms of Control model by Braver (2012). Proactive control refers to cognitive processes that keep goal-relevant information sustained and active until the goal is completed; however, this requires a lot of attention and focus, which makes proactive control cost-heavy. Reactive control refers to the mechanisms involved that integrate new incoming information and shift from one task to the other. This type of cognitive control operates in a more transient and spontaneous manner, and is thus, more prone to error, but does not require such a high mental load (see section 7.6). If multilinguals are more skilled at engaging in proactive and reactive control, as well as operate with a better working memory capacity, then their engaging in the process-of-elimination should differ from that of monolinguals by exhibiting faster processing times. Thus, in a study like ours, which examines how the different variables of the multilingual experience might impact disambiguation, we also examined WM and EF differences to disentangle the various indirect effects of multilingualism.

However, multilinguals’ performance on a looking-while-listening paradigm testing disambiguation may also have a more *direct* impact as outlined by Hirosh & Degani (2018). For instance, a multilingual speaker’s languages often vary in levels of proficiency. If they have to perform the task in a language where their proficiency is low, recognition of the familiar distractor item and accessing the familiar word bank of this language may take longer. Furthermore, multilinguals vary in the amount of exposure to a language compared to their monolingual peers. This means that if the task is to be performed in a language that is currently not heard or spoken very often, the learner will take longer to activate the access to this language. Lastly, multilinguals might generally be more inclined to accept many-to-one mappings and thus go against the underlying assumptions of disambiguation (Jacky Chan & Monaghan, 2019). This, however, would be reflected in their accuracy rather than processing time performances.

In summary, the multilingual experience may modulate the disambiguation process in direct and indirect ways, and these differences may manifest in faster processing speeds. However, mapping a label to an object is just the first step of learning a word, and little is known with regards to retaining such mappings using disambiguation in adult multilinguals.

7.5 Disambiguation and retention

For a word to be fully learned, mapping the correct label to a referent is not enough. It must also be stored in memory and accessed in the future. Disambiguation, whilst being studied under the scope of word learning, is now rather seen as a mapping strategy. Success on selecting – or mapping – a novel label to its referent in a situation of referential ambiguity, does not guarantee this word-object link will also be retained in the future. Two-year-olds, for example, have been shown to map novel labels to their novel referent successfully, but perform very poorly on retention, even after an only 5-minute delay (Horst & Samuelson, 2008). It is argued that this is due to separately developing, albeit interactive, trajectories for *fast mapping* and *slow learning* (Horst & Samuelson, 2008; McMurray, Horst, Toscano, & Samuelson, 2009). Referent selection is described as a simple and dynamic "probabilistic constraint-satisfaction device", whereas associative learning mechanisms with statistical learning patterns seek to explain why word learning can be slow over time (Bion, Borovsky, & Fernald, 2013, p. 40). Both processes are highly interrelated but cannot be collapsed into one as they operate on different time scales. When resolving referential ambiguity, the primary goal is to select a referent, not to retain it for later - at least not the first time a new novel word-object link is encountered. Kucker, Mcmurray, & Samuelson (2015) explain that word learning happens at two different times: the *situation time* which supports *fast mapped* communication at a specific moment in time by inferring, solving problems, or satisfying constraints, but these are not synonymous to learning per se; and the *developmental time* which describes the repeated encounters or uses of a word, whereby the link between an object and its label gets reactivated over and over again in the mental lexicon to form strong pathways and a durable vocabulary (*slow learning*). Traditionally, disambiguation has been regarded as a language-specific constraint that occurs early on in a child's word learning journey and helps to accumulate many one-to-one mappings (Markman, 1990). However, when resolving ambiguity in a specific situation, solving this problem also relies heavily on other non-linguistic factors, such as attention, memory, salience, object novelty, or visual constraints (Horst, Samuelson, et al., 2011). While this newer line of research does not deny the existence of the disambiguation effect, it questions its origin by positing that inferential constraints like disambiguation are the consequence of an appropriately strengthened and pruned associative network, and it is the latter which shapes real-time referent selection. At the heart of this account lie content-free processes like associative learning and competition rather than language-specific knowledge (Kucker et al., 2015). Furthermore, studies have shown that disambiguation biases might be caused by vocabulary growth and its accompanying increasing word-learning skill, meaning that disambiguation reflects a learning-heuristic rather than the reason for initial word learning (Kalashnikova et al., 2016). Although the majority of these studies have investigated the use and emergence of disambiguation in children, adult learners are also impacted by the non-linguistic factors mentioned, as well as vocabulary growth and how this shapes their mental lexicon and their use of an associative network.

Furthermore, a recent study found that bilinguals outperformed monolinguals on an implicit *cross-situational word learning* (XSWL) paradigm (Escudero, Mulak, Fu, & Singh, 2016). XSWL is a type of learning whereby learners track the co-occurrence of words across multiple representations in the context of other potential candidates. Stimuli can be text or auditory representations of the words of which the latter was used by Escudero et al. (2016). During a learning phase, participants are presented with several ambiguous trials and given no instructions as to what the task entails. Afterwards, they complete a forced-choice test asking them to identify the word-object mappings encountered during the learning phase. The results showed that both monolingual and bilingual adults successfully retained the mappings, thus indicating that XSWL is an implicit learning strategy available to adults, not only children (Smith & Yu, 2008; Vlach & Johnson, 2013; Vouloumanos & Werker, 2009). Furthermore, the bilingual group performed overall more accurately than the monolingual group.

7.6 Executive functioning in multilinguals

Further to language-specific factors, learning is also underpinned by executive functions. *Executive functioning (EF)* is a term used to describe a variety of cognitive skills that the brain relies on to accomplish everyday tasks. For example, planning the trip to the grocery store and what food to buy there, adapting plans to include new and incoming information, shifting between remembering the shopping list and concentrating on driving the car to the supermarket or inhibiting distracting stimuli such as noises from traffic. In laboratory settings, many tasks require EF for their successful completion, and specific tasks, such as the Flanker, Simon or Stroop task, were designed to measure different components of EF. According to a well-known model, EF encompasses three core abilities: *inhibiting* previous response or incoming interferences; *shifting* or switching between mental sets; and the *working memory*, which involves updating and monitoring of information (Miyake et al., 2000). Within working memory, the phonological loop is of utmost importance for language processing. It comprises a verbal short-term storage buffer that refreshes and maintains phonological information for a short period (Montgomery, 2003). In other words, the phonological loop keeps speech input stored long enough for it to be processed further by other faculties (Baddeley et al., 1998).

A considerable body of research has indicated that multilingualism impacts cognitive development positively (Bialystok, 2011; Bialystok, Barac, Blaye, & Poulin-Dubois, 2010). While there is a considerable body of literature supporting the positive effect of multilingualism, there remains a controversy in which components of the executive control system these advantages manifest. Working memory, in particular, has received less attention within the research community with only a handful of studies investigating the components of working memory as a function of multilingual experience (Calvo et al., 2016; de Bruin et al., 2015; Dong & Li, 2015; Paap & Greenberg, 2013). It has to be noted that most studies investigating these cognitive aspects recruited speakers of two languages, and it is still unclear whether testing speakers of three or more languages may result in similar cognitive differences. An exception is a recent study by Cockcroft, Wigdorowitz, & Liversage (2019) which examined the working memory ability of multilingual (speaking three or more languages) and monolingual adults on four components (verbal and visuospatial processing, verbal and visuospatial storage). They found evidence for a multilingual advantage in all four components. Additionally, the authors examined the background factors that influenced this working memory advantage. These background factors included language proficiency, age of (L2) acquisition, frequency of language use, as well as socio-economic variables. These results support those found in bilinguals, namely that cognitive advantages go beyond inhibitory control, and lead to the conclusion that multilingualism in general impacts on the executive control mechanism more generally, which is currently a focal point in the discussion around effects of multilingualism on EF.

The first studies to have found a 'bilingual effects' focussed on components of the executive control system that involved processes such as conflict management and inhibitory control (Baum & Titone, 2014; Bialystok, 2009, 2017; Kroll & Bialystok, 2013; Valian, 2015) as well as cognitive flexibility (Mikaye et al., 2000). A model in line with the 'unity and diversity' approach (Miyake et al., 2000) is the dual mechanisms of control (DMC) model (Braver, 2012; Braver et al., 2007). This framework describes cognitive control as two independent, but interconnected components: proactive control and reactive control. Proactive control can be conceptualised as a form of 'early selection', whereby goal-relevant information is actively maintained in a sustained manner before the occurrence of the actual event in order to optimally bias attention perception and action systems in a goal-driven manner. Proactive control is associated with sustained activation of the lateral prefrontal cortex and can be described as top-down. Reactive control, on the other hand, can be described as `late correction'. With this the mechanisms are only activated or mobilised as needed in a just-in-time or transient manner. Reactive control is the transient activation of the lateral prefrontal cortex along with a broader network of additional brain regions; furthermore, it can be described as a bottom-up reactivation of goals. Recent research on bilingual adults explored the effect that language experience variables, such as not only proficiency, but also the age of acquisition, and language exposure, may have on bilingual language control (Bonfieni et al., 2019). Although this study did not explicitly test multilinguals, it supports the idea that any multilingual experience should be viewed in its totality. With more studies emerging that recognise and acknowledge the diversity of multilingualism, researchers can no longer treat bilinguals or multilinguals in dichotomous ways (such as merely comparing monolingual vs bilingual samples). The growing body of research exploring the effects of multilingualism in such ‘holistic’ way supports the theoretical framework proposed by Hirosh & Degani (2018), and language experience variables, as well as cognitive control measures, need to be controlled for when researching any aspect of novel language learning within a multilingual population, which is what the present study seeks to do.

7.7 Present Study

The present study aims to investigate how multilingualism and cognitive functions may individually modulate the use of *disambiguation* as a word mapping and retention strategy in adults. In order to do this, we designed a task requiring them to resolve referential ambiguity in English and establish novel word-object pairings. To account for nuances of the multilingual experience, we factored in these continuous English language variables: age of acquisition, proficiency, current exposure, and the number of other languages. Furthermore, we took into account that multilingualism may have had indirect effects on executive functioning and working memory by including measures for these variables.

We were specifically interested in how their linguistic experience in English might modulate the use of disambiguation. We focussed on English as this was the language spoken by all subjects daily. We predicted that adults regardless of their linguistic experience would have no problems in engaging in the Disjunctive Syllogism required by disambiguation, as the task was implemented in English. Participants were not only exposed to it daily but also were highly proficient in it, which made it clear to them that our experimental items adhered to the phonotactic properties of English. Thus, they were expected to be in a more ‘monolingual mode’. Being in this mode, we expected the multilingual experience to enhance their performance rather than inhibit it by considering translational equivalents. Thus, we expected differences in processing speed (impacting reaction times) for adults coming from a multilingual background to be faster, as they tend to perform better on EF and

WM tasks, both of which test cognitive abilities required in the resolution of the Disjunctive Syllogism that underlies the process-of-elimination. In a word mapping and retention study like this one, it is therefore vital to also account for potential differences in these domains, as it is well established that storing and managing the information handled in such as task is strongly reliant on EF (Archibald & Gathercole, 2006).

We expected the multilingual experience variables to have a positive effect on processing times. Subjects with higher English proficiencies were expected to be faster because a more consolidated English lexicon would lead to a faster assessment of the familiar and novel item during the elimination step of the Disjunctive Syllogism. Current exposure of English was also expected to have an effect, as higher exposure rates would lead to faster access of the familiar item, and thus, faster elimination. An earlier age of acquisition was expected to lead to faster resolution of the elimination step, as AoA and proficiency are naturally correlated. A larger number of languages was not expected to have a direct impact on processing times. This is because all participants spoke English, which was also the language in which the task was administered. Thus, having overt knowledge in other languages was unlikely to affect performance in an English task via the direct route (Hirosh & Degani, 2018) if multilinguals entertained a 'monolingual mode'.

Furthermore, we tested if multilinguals were able to retain these novel word-object mappings upon subsequent retention trials, and how their linguistic experience, as well as their cognitive functioning, would affect their performance. We defined three retention conditions:

- ◊ *easy retention,* where one of the previously fast-mapped items (during disambiguation trials) was juxtaposed to a previously unseen item, and he prompt required them to select the previously fast-mapped one.
- ◊ *hard retention*, whereby two previously fast-mapped items were juxtaposed, and the participant had to select the correct one; and
- ◊ *reverse retention*, whereby a previously fast-mapped item was juxtaposed to an entirely, previously unseen item. Here, subjects were asked to select the unseen item via process-of-elimination.

Between these retention conditions, we expected significant effects of accuracy and reaction times for all subjects regardless of their language background.

For the easy retention condition, we predicted the fastest and most accurate results compared to the remaining two retention conditions. This condition was rather easy, as subjects could infer the answer by recalling whether they had seen the item or heard the label during the disambiguation round or not. However, they were not necessarily required to establish a link between the two to succeed here. Due to the potential for this 'visual' bypassing, potential advantages for multilinguals could be attributed to better visuospatial working memory (Cockcroft et al., 2019); however, we only controlled for verbal working memory.

The hard and reverse retention condition, in contrast, required the subjects to recall the labels of both items shown in order to select the correct answer. We expected the multilingual experience variables to have a positive effect on processing times. Subjects with higher English proficiency were expected to be faster because a more consolidated English lexicon would lead to a faster assessment of the familiar and novel item during the elimination step of the Disjunctive Syllogism. We expected current exposure of English to have an effect, as higher exposure rates would lead to faster access of the familiar item, and thus, faster elimination. An earlier age of acquisition was expected to lead to faster resolution of the elimination step, as AoA and proficiency are naturally correlated. A larger number of languages was not expected to have a direct impact on processing times but may have a modulating contribution via EF. However, the number of languages may impact on accuracy rates on retention in the following way: multilinguals may be more accepting of several labels for one referent, and thus, show lower accuracy rates for items that are mapped with a strategy (i.e. disambiguation) that favours one-to-one mappings. That is not to say that multilinguals do not exhibit the disambiguation effect, but when it comes to recalling the fast-mapped item, they may be more acceptant to go against the mutual exclusivity constraint, as we found in our previous study with children (see Chapter 6).

One caveat in our design was the potential of 'visually bypassing', as briefly outlined above. In the 'easy' and the 'reverse' condition, it was possible to reach high accuracy scores by simply recognising that they have encountered or seen the item before, regardless of whether they remembered its label. If this were to be the case, then these two conditions fare on the same level of difficulty which would result in similar accuracy and processing times.

For our EF measures, working memory and pro-/reactive control, we predicted that participants scoring higher on the counting recall task or AX-CPT task would perform faster during the elimination step of the Disjunctive Syllogism as better working memory, and cognitive control abilities would lead to faster processing, consolidation, and rejection of the distractor item, and ultimately a faster decision towards the target item. This would be reflected in faster reaction times, yet not necessarily in higher rates of accuracy due to a well-documented speed-accuracy trade-off (Struys, Duyck, & Woumans, 2018; Zhou & Krott, 2016).

In summary, we were interested in how multilinguals' linguistic background variables modulated the use and processing times of disambiguation, and in separate step, how working memory and cognitive control affected the use and processing times of disambiguation. We expected these language variables to modulate the processing speeds in a significant way. In contrast, the use of disambiguation itself (i.e. measured by accuracy) modulated to a lesser extent if at all, as the nature of the task was relatively simple, and using the process-of-elimination as a solution strategy would be expected by any adult regardless of their language background. For our retention conditions, we expected significant differences in accuracy and reaction times due to their varying degree of difficulty. We expected that speakers of many languages might be more accepting of several labels for the same object, and thus may be less inclined to remember the fast-mapped item form the disambiguation trials. Lastly, we expected multilingual speakers with higher accuracy scores on our WM and EF task to perform faster on the disambiguation as well as retention conditions.

7.8 Method

7.8.1 Participants

A total of 75 adult speakers (M_{age} = 24;0*; SD* = 3.22; 54 female*)* of English with a variety of backgrounds in other languages were recruited. Eight participants were excluded due to visual impairment (4), learning disabilities (2), failure to calibrate (1), and failure to complete the language questionnaire (1). The final sample entailed 67 subjects, of which 23 participants had English as their first language, and every participant used English daily. Other languages included Arabic, Cantonese, Czech, Danish, Estonian, Finnish, French, German, Greek, Hindi, Hungarian, Indonesian, Irish, Italian, Japanese, Korean, Lithuanian, Malay, Mandarin, Polish, Punjabi, Russian, Serbo-Croatian, Slovenian, Spanish, Swedish, Swiss-German, Tagalog, Taiwanese Hokkien, Tamil, Turkish, Ukrainian, Urdu, and Welsh.

Number of languages	Current Exposure English	Current Exposure OLs	SD	Age of acquisition (in years) English	SD	LexTale	SD	% English as L1	SD	N
1	100.00	0.00	-	0.00	-	0.92	0.06	1.00	-	6
2	82.67	17.33	17.65	2.00	1.86	0.88	0.14	0.50	0.52	12
3	65.63	34.38	22.05	5.94	4.40	0.83	0.15	0.19	0.40	16
4	67.00	33.00	17.50	4.90	3.34	0.81	0.15	0.20	0.41	20
5	67.53	32.47	15.07	4.62	3.28	0.87	0.10	0.31	0.48	14

Table 7.8.1: Composition of the multilingual sample by number of languages. Abbreviations: SD = standard deviation; L1 = first language; OLs = other languages; N = number of participants

7.8.2 Stimuli

Visual stimuli consisted of 57 computer-generated three-dimensional objects from the TarrLab Object data bank (2006) and the NOUN Database (Horst & Hout, 2016). Thirty-two of these items were *familiar items*, and 25 were *novel*. Due to the procedure, 14 of the novel items formed a group that was presented in the first and second half of the experiment and referred to as *disambiguated items*, while the remaining seven formed a group that is presented only in the second half and referred to as *unseen items*.

Auditory stimuli consisted of 30 labelling phrases recorded by a native speaker of Standard Scottish English. The target label came at the end of a carrier phrase, such as "Where is the …?", "Look at the …!", and "Find the …!". The experiment consisted of five conditions:

Condition	Items	Probe/Target	Number of trials
Practice	Familiar vs novel	Familiar	4
Familiar (control)	Familiar vs familiar	Familiar	14
Disambiguation	Familiar vs disambiguated novel	Disambiguated novel	7
Easy retention	disambiguated novel vs unseen novel	Disambiguated seen	7
Hard retention	disambiguated seen vs disambiguated seen	Disambiguated seen	7
Reverse retention	Unseen novel vs disambiguated seen novel	Unseen	7

Table 7.8.2: Conditions and items

7.8.3 Apparatus

The visual stimuli were presented on a 23-inch screen with auditory stimuli being played from one loudspeaker on either side of the monitor concealed behind a black curtain. During the presentation of stimuli, participants' eye movements were recorded. Behavioural responses were recorded using button response via keyboard, and eye gaze data was collected using a Tobii TX300 eye-tracker via E-Prime presentation software using extensions for Tobii. Recordings were sampled at a refresh rate of 60 Hz. The analysis of the eye-tracking data was not part of this paper. Participants were seated approximately 60 cm away from the screen in a dimly lit room. At the beginning of the experiment, a 9-point calibration was performed.

7.8.4 Procedure

7.8.4.1 Word mapping & retention task

All items were presented in pairs on black background. Every trial started with two objects being displayed in silence for 3000 ms, at which point the auditory cue was played. Participants were told to make a choice between the two objects via keyboard response while their eye movements were being tracked. In total, objects remained on the screen until participants made a choice or maximally 9000 ms. No feedback was given.

After four practice trials, 42 trials test trials were presented. Trials were presented in two blocks: the first block contained familiar interspersed with disambiguation trials; the second block contained familiar word interspersed with all three types of retention trials. This interspersion procedure was modelled after (Bion et al., 2013) and adapted for adults. Disambiguated items were the target during the disambiguation round, during the easy retention round, and during the hard retention. In the reverse retention condition, the disambiguated items were displayed on the screen, but participants had to select the opposite. Familiar items were only presented once.

Trials were pseudo-randomised to ensure target items were not presented on the same side more than two consecutive times. Two different orders were constructed, and an equal number of participants completed each order. Items that were labelled as the target in the first order, served as the distractor in the second order, and vice versa.

After the main task, participants were asked to complete a cognitive control task, a working memory task, and a lexical decision task. All participants gave informed consent and were paid. The entire session lasted approximately 60 minutes.

7.8.4.2 Language background

To assess participants' individual language history, they were asked to complete a digitised version of the LEAP-Q (Marian, Blumenfeld, & Kaushanskaya, 2007). The LEAP-Q (see Appendix D) is a tool for assessing the linguistic background of bilinguals or second language learners and for generating self-reported proficiency in multiple languages. We adapted the questionnaire, so participants were able to complete it on a web-based interface ahead of the in-person session. For this, we used the Qualtrics XM survey tool. Completing the questionnaire took between 15 – 30 minutes, depending on the extensiveness of language background. The questionnaire started by outlining the nature of the study, and participants were required to give informed consent. In addition to the pre-session questionnaire, participants completed the LexTale task (Lemhöfer & Broersma, 2012), which a lexical test for advanced learners of English that is quick and whose validity was compared to that of self-rated proficiency.

7.8.4.3 Executive control tasks

In the present study, adults required proactive and reactive control mechanisms to master the task successfully. When subjects were asked to fast-map certain object-word or object-fact pairings, they needed to be able to swiftly shift from one mapping to the subsequent one in order to perform well. This shift required reactive control or certain flexibility between trials. When subjects were asked tested on the retention of these mappings, they needed to find a suitable combination of proactive and reactive control. Proactive control is required to sustain activation of a novel item for long enough to memorise it; yet, reactive control is required to shift to the next trial (as with fast mapping), and also to reactivate and recall mappings from earlier rounds (first block). Morales, Gómez-Ariza, & Bajo (2013) argue that bilinguals have an advantage in terms of modulating and juggling those two mechanisms, which could lead to better performance on retention.

During the AX-CPT, participants were exposed to fast sequences of letters in four types of trials (“AX”, “AY”, “BY”, “BX”, whereby Y represented any probe other than X, and B any cue other than A). Participants were instructed to respond “yes” via button response, every time they saw a red “X” preceded by a red “A” in the same sequence. In every other case, they were told to press “no”. A sequence was made up of five letters, of which the first one was red forming the cue, the last one was red forming the probe, and the three interjacent letters were white forming the distractors. Each letter was presented on a black background and remained on screen for 300 ms with a 1000 ms interval between them, totalling to 4900 ms per trial. The task entailed 100 trials of which 70 were “AX” trials, 10 “AY”, 10 “BY”, and 10 “BX”. “AX” trials were considered target trials and participants were overall primed to press “yes” for the majority of the task due to their high frequency of 70%. “AY” and “BX” trials required participants to engage in increased cognitive control, due to their interference with the target “AX” trials. In “AY” trials, participants had to proactively maintain the “A” cue, as they did in the “AX” target trials, but then also had to inhibit the urge to press “yes” on the probe upon the realisation that it was **not** an “X”, but another letter. “BX” trials required participants to proactively maintain the “B” cue in order to avoid pressing “yes” upon seeing the “X” probe. The task took approximately 12 minutes, and participants received instructions, examples, and underwent a practice session, including ten trials before the start. To account for cognitive control, we adopted the accuracy score of the “AY” trials provided by the AX-CPT. “AY” trials tested proactive and reactive control and are therefore suitable to control for both in our subsequent main analysis. To analyse these trials, we split the dataset according to trial type and regressed out the age, and years of formal education (M = -717410.6, SD = *1496196)* (Coco & Keller, 2015).

The session was continued by completing a counting recall task which measures the verbal component of the working memory. Participants were presented with a varying number between four to seven of blue triangles and red circles on the screen. They were instructed to count only the number of red circles and memorise it. The number of images shown forming the sequence to be recalled increased from one to seven. During the recall, the sequence was entered via the number pad on the keyboard. Participants were instructed to answer as accurately as possible but were not limited by time. Subjects' performance on the counting recall assessment was high (*M* = 0.80, *SD* = 0.12, range: .53 – 1.00).

7.9 Data processing and analysis

Prior to our main analysis, we explored which of our collected language variables would be suitable predictors in the following models. In order to do so, we performed a correlation analysis between the accuracy scores (and processing times) and the language and cognition variables for each of the four condition. The four correlation matrices can be found in Appendix B. Decisions on whether to add a measure as a predictor for the models was either data-driven (i.e., those with r ~ .3) or theoretically motivated (i.e., it was specific to the research question we posed). This led to the inclusion of language proficiency ("LexTale"), which showed a negative correlation in all three retention conditions, as well as English exposure, which showed positive correlations above .2. Although these correlations did not reach our cut-off point per se, they were included since current English exposure, akin to proficiency, is one of the most suitable ways to describe and measure language experience. The third variable added to our predictors was the number of languages spoken based on theoretical motivation, as this variable measures the breadth of someone's multilingual expertise.

We analysed the data in two ways: 1) by effect of condition; 2) by effect of participant variables, i.e., 2a) language variables, and 2b) cognitive functioning variables. For each of these, we analysed accuracies in binomial mixed-effect models accounting for the individual variability of target and trial by adding a random intercept for Target and TrialId respectively. This was followed by an analysis of behavioural reaction times in linear mixed-effect models using the same random effect structure as in the analysis for accuracies. For 2a), main predictors were the number of languages, current exposure of English, and language proficiency (LexTale in tables). We kept the analysis of participant-related variables (language and cognition variables) separate from each other allows for a more nuanced approach, as it not only increases the statistical power of the models, but also creates clearer results with regards to interactions between item- and participant-related variables. Thus, for 2b), the main predictors were working memory, pro-/reactive control, and Condition. The residual for the model run on the "AY trials" of the AX-CPT task was then used as a covariate for further analysis.

7.9.1 Descriptive statistics

Raw measures of accuracy and RT are presented by the number of languages spoken in Table 7.9.1 and Table 7.9.2. Outliers in RTs were calculated using two SDs and were excluded from further analysis (12.21% were eliminated). For descriptive analysis, mean RTs excluded incorrect responses (22.93% were excluded).

Number of languages	*1*	*2*	*3*	*4*	*5*	*Overall*
Condition						
Familiar	1.00 (-)	0.95 (0.10)	0.99 (0.03)	0.96 (0.11)	1.00 (-)	0.98 (0.08)
Disambiguation	0.95 (0.12)	0.90 (0.13)	0.85 (0.18)	0.88 (0.18)	0.92 (0.14)	0.89 (0.16)
Easy retention	0.88 (0.15)	0.79 (0.17)	0.78 (0.18)	0.77 (0.23)	0.79 (0.17)	0.79 (0.19)
Hard retention	0.75 (0.31)	0.82 (0.19)	0.69 (0.27)	0.77 (0.21)	0.77 (0.21)	0.76 (0.23)
Reverse retention	0.97 (0.08)	0.90 (0.16)	0.81 (0.17)	0.81 (0.24)	0.89 (0.13)	0.86 (0.18)

Table 7.9.1: Mean accuracy (proportions) and SD (in parentheses) across conditions and number of languages

Number of languages	*1*	*2*	*3*	*4*	*5*	*Overall*
Condition						
Familiar	1517 (132)	1377 (88)	1383 (142)	1509 (212)	1326 (104)	1421 (166)
Disambiguation	2247 (349)	2077 (251)	2000 (497)	2110 (412)	1947 (486)	2059 (418)
Easy retention	1971 (320)	1900 (239)	1939 (404)	1995 (399)	1941 (425)	1952 (366)
Hard retention	2205 (301)	1996 (314)	1855 (344)	2070 (367)	1960 (613)	1996 (410)
Reverse retention	2052 (243)	1914 (294)	1921 (375)	1961 (394)	1889 (504)	1937 (379)

Table 7.9.2: Mean reaction times (ms) and SD (in parentheses) across conditions and number of languages

7.9.2 Analysis by effect of condition

To determine whether the four experimental conditions differed from one another, we entered the overall accuracy across the four trial types into a binomial mixed-model regression. Fixed effect was Condition as a categorical variable (**familiar,** disambiguation, retention easy, retention hard, retention reverse) together with the random effect structure outlined above. We found significant negative main effects for each condition indicating that our item-related variables differed significantly from the baseline condition (familiar word trials), and resulted in lower accuracies. All model coefficients and p-values can be found in Table 7.9.3. Prediction accuracy of this model was 84.9%, and *C*= 0.74. This model differed significantly from the null model ($\chi^2(4) = 2764.2\,;\ p < .001$). In order to address the caveat of 'visual bypassing', we changed the reference level to 'easy retention', and found a positive main effect for 'reverse retention' ($e^{\beta} = 1.31\,;\ \mathrm{SE} = 1.02\,;\ \mathrm{z} = 1.05\,;\ \mathrm{p} < .001$). This indicates that reverse retention yielded higher accuracies.

	e^{β}	Std. Error	z value	Pr(>|z|)
(Intercept)	944.368	1.91	39566.425	<.001***
Disambiguation	0.008	3.063	0.014	<.001***
Retention easy	0.004	3.062	0.008	<.001***
Retention hard	0.003	3.062	0.005	<.001***
Retention reverse	0.006	3.062	0.01	<.001***

Table 7.9.3: Formula: Accuracy ~ Condition + (1|Target) + (1|TrialId). P-values <.05 are marked with '',p-values <.01 with '**', and p-values <.001 with '***'*

For reaction times, we entered the same fixed effect into a linear model. Similarly to accuracy, we found positive main effects for condition indicating that compared to the baseline condition, each of our experimental condition required more time to respond and process. The conditional R^2 = .30, which includes fixed and random effects, for this model. In order to address the potential visual similarity between the easy and reverse retention condition, we changed the reference level to 'easy' for this model in order to calculate the significance of this effect. We found that the reverse retention condition yielded significantly faster reaction times than the easy condition ($\beta = -9.18\,;\ SE = 4.05\,;\ t = -2.27\,;\ p = .024$).

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	1439.427	25.455	75.67	56.547	<.001***
Disambiguation	719.379	39.774	47.858	18.087	<.001***
Retention easy	614.473	39.777	47.875	15.448	<.001***
Retention hard	759.838	39.791	47.94	19.096	<.001***
Retention reverse	605.296	39.785	47.912	15.214	<.001***

Table 7.9.4: Formula: RT ~ Condition + (1|Target) + (1|TrialId). P-values <.05 are marked with '',p-values <.01 with '**', and p-values <.001 with '****

7.9.3 Analyses of participant-related variables

7.9.3.1 Effect of language variables

In this analysis, we explore how our selected language variables impact on the accuracy and processing times, and how they interact with the experiment conditions. For accuracy, we entered language proficiency and current English exposure as continuous variables, and number of languages as categorical variable into a binomial mixed effect model together with an interaction term for Condition (**familiar**, retention easy, retention hard, retention reverse). The random effect structure is analogous to above. This analysis revealed three main effects of language proficiency, English exposure, and number of languages. The effects of proficiency and number of languages were positive, indicating greater accuracy, while the effect of English exposure was negative. We did not find a main effect for Condition. However, the analysis yielded significant interactions between the conditions and the language variables. Language proficiency (LexTale) had a positive influence on the accuracy within each condition (see Figure 7.2). All coefficients and p-values can be found in Table 7.9.5. The model had a prediction accuracy of 84.7%, and a C-statistic of C= .77.

A linear model analogous to above was computed for reaction times including the same interaction term and fixed effect, as well as random effect structure. This model resulted in main effects of condition, LexTale, and number of languages, but not current exposure of English. The effect of condition was positive resulting in longer reaction times, whereas the effects of LexTale and number of languages was negative resulting in shorter reaction times. Furthermore, we found numerous significant interactions between Condition and the other language variables. Hereby, the interactions with LexTale showed a negative directionality, i.e. participants with higher scores on language proficiency performed faster (see Figure 7.3), whereas the other interactions showed a predominant positive directionality, i.e. participants speaking more languages or having more current exposure to English were slower. All coefficients and p-values can be found in Table 7.9.6. This model had a conditional R^2 = .33.

	e^{β}	Std. Error	z value	Pr(>|z|)
(Intercept)	0.819	2.003	0.750	0.773
Disambiguation	0.602	3.218	0.648	0.664
Retention easy	1.102	3.213	1.087	0.934
Retention hard	0.222	3.212	0.275	0.197
Retention reverse	0.627	3.216	0.670	0.689
LexTale	8289.854	1.254	2.04E+17	<.001***
Exposure English	0.992	1.002	0.009	<.001***
Number of languages	1.274	1.030	3358.289	<.001***
Disambiguation : LexTale	0.002	1.291	0.000	<.001***
Retention easy : LexTale	0.001	1.281	0.000	<.001***
Retention hard : LexTale	0.001	1.280	0.000	<.001***
Retention reverse : LexTale	0.005	1.285	0.000	<.001***
Disambiguation : Exposure English	1.014	1.002	1252.368	<.001***
Retention easy : Exposure English	1.006	1.002	23.789	0.002**
Retention hard : Exposure English	1.013	1.002	1273.198	<.001***
Retention reverse : Exposure English	1.007	1.002	32.918	<.001***
Disambiguation : Number of languages	0.841	1.034	0.006	<.001***
Retention easy : Number of languages	0.739	1.033	0.000	<.001***
Retention hard : Number of languages	0.868	1.033	0.012	<.001***
Retention reverse : Number of languages	0.652	1.033	0.000	<.001***

Table 7.9.5: Formula: Accuracy ~ Condition(LexTale + Exposure English + Number of languages) + (1|Target) + (1|TrialId). P-values <.05 are marked with '*',p-values <.01 with '**', and p-values <.001 with '****

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	1829.304	30.735	171.065	59.52	<.001***
Disambiguation	880.92	48.337	109.703	18.224	<.001***
Retention easy	1243.13	47.844	105.293	25.983	<.001***
Retention hard	1071.197	48.714	113.16	21.99	<.001***
Retention reverse	1049.46	48.618	112.272	21.586	<.001***
LexTale	-408.614	19.324	186068.264	-21.145	<.001***
Exposure English	0.089	0.139	186005.74	0.641	0.522
Number of languages	-14.181	2.056	186035.574	-6.897	<.001***
Retention easy : LexTale	-574.198	30.424	186079.551	-18.873	<.001***
Disambiguation : LexTale	-659.38	29.277	186078.635	-22.522	<.001***
Retention hard : LexTale	-755.717	30.34	186083.788	-24.909	<.001***
Retention reverse : LexTale	-922.914	31.096	186086.288	-29.68	<.001***
Retention easy : Exposure English	1.747	0.215	186087.94	8.137	<.001***
Disambiguation : Exposure English	1.431	0.212	186081.341	6.747	<.001***
Retention hard : Exposure English	3.522	0.216	186091.874	16.295	<.001***
Retention reverse : Exposure English	3.458	0.221	186083.96	15.668	<.001***
Retention easy : Number of languages	27.732	3.156	186043.949	8.786	<.001***
Disambiguation : Number of languages	-21.753	3.141	186034.487	-6.926	<.001***
Retention hard : Number of languages	20.071	3.285	186050.135	6.11	<.001***
Retention reverse : Number of languages	25.134	3.233	186042.711	7.774	<.001***

Table 7.9.6: Formula: RT ~ Condition(LexTale + Exposure English + Number of languages) + (1|Target) + (1|TrialId). P-values <.05 are marked with '*',p-values <.01 with '**', and p-values <.001 with '****

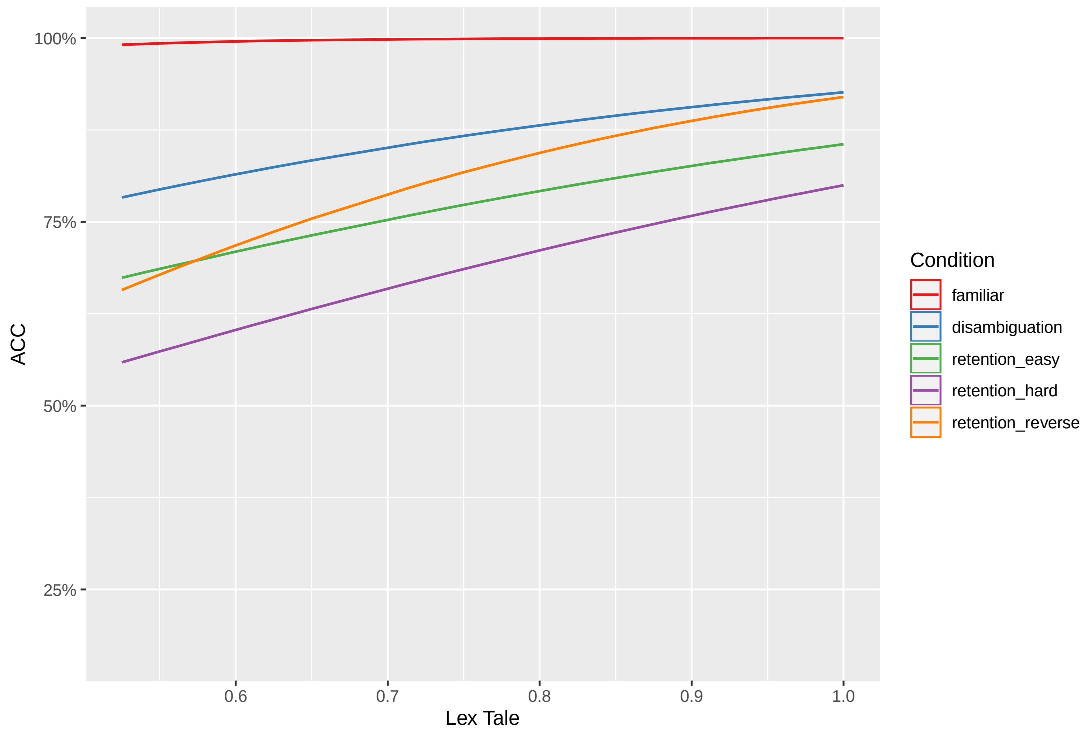


Figure 7.2: Predicted accuracies for the interaction between LexTale and Condition (reference level = 'familiar'; marginal effects)

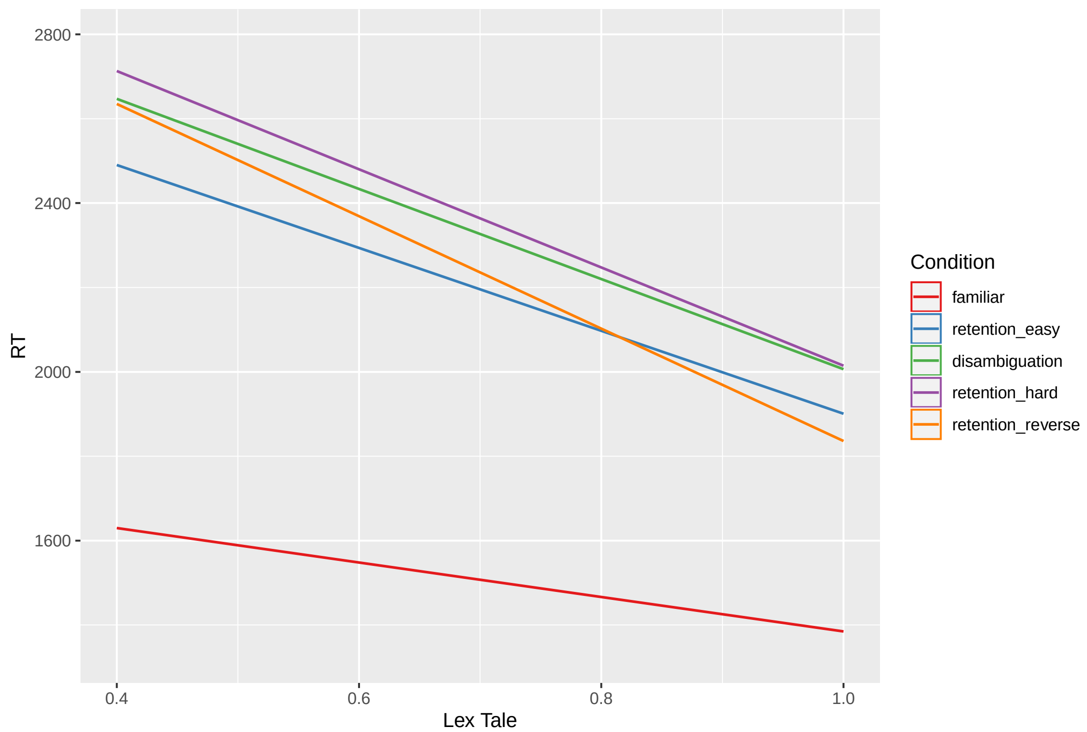


Figure 7.3: Predicted reaction times for the interaction between LexTale and Condition (reference level = 'familiar'; marginal effects)

7.9.3.2 Effect of cognition variables

In order to calculate the individual contribution working memory and executive control, our other set of participant-related variables, had on the dependent variables (accuracy and reaction times), two models similar to above were built with a by-Subject and by-TrialId random intercept. However, instead of language variables, we entered the individual working memory score and pro-/reactive control score as continuous predictor variables.

For accuracy, we entered the predictor variables into a binomial mixed effect model together with an interaction term for Condition (**familiar**, retention easy, retention hard, retention reverse). This analysis revealed three negative main effects of working memory, pro-/reactive control, and Condition. The analysis also yielded significant positive interactions between the conditions and working memory score, and pro-/reactive control score respectively. Better scores on the working memory task positively affected the accuracy within all test conditions. The score calculated for pro-/reactive control also resulted in positive interactions with all but the familiar condition. All coefficients and p-values can be found in Table 7.9.7. The model had a prediction accuracy of 84.9%, and a C-statistic of $C = .76$.

	e^{β}	Std. Error	z value	Pr(>|z|)
(Intercept)	1513.556	1.942	61635.213	<.001***
Disambiguation	0.003	3.155	0.006	<.001***
Retention easy	0.005	3.156	0.011	<.001***
Retention hard	0.002	3.155	0.004	<.001***
Retention reverse	0.004	3.156	0.008	<.001***
WM	0.754	1.028	0.000	<.001***
pro-/reactive control	0.337	1.045	0.000	<.001***
Retention easy : WM	1.274	1.031	3032.598	<.001***
Disambiguation : WM	1.275	1.032	2200.200	<.001***
Retention hard : WM	1.074	1.031	10.567	0.018*
Retention reverse : WM	1.067	1.032	7.877	0.039*
Retention easy : pro-/reactive control	2.511	1.047	449952400.810	<.001***
Disambiguation : pro-/reactive control	2.213	1.049	15189663.140	<.001***
Retention hard : pro-/reactive control	2.345	1.048	90426985.812	<.001***

Retention reverse : pro-/reactive control	2.030	1.049	2745521.889	<.001***

Table 7.9.7: Formula: Accuracy ~ Condition(WM + pro-/reactive control) + (1|Target) + (1|TrialId). P-values <.05 are marked with '*',p-values <.01 with '**', and p-values <.001 with '****

A linear model analogous to above was computed for reaction times including the same interaction term and fixed effect, as well as random effect structure. This model resulted in positive main effects of condition, working memory, and pro-/reactive control, which represents an increase in reaction times. Furthermore, we found numerous significant interactions between Condition and working memory, and pro-/reactive control respectively. Hereby, the interactions with working memory showed a negative directionality, i.e., participants with higher scores on the working memory performed faster, whereas the interactions with pro-/reactive control showed a positive directionality, i.e., participants scoring higher on this measure were slightly slower. All coefficients and p-values can be found in Table 7.9.8. This model had a conditional $R^2 = .31$.

	Estimate	**Std. Error**	**df**	**t value**	**Pr(>|t|)**
(Intercept)	1327.164	30.032	151.594	44.191	<.001***
Disambiguation	890.722	47.008	93.620	18.948	<.001***
Retention easy	1096.414	47.064	94.072	23.296	<.001***
Retention hard	1318.583	47.459	97.263	27.784	<.001***
Retention reverse	1214.397	47.433	97.054	25.602	<.001***
WM	151.701	20.219	186051.468	7.503	<.001***
pro-/reactive control	13.359	1.562	186083.308	8.555	<.001***
Disambiguation : WM	-172.124	31.053	186052.557	-5.543	<.001***
Retention easy : WM	-579.204	31.309	186052.368	-18.500	<.001***
Retention hard : WM	-662.621	32.206	186052.892	-20.574	<.001***
Retention reverse : WM	-713.716	32.193	186055.044	-22.170	<.001***
Disambiguation : pro-/reactive control	48.950	2.398	186076.287	20.414	<.001***
Retention easy : pro-/reactive control	30.005	2.385	186076.072	12.580	<.001***
Retention hard : pro-/reactive control	45.994	2.530	186078.319	18.178	<.001***

Retention reverse : pro-/reactive control	62.286	2.471	186076.642	25.208	<.001***

Table 7.9.8: Formula: RT ~ Condition(WM + pro-/reactive control) + (1|Target) + (1|TrialId). P-values <.05 are marked with '*',p-values <.01 with '**', and p-values <.001 with '****

7.10 Discussion

The present study investigated whether multilingual adults used disambiguation as a mapping strategy in a task requiring them to resolve referential ambiguity and establish novel word-object pairings, and how their linguistic experience modulated processing speeds. Furthermore, we tested (1) whether they were able to retain novel word-object mappings in subsequent retention trials, (2) how their linguistic experience impacted on accuracy and processing speeds, and (3) how WM and EF modulated their performance. Unlike traditional approaches to this question, which test the impact of multilingualism in dichotomous groups (monolingual control group vs. a multilingual test group), we aimed to provide a more holistic account of how multilingualism shapes the use of disambiguation. To allow for the nuances that shape someone's multilingual experience, we included the following linguistic variables to our paradigm and analysis: English proficiency, current exposure, and the number of languages. We focussed explicitly on how multilingual speakers' experience in English modulated the use of disambiguation in a fast-mapping task and their performance on retention. According to Hirosh & Degani (2018), multilingualism may impact on novel language learning in direct and indirect pathways of which the latter includes effects on non-linguistic factors such as executive functioning. These indirect effects can be said to stem from previous the multilingual experience participants have had, and affect novel word learning situations a multilingual might find themselves in. Previous studies (Bialystok, 2011; Bialystok, Barac, et al., 2010; Cockcroft et al., 2019) have shown that adults from multilingual backgrounds perform differently on certain cognitive function tasks that measure working memory ability and cognitive control compared to their monolingual peers. Thus, our study not only aimed to include the specific language experience variables outlined above but also to account for the indirect effects on cognitive functioning multilingualism may have.

7.10.1 Multilinguals accept the premise of one-to-one mappings

When engaging in disambiguation or the process-of-elimination, the underlying mental and logical operation is attributed to the Disjunctive Syllogism (Halberda, 2006). Part of the Syllogism is the completion of a rejection step of the distractor item, or the brief engagement and assessment of the non-target item in a task. The assessments made during the rejection step require not only working memory, but also the ability to inhibit the other item and shift between the two (in our task, we had two items on screen).

As predicted, all participants in our study performed well above chance-level during disambiguation trials, but our language variables further modulated this performance. The largest contributing effects to the performance on disambiguation trials could be attributed to participants' English language exposure, their English proficiency, and the number of languages. Participants displaying more exposure of English also performed better on disambiguation trials, whereas the number of languages and language proficiency modulated disambiguation slightly negatively, however, these effects were rather small. This may result from the fact that all participants showed high accuracy scores.

More interestingly, perhaps, was the impact the English linguistic experience variables had on the processing speeds in the disambiguation trials, as they all modulated RTs significantly. The largest effect was found for English proficiency, indicating that highly proficient speakers performed faster. This result was expected as higher proficiency leads to faster completion of the Syllogism's rejection step, as someone with a more consolidated vocabulary in English had faster access to the familiar distractor item and could thus eliminate it more quickly. An increase in the number of languages also led to a faster response within the disambiguation condition. This is in line with our predictions, as we assumed that the number of languages might have previously impacted on cognitive functioning abilities indirectly, which led to faster processing times in the task present. Interestingly, current English exposure negatively impacted processing times, albeit to a very small extent. Together with the accuracy results, this may be due to speed-accuracy trade-off, which is often found in multilinguals (Struys et al., 2018), whereby accuracy was traded for speed in participants with higher proficiency scores, and speed traded for accuracy in those participants with more exposure to English. These findings show a certain variability in strategic task tendencies. The idea that multilinguals are less accepting of one-to-one mappings, which used to be at the premise for disambiguation, cannot be verified with our findings, as multilinguals' processing times on disambiguation was positively impacted by the number of languages they spoke. These results also lead to the conclusion that multilinguals are indeed able to accept one-to-one mappings, especially in a task like ours where switching to another language was not required, and they operated from a 'monolingual mode'. In this sense, being in a 'monolingual mode' during the experiment may have allowed them to accept the notion of one-to-one mappings. In a situation where two or more languages were to be activated, leading to cross-linguistic activation, the idea of one-to-one mappings proposed by the Disjunctive Syllogism might not help resolve referential ambiguity, which needs to be investigated in future studies.

7.10.2 Retention: Performance strongly influenced by language proficiency and English exposure

In addition to the initial fast-mapping of novel word-object links (in the disambiguation trials), we verified whether participants were able to retain these novel fast-mapped word-object combination in the subsequent retention trials, and how their linguistic experience would affect their performance and processing speeds. We tested retention in three slightly differing retention conditions, of which the hard retention condition yielded in significant performance differences compared to the easy and reverse retention condition. Therefore, we discuss each retention condition separately.

In the easy condition, a previously unseen item and a fast-mapped item during disambiguation trials were juxtaposed. We predicted the most accurate results compared to the remaining two retention conditions as it was rather easy. However, participants performed worse in this condition than in the reverse condition, but better than in the hard retention condition. Their accuracy performance was positively modulated by English exposure, but negatively by English proficiency and the number of languages spoken. In line with our predictions, the easy retention condition seems to have been more difficult to master than the reverse condition. Although not all language variables impacted the performance on accuracy as strongly, they were impactful with regards to RTs. The process-of-elimination is not exclusive to the disambiguation condition, as it describes a mental operation that happens when a decision between two or more items must be made. This is also true for the retention trials, although here their ability to retain the fast-mapped items adds to the impact on processing times of the elimination step alongside the cognitive function ability, and the English language variables. Participants with high English proficiency performed significantly faster, as was to be expected since they can complete the elimination step required by the process-of-elimination faster. Rather surprising in this condition was the result that the number of languages spoken and current exposure to English slightly elongated reaction times. However, the effect of English proficiency was significantly stronger.

The hard retention condition, in contrast, required participants to retain the labels of both items shown in order to select the correct answer. This condition yielded the lowest accuracy scores and the longest response times between the three retention conditions. The accuracy was modulated by English proficiency, current exposure of English, and the number of languages. A positive effect was visible in higher proportions of current English exposure leading to better accuracy. An increasing number of languages and higher scores on English proficiency led to lower accuracy scores, which displays a pattern similar to the one found in the easy retention condition. We predicted that multilinguals' proficiency in English would impact their processing speeds. We found a strong effect of proficiency, indicating that highly proficient speakers performed faster. Similar to the easy condition, speakers of more languages or less current exposure to English performed somewhat slower. We expected to find positively modulating effects for current exposure of English, as it contributes in some way or another to proficiency, however, this was not the case. Again, this may be due to some language variables impacting accuracy, and others processing times.

In the reverse condition, participants were shown two items of whom one was fast-mapped during the disambiguation phase of the experiment, and the other was previously unseen. In contrast to the easy condition, the prompt here was to select the novel unseen item rather than the disambiguated item. This condition not only required participants to remember the label of the fast-mapped item but also to subsequently select the other item engaging in the second round of Disjunctive Syllogism or reverse disambiguation. This condition is especially interesting because according to Halberda (2006) applying the Disjunctive Syllogism on an item is a way of 'using' the word, and thus knowing it without having to utter its name explicitly. Accessing the semantic knowledge of the word-object mapping in order to perform a Disjunctive Syllogism on it implies that the mapping can be considered known (within the realm of the task). Here, we had two sets of predictions: either this additional step would take longer to perform, or it would be visually by-passed. This condition had the highest accuracy scores of all three retention conditions, and processing speeds were significantly shorter than those of the easy retention despite the requirement of engaging in an additional step to make a decision. A possible explanation might be that instead of accessing and consolidating the item to be rejected during the elimination step, which in this case is the previously during disambiguation trials fast-mapped item, participants visually by-passed this entire extra step by choosing the unseen novel item directly. Choosing a novel and unseen item forthwith would be a decision-making strategy involving fewer steps, but with the same success rate in this specific looking-while-listening paradigm. Hence, it is possible that using a novelty bias, be it either because the item is visually new or because the label sounds even more unfamiliar that those 'learnt' during the disambiguation condition, might be a faster and more accurate decision-making strategy that the process-of-elimination in this specific scenario. This decision-making process was quite possible since our experimental design juxtaposed only two items. In a visual-world paradigm with one target and three novel unseen distractor items, for instance, adhering to a novelty bias would not lead to success, in which case relying on the 'reverse disambiguation' that we had anticipated in our study may become more likely. Accuracy and reaction times were modulated by the language experience variables in analogous patterns to the other two retention conditions.

7.10.3 Working memory positively impacts performance across all conditions

Lastly, we checked for the individual contribution our EF and WM measures had on disambiguation and retention accuracy and processing speeds. We discuss the results from the disambiguation and retention conditions together because they all showed a similar pattern. The accuracy scores of all conditions were positively influenced by higher working memory and pro-/reactive control scores. Particularly those who participants who were able to focus attention, shift, and inhibit better during the AX-CPT task yielded higher accuracy scores during disambiguation and retention trials, which was in line with our predictions. With regards to processing times, the effect of working memory and pro-/reactive control differed. As we predicted, higher performance on working memory resulted in much faster reaction times in all experiment conditions, particularly in the retention conditions. However, people with better pro-/reactive control responded slightly slower. We found that better working memory ability resulted in faster processing times, which we expected, since keeping the stimuli active in the phonological loop while processing them was an essential requirement for this specific task. Unexpectedly, higher performance in the combined proactive and reactive control score impacted on reaction times in a decelerating manner. Although this slowing down was likely compensated by the working memory (due to the latter's larger effect size), this effect was not foreseen. The EF measure taken from the AX-CPT was used for analysis to account for the inhibiting, shifting, and updating processes of cognitive control. Possible explanations as to why this measure did not yield the expected result could be that (1) the amount of inhibitory control, shifting and updating within this task was not as relevant as we had anticipated; (2) and in the same vein, participants' ignorance that they had to recall the fast-mapped items, later on, may not have triggered any specific form of planning. Tasks measuring proactive and reactive control usually measure the performance of a longer trial sequence that requires certain aspects of planning, such as inhibiting, shifting, and updating of information. However, in the word-learning task at hand, the trial sequence per se was rather short, and therefore, a better pro-/reactive control score may not impact processing speeds the same way a working memory score would, which measures working memory differently. Pro-active and reactive control records someone's ability to plan and update the completion of task over a longer period, which means that a better performance therein may translate into a statistical interaction by trial numbers of the course of the experiment. In other words, once participants entered the retention phase of the experiment, they may have quickly realised that they were tested on retention as they started to recognise some of the stimuli from the mapping phase. This realisation is akin to a learning effect throughout the experiment, and it is this learning effect that may have the potential to interact with a longer measure of task planning, such as the pro- and reactive control measure. That being said, the slowing down effect caused by a higher pro-/reactive control measure was always compensated by the stronger expediting effect of the working memory measure. Thus, it is rather unlikely that those modulations of the pro-/active reactive control score had any ‘detrimental’ impact on the processing speeds.

7.11 Conclusion and future considerations

In this study, we tested the contributions of multilingualism and cognitive functioning on the process-of-elimination or disambiguation, which is a mechanism that supports mapping novel labels to novel objects. We found that multilinguals were willing to accept one-to-one mappings to resolve referential ambiguity. Moreover, we tested if and how their language experience modulated multilinguals’ ability to retain these novel word-object mappings. We found that accuracy and processing times were affected in different, often advantageous ways. The multilingual experience modulated performance, but it did not put multilinguals at a disadvantage. Especially if speakers were highly proficient in English, they performed accurately and fast, as English proficiency yielded the largest effects over all the retention conditions. Furthermore, we reiterate that studies investigating multilingual populations should refrain from treating them in dichotomous ways (monolingual vs. multilingual categories) in the future, and should, where possible, include language variables such as language proficiency, number of languages, age of acquisition, and exposure in order to portray a complete picture of the multilingual experience. New ways of statistically analysing data resulting from the complexity of multilingualism could be found in adopting Factor Mixture Models or Grade-of-membership models (Kremin & Byers-Heinlein, 2020). These models allow for the fluidity found on the spectrum of the multilingual experience.

8 “This one looked more dog-friendly.” Disambiguation strategies in multilingual adults.

8.1 Introducing disambiguation

The process-of-elimination is a widely applied reasoning strategy that enables decision-making based on some prior knowledge about the available options. It can also be found within the realm of word learning. When adults attempt to assign meanings to novel words, they often reason by exclusivity (Halberda, 2006). In the presence of familiar known objects, they tend to map an unheard name to an unseen object due to their knowledge about the familiar objects. This phenomenon, also referred to as the *disambiguation effect*, has been widely studied among children, who use it in their early lexical acquisition stages (Markman & Wachtel, 1988; Merriman, Bowman, & MacWhinney, 1989), but has also been found in adults (Halberda, 2006). Disambiguation has been predominantly examined under the scope of fast mapping, i.e. the fast assignment of a novel word to a novel item during first encounters. Studies have shown that an individual’s language experience, such as growing up with multiple languages, can have a profound impact on the use of disambiguation in adults (see previous study, chapter 7) and children (Byers-Heinlein & Werker, 2009; Kalashnikova, Oliveri, & Mattock, 2018). However, only a few studies have investigated the use of disambiguation within other communicative contexts, such as using facts (e.g. “This is the one I got from Thailand”) instead of labels (e.g. “This is a *dax*”) when referring to objects. It was found that children extended the use of disambiguation and applied it to factual statements (Diesendruck & Markson, 2001; Kalashnikova et al., 2014), whereas adults did not show the disambiguation effect and performed at chance levels. These results led to the debate of domain specificity of disambiguation with regards to resolving referential ambiguity, which researchers have since been trying to settle. The domain specificity in this context is essential because referring to labels is different from referring to factual expressions. Although both use language as a medium, there are different levels of linguistic processing involved. In semiotics, a *sign* is defined as the relationship between a *signifier,* which is the label or word form, and a *signified*, which is the concept/object or referent (de Saussure & Baskin, 2011). An inherent quality of this relationship is its arbitrariness, which Saussure saw motivated only by social convention. Thus, the process of mapping a novel label to a novel object is purely linguistically arbitrary, and people accept this arbitrariness to communicate successfully. Thus, when we refer to domain- or language-specific with the context of disambiguation, it pertains to this specific arbitrary property of language. However, some theoretical accounts suggest that disambiguation can also be used in a broader, more general context. Hence, researchers started investigating the disambiguation of factual expressions.

In a situation of referential ambiguity between labels, attaching a label to an object is rarely questioned unless there is reason to do so. Attaching a factual expression to an object, however, possesses different levels of processing on the syntactic and socio-pragmatic level. In other words, processing the factual information itself is not arbitrary and to establish meaning, people draw on their word knowledge. Due to this need to understand and make sense of the factual expression, in a situation of referential ambiguity, it would not be sufficient to accept a factual expression about the referent based on linguistic arbitrariness. Since this decision has to be integrated with existing world knowledge, it should be in congruence with it. To check if a factual expression is sensible, people could, for example, rely on visual properties of an item to establish meaning. Since this information processing is based on other cognitive processes, some of which are linguistic such as syntactic or socio-pragmatic processing, we refer to this as domain-general. One way of gaining further insight into this debate is to investigate how language background variables may modulate the use of disambiguation in the context of labels versus factual expressions. It is often not clear whether disambiguation works equally well across all referential contexts because different unobservable reasoning strategies might lead to the same surface-level observable disambiguation effect. To examine those strategies, Malone et al. (2016) tested adults on a disambiguation task using made-up labels referring to objects and made-up factual expressions referring to objects. They subsequently requested verbal explanations from their participants., and found that disambiguation was only observable when assigning labels, but not when facts were involved.

To better understand the referential resolution of facts and whether disambiguation is a mechanism that operates more specifically with labels or also more generally with other referential expressions, we adapted Malone's study for an eye-tracking design. This helped us visualise and better understand what happens online during the mapping of labels and facts. Furthermore, we examined a multilingual adult population, as previous research on disambiguation has shown that multilingualism can modulate its use in the context of labels, but no study to date has examined whether this also extends to facts. Hence, it makes sense to investigate the latter, because findings could contribute to the domain-specificity debate around disambiguation. We were specifically interested in how English language proficiency, the number of languages, current English exposure, and age of English acquisition may not only impact on the use of disambiguation but also the strategies underlying the decision-making process.

8.2 Disambiguation of labels

The assignment of labels onto new objects becomes necessary when learners encounter a situation of referential ambiguity. Referential ambiguity constitutes a situation whereby the referent of a label is not yet clear or decided, usually because the label is novel and unfamiliar to the learner (e.g. "Find the *sprock*"). It is often considered one of the most challenging tasks of language acquisition. In a real-world context, learners often encounter multiple possible referents for a novel word. To reduce this complexity learners might use certain language constraints, one of which is *disambiguation*, and its use is observable in the so-called *disambiguation effect.* The *disambiguation effect* was found in adults (Halberda, 2006) and children (Halberda, 2003; Markman, 1990; Merriman et al., 1989) alike. The underlying process is also known as process-of-elimination and is one of many biases that learners might use to limit the number of possible referents. For instance, monolingual children's acquisition of new words is said to be guided by disambiguation, or the assumption that new words tend to refer to new referents. This means that children assume that each concept or object only has one name or referent, and it helps children to identify whether a label for a referent is already familiar or not and allows them to build up a vocabulary without overlapping meanings in the beginning. However, learning multiple names for the same object or class inclusion, such as cat/animal, is difficult to acquire. As children age, they will eventually be able to override this constraint (Gathercole, 1989; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Liittschwager & Markman, 1994). Originally seen as a strategy specific to word learning (Markman & Wachtel, 1988), it has since been investigated and demonstrated in other contexts, such as those of referential expressions regarding facts about objects (Diesendruck & Markson, 2001), object functions (Diesendruck et al., 2010), and gestures (Childers & Tomasello, 2003). These findings led to the debate as to whether disambiguation and its underlying cognitive and linguistic mechanisms are domain-specific or domain-general. Theoretical frameworks for both sides have been postulated over the years, with the main focus on children.

The domain-specific account describes disambiguation as a strategy specific to the facilitation of lexical acquisition (Markman, 1990). Hence, the disambiguation effect is manifesting as a lexical constraint under this account, which guides children to presume that one-to-one mappings are established between words and their referents. Two well-known theories which fall under this account are the Principle of Mutual Exclusivity (Markman, 1990; Merriman et al., 1989), and the Novel-Name Nameless-Category (N3C) Principle (Golinkoff et al., 1994). Both of these explain children's use of disambiguation by postulating that children reason under the assumption that the new label cannot refer to the familiar referent as the latter already possesses a label. Therefore, it must be linked to the novel unfamiliar item instead.

In comparison, the domain-general account suggests that in order to make inferences of the meanings of new words, children are said to map words to objects based on having an understanding as to what their interlocutor's intentions were, and general knowledge about communication (Diesendruck & Markson, 2001; Tomasello, 2000). In 1990, Clark proposed the pragmatic principles of contrast and conventionality that establish that each linguistic form is entailed in the shared knowledge of a linguistic community. Hence, if the word form is changed, it must, therefore, imply a change in meaning. However, under this approach, this conclusion would also be reached if there were a change in referential expressions. Overall, the domain-general approach postulates that children will infer meaning between two objects by referring to their interlocuter's underlying intention and will make determine the word-object mapping accordingly.

Although disambiguation was first observed in monolingual children, research with multilingual infants has shown that they also engage in disambiguation processes when resolving referential ambiguity. More importantly, studies on children have shown that their multilingual experience impacts their use of disambiguation (e.g. Byers-Heinlein & Werker, 2009, 2013; Davidson & Tell, 2005; Kalashnikova, Oliveri, & Mattock, 2018). However, very little research has been carried out as to how adults' linguistic experience, and especially multilingualism, might impact on the use of disambiguation. In Repnik et al. (Chapter 7), we were able to show that adults' multilingual experience, and specifically proficiency, modulated the use and processing times of disambiguation. We also found that other variables such as the age of English acquisition, current exposure of English, and the number of languages affected the disambiguation in a label-only context; however, this study did not consider facts, and this is what we investigate in the present paper.

8.3 Disambiguation of other referential expressions

Researchers attempted to settle the debate around domain specificity of disambiguation by investigating whether children would show the same word-learning assumptions for other referential expressions as they did when learning labels. Markson & Bloom (1997) found that when testing adults and 3- and 4-year-old children, assumptions about word learning also applied to general facts, e.g. that the item was given to the experimenter by the child's uncle. Both groups successfully fast-mapped the novel word (*koba*) and the novel fact about another item to their novel referents. However, this study did not specifically look at disambiguation as such, but whether children would be able to retain these label-object and fact-object mappings over time (1-week, and 1-month delay). Thus, the extension of this design to disambiguation by Diesendruck and Markson (2001), helped gain further insight into this phenomenon. In their study, 3- and 4-year-old children were presented with two new objects, of which one was first introduced with a label (e.g. "this is a *jop"*) or a referential fact (e.g. "my dad gave me this one"). During the test phase, children were prompted to select and find the referent of another novel fact, or label. Results showed that children consequently adhered to the using disambiguation in both the fact and label conditions which corroborates the notion of a domain-general account.

Albeit children's identical observed behaviour in the label and fact condition in the disambiguation task, distinct underlying mechanisms may have been at play and resulted in manifestations of disambiguation in these different contexts of communication (Waxman & Booth, 2000). In other words, while the disambiguation of new labels is the manifestation of a domain-specific tendency towards arbitrary one-to-one mappings, the disambiguation of factual information is the manifestation of socio-pragmatic comprehension and general knowledge about the world. This view is supported by recent research that proposes a different developmental trajectory for the disambiguation of words and that of general facts. In 2007, a seminal study by Scofield & Behrend reported toddlers' ability not only to disambiguate words but also facts. They tested 49 two-, three-, and four-year-old monolingual toddlers using the same preferential looking-while listening that many other studies before have used (Halberda, 2003). However, they further adapted the experiment by adding more conditions to address the questions whether children would extend the disambiguation heuristic from a purely word-learning context to other learning contexts, such as facts about objects which are more pragmatic. The distractor was either introduced with a label (e.g. *koba)* or fact (e.g. "This fell in the sink.") followed by the disambiguation prompt, which could either be a label or a fact. Children only completed one trial per condition, which kept the completion rate of the experiment high but reduced the statistical power of the data collected. The predictions for this study were twofold. Firstly, if children disambiguated in all of the four conditions (including the ones were the item was introduced with a fact), then this would support the Pragmatic Account (Clark, 1990; Diesendruck & Markson, 2001) as children would apply disambiguation in contexts that are not about purely semantic (and arbitrary) mappings, but also in contexts of other linguistic domains such as socio-pragmatics. Secondly, if children only disambiguated in the condition where the item was introduced with a label, it would support the word learning principles accounts, such as mutual exclusivity and N3C (Golinkoff et al., 1994; Markman & Wachtel, 1988) because these accounts regard disambiguation as a process facilitating lexical acquisition only. Thus, they do not expect disambiguation to play a role outside the lexical domain, i.e. the domains in which factual information are processed. The research question this study sought to answer was whether disambiguation is instead a domain-general (used across multiple language domains) or a domain-specific strategy (i.e. specific to arbitrary semantic mappings). Results indicated that children succeeded in disambiguation trials if the disambiguation prompt was a label, but only three- and four-year-olds reliably performed above chance if the disambiguation prompt was a fact. These results indicate that disambiguation beyond word-learning situation was a function of age in this study, and imply that disambiguation of facts and labels develops on two different timescales.

A study using a similar design with more trials per condition (Kalashnikova et al., 2014) addressed the same questions surrounding domain-specificity of disambiguation of facts and labels by testing adults and children of two age groups (ages 3;7 to 4;6 and 4;7 to 5;7). This design allowed for a more developmental perspective on the research question. The authors performed a linear contrast analysis that highlighted that the difference between disambiguation from labels versus facts increased significantly with age. At the early stages of word learning, children extend reasoning by exclusion (or mutual exclusivity) to other referential actions. However, as children mature and reach adult age, their understanding of communication increases, and this inferential strategy is limited to only word learning contexts. An aspect these authors could not test due to their subjects being monolingual is whether children who grow up with more than one language, and thus, potentially have a more developed understanding about the communicative process, will decrease their use of disambiguation from facts earlier than their monolingual peers. We know that multilingual children disambiguate labels in different ways (e.g. Byers-Heinlein & Werker, 2009; Kalashnikova, Escudero, & Kidd, 2018); hence, it is easy to assume that multilingualism may also impact the use of disambiguation of factual expressions. Testing multilingual adults would contribute to discerning whether the developmental trajectory of label disambiguation differs from that of factual disambiguation.

Following up, Malone, Kalashnikova, & Davis (2016) tested adults using a design modelled after Scofield & Behrend (2007) and adjusted it for adult use. The novelty here was the verbal reports collected from participants to explain the reasoning behind their decision-making. The experiment showed item pairs (target and distractor) and had four conditions: label/label, fact/fact, label/fact, and fact/label whereby the first term refers to the introduction of the distractor, and the second term refers to the disambiguation probe. For example, in the label/label condition, the distractor of the two items was introduced with a label (e.g. "this is a *dax*") while the target item was introduced with a general filler statement (e.g. "This one is nice"). A probe asking for a different label (e.g. a *koba*) followed, which should lead participants to choose the unnamed target item. In the fact/fact condition, the distractor was introduced with a factual expression (e.g. "This is the one my sister gave to me"), whilst the target, again, was introduced with the same general filler statement. The probe this time was another factual expression, such as "Select the one I got from the supermarket". In the remaining two conditions, the distractor was either introduced with a label or a fact, respectively, while the target was introduced with the same general fact. The probe that followed was either a fact or a label, respectively. In cases, where factual expressions are involved, the resolution of referential ambiguity is more difficult because facts are not arbitrary, unlike labels, and thus, participants engage in this process of establishing meaning based on pragmatic and world knowledge. Similar to the previous findings (Kalashnikova et al., 2014), in Scofield & Behrend (2007) adults did not rely on disambiguation from facts, and only made use of the strategy when the target item was introduced with a label. This supports the idea that disambiguating facts versus labels operates and develops differently. Of interest here are the reported reasoning strategies which the authors summarised into four categories (Malone et al., 2016): contrast-based, topic-based, logic-based, and other. The contrast-based strategy was most often selected when both items presented were introduced with labels. An example of contrast-based reasoning would be "Object on the right is the *blicket* because you already named the object on the left as the *toma*" (Malone et al., 2016, p.2101). Logic-based reasoning was used most often in the fact/fact and label/fact condition, i.e. when the disambiguation probe was the fact. The statistical model run on topic-based approaches was not significant, and this strategy was not used very often regardless of the condition. The results of this study do not entirely support the predictions of the domain-general account since disambiguation as a strategy is not extended to other referential contexts.

The research conducted on referential expressions shows that it is an important area to be explored further, especially in the realm of adults since disambiguation has predominantly been studied among children. More recently, researchers have developed an interest in studying a multilingual sample and testing their use of disambiguation. However, none of this research has thus far investigated the use of disambiguation towards factual expressions within a multilingual adult population. Studying multilingual adults is of importance since their multilingual experience may help us disentangle the domain-specificity debate around disambiguation. From previous research, we know that linguistic experience variables modulate the use of disambiguation of labels (Repnik et al., chapter 7*)*. If disambiguation is rather domain-specific, then varying language background variables such as proficiency or exposure should not affect multilingual adults' performance when disambiguating factual expressions. If disambiguation is a mechanism required to parse the information of factual expressions, then this modulation of disambiguation of labels by language background within a multilingual sample should extend to conditions and situations that entail facts as well.

Furthermore, multilingualism may impact on the strategies used to infer meaning from facts. This may be rooted in multilingual speaker's often multicultural upbringing possibly resulting in a more extensive knowledge of the world, which is the kind of knowledge necessary to solve a task that requires the referential solution of facts. Moreover, due to their speaking two or more languages, multilinguals may possess a more pronounced meta-linguistic awareness than monolinguals which may contribute to the formation of different strategies to resolve referential ambiguity between labels and facts (as found in the label/fact and fact/label condition). This may be because multilinguals have a more nuanced understanding of phonetic qualities of labels, for example, and may use these qualities to infer meaning. They may also establish meaning through potential co-activation of cognates in their spoken language, because even if the labels used in studies are pseudo-words, they may sound familiar to some people.

Interestingly, none of the above studies used online measures to investigate eye gaze during the decision-making processes, which we believe to be a valuable addition to the research design as it may unveil distinct visual gaze patterns with regards to the different label and fact conditions. Whilst behavioural data reveals the presence of a disambiguation effect, the eye gaze data allowed us to discern how the underlying looking patterns unfolded over time and how items were visually processes before a decision was made. Thus, we developed a study that (1) sheds light on the impact multilingualism may have on the resolution of referential ambiguity of facts, and (2) visualises the online time course of looking for the different conditions.

8.4 Research questions and predictions

The present study was closely modelled after Malone et al. (2016) but adapted for eye-tracking use. Not only does the use of eye-tracking allow for a measure of online processing, but it also makes it possible to disentangle further the underlying reasoning strategies adults use by examining looking patterns as they unfold in a trial, in addition to their verbal reports. Analysing time-course looking between the different conditions also gave further insights as to why disambiguation is used in some, but not other referential contexts. Furthermore, considering how language experience/background impacted on the use of disambiguation and the underlying reasoning helped to determine the key factors necessary for disambiguation. We described linguistic experience encompassing four factors: English proficiency, the age of acquisition of English, the current exposure of English, and the number of languages spoken. The three main research questions of this study were:

A. How does the linguistic experience of multilingual speakers modulate the accuracy of the different label and fact conditions?
B. How does the time course of looking proportions vary as a function of condition?
C. Which strategies served which conditions? Moreover, (How) does the linguistic experience of multilinguals impact on the kind of strategy used to infer meaning in the various label and fact conditions?

For A, the dependent variable is the accuracy of the behavioural response. We predicted a high performance in the label/label condition, the condition which introduces the distractor with a label and probes the target with another label, in line with previous studies (Malone et al., 2016; Scofield & Behrend, 2007). We predicted that the performance in the label/label condition was modulated by the language background variables, as it was found in another of our studies examining the use of disambiguation and retention within a multilingual adult sample. Depending on the domain-specificity approach, two antithetic predictions were made for the conditions entailing factual expressions (either as introductory or probing statement or both). If we adopted the domain-specific account of disambiguation, we would expect no disambiguation, which would be reflected in a chance performance concerning accuracy. Moreover, our specific language background variables were not expected to modulate the accuracy in the factual conditions because these are processed more syntactically and pragmatically, as no foreign-sounding words would be encountered, hence reducing the need for phonetic and semantic processing. Syntactic and pragmatic processing may respond differently to the changes in language background compared to novel label processing which operates on a purely phonetic and semantic level, which are linguistic domains prone to more direct modulation caused by changes in language background. Previous findings were indicating that our specific language background variables modulated the use of disambiguation of labels (Repnik et al., chapter 7). Thus, if we adopted a domain-general account of disambiguation, it would mean that disambiguation would be reflected in an above-chance accuracy performance. Furthermore, our language background variables would be expected to modulate the accuracy in all our conditions, regardless of the type of referential expression used.

For B, we expected varying gaze patterns based on condition whereby we predicted that participants would swiftly look towards the target item in the label/label condition and fixate here until the decision was made (via keyboard response). For the other conditions, similar antithetic predictions were made. According to the domain-specific account, we predicted that gazes towards target and distractor item would fluctuate significantly more, which would reflect no disambiguation. According to the domain-general account, we expected a visual gaze fixation similar to the one in the label/label condition.

For C, the dependent variable is whether a strategy within a condition was used or not. In line with previous findings (Malone et al., 2016), we predicted that participants would exhibit the contrast-based strategy mainly in the label/label condition. The logic-based strategy was expected to be found primarily in the factual conditions (fact/label, label/fact, and fact/fact) and to be the most widely adopted strategy. The topic-based strategy was expected to find the least application in any condition. Since we were interested in whether multilinguals may draw on phonological, orthographical or other semantic-related reasoning, we defined such reasoning as ‘linguistic’ strategy distinct from the logic-based strategy. We expected our language background variables to impact on the contrast-based strategy, as this strategy is based on the *Disjunctive Syllogism* and has previously been found to be prone to influences based on linguistic experience (Repnik et al., chapter 7*).* We expected the linguistic strategy to be modulated by multilinguals’ number of languages because a more significant number of languages spoken could create higher meta-linguistic awareness (Sanz, 2019), and thus, the potential for more reasoning based on linguistic knowledge. We expected the logic-based strategy to be moderately impacted by the number of languages, as the number of languages could be seen as a proxy for multiculturalism, which in turn may have led to a broader knowledge of the world that participants could apply in this task. However, since this effect was expected to be rather small, as the factual expression used in the task are rather generic, and we tested adults from a wide range of different languages. For the topic-based strategy, we did not expect that language background variables would have any impact since this strategy is preferably used in naturalistic conversations about a specific topic which is not the case in this study.

8.5 Method

8.5.1 Subjects

A total of 69 adults were recruited with a final sample of 61 native (N= 17) and non-native (N = 44) speakers (M_{age} = 24;0*; SD* = 3.25; 48 female) of English with a variety of backgrounds in other languages were recruited. Eight participants were excluded due to visual impairment (4), learning disabilities (2), failure to calibrate (1), and failure to complete language questionnaire (1). All participants spoke at least two languages. Native English speakers spoke on average of 3.43 (SD = 1.20) languages, including English, and non-native English speakers spoke an average of 3.60 (SD =

0.96) languages, including English. The difference between the number of languages spoken by native and non-native speakers was not significant ($F(1{,}59) = 0.91, p = 0.35$). Every participant used English daily. Other first and second languages included Arabic, Cantonese, Czech, Danish, Estonian, Finnish, French, German, Greek, Hindi, Hungarian, Indonesian, Irish, Italian, Japanese, Korean, Lithuanian, Malay, Mandarin, Polish, Punjabi, Russian, Serbo-Croatian, Slovenian, Spanish, Swedish, Swiss-German, Tagalog, Taiwanese Hokkien, Tamil, Turkish, Ukrainian, Urdu, and Welsh.

Number of languages	**Current Exposure English**	**Current Exposure OLs**	**SD**	**Age of acquisition (in years) English**	**SD**	**LexTale**	**SD**	**% English as L1**	**SD**	**N**
2	82.67	17.33	17.65	2.00	1.86	0.88	0.14	0.50	0.52	12
3	65.63	34.38	22.05	5.94	4.40	0.83	0.15	0.19	0.40	16
4	67.00	33.00	17.50	4.90	3.34	0.81	0.15	0.20	0.41	20
5	67.53	32.47	15.07	4.62	3.28	0.87	0.10	0.31	0.48	13

Table 8.5.1: Composition of the multilingual sample by number of languages. Abbreviations: SD = standard deviation; L1 = first language; OLs = other languages; N = number of participants

8.5.2 Stimuli

Visual stimuli consisted of 48 computer-generated three-dimensional novel objects (see Appendix C) from the NOUN database (Horst & Hout, 2016). Objects were combined into random pairs and then randomly assigned to one of four conditions (six pairs per condition) for each participant.

Twenty-four labels and facts each provided referential information for the objects. All labels were two syllables long and taken from Malone et al. (2016), and facts were adapted from Diesendruck & Markson (2001). For an overview, see Appendix C.

Auditory stimuli consisted of 48 phrases recorded by a native male speaker of British English, of which one half referred to labels and the other half to facts about items. Phrases referring to labels had the following structure: “It’s a *toma*. See it’s a *toma*. This is a *toma*”. Phrases indicating facts had the following structure: “This is the one my mum gave to me. My mum gave this to me. My mum gave it to me”. Both types of phrases were modelled after Malone et al. (2016), and factual expressions were adapted for participants residing in the United Kingdom.

8.5.3 Apparatus

The visual stimuli were presented on a 23-inch screen with auditory stimuli being played from one loudspeaker on either side of the monitor concealed behind a black curtain. During the presentation of stimuli, participants' eye movements were recorded. Behavioural responses were recorded using button response via keyboard, and eye gaze data was collected using a Tobii TX300 eye-tracker via E-Prime presentation software using extensions for Tobii. Recordings were sampled at a refresh rate of 60 Hz. Participants were seated approximately 60 cm away from the screen in a dimly lit room. At the beginning of the experiment, a 9-point calibration was performed. For all analyses, we used the statistical software package *R* (R Core Team, 2019).

8.6 Procedure

8.6.1 Disambiguation task

The procedure was partly modelled after Malone et al. (2016) who had adapted the original design by Scofield & Behrend (2007) for adults. Additionally, the design was modified for eye-tracking use. The experiment had four conditions: label/label, fact/fact, label/fact, and fact/label. Here, the first term of the expression refers to how the distractor was introduced, and the second term refers to how the target was introduced. The procedure for all trials across all conditions was the same. The order of condition was randomised across participants, i.e. every participant encountered different object-label and object-fact pairings. The assignment of the target object (left or right) and which object was auditorily introduced first (target or distractor) were counterbalanced across conditions and participants.

A trial started showing an object pairing on the screen (for examples see Figure 8.1). After a 2-second delay, a red arrow appeared above the distractor item together with an auditory labelling phrase (either using a label or fact). After the distractor's introduction, the red arrow moved over to the target item, which was always introduced with the generic filler statement. After that, the arrow disappeared, and a disambiguation probe prompted the participant to choose between the two items via a button response on the keyboard (see Table 8.6.1). The trial ended immediately after the button press, which made the trial length variable. In total, the experiment took less than ten minutes.

Condition	Distractor introduction	Target introduction	Target probe
label label	"It's a *toma*. See, it's a *toma*. This is a *toma*."	"This one is nice. Isn't it pretty? It's really nice."	"Select the *bink*."
fact fact	"This is the one my sister gave me. My sister gave this to me. My sister gave it to me."		"Select the one I keep at work."
fact label	"This is the one I got online. I got this online. I got it online."		"Select the *coodle*."
label fact	"It's a *zepper*. See, it's a *zepper*. This is a *zepper*."		"Select the one I got from a friend".

Table 8.6.1: Conditions and stimuli with target and distractor introductions (examples).

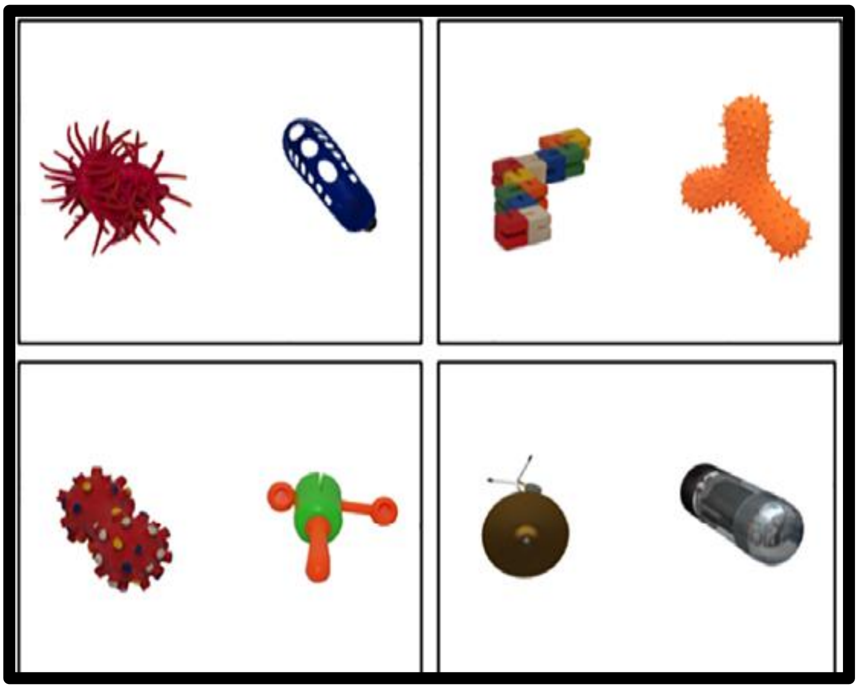


Figure 8.1: Example of stimuli.

8.6.2 Verbal protocol

Furthermore, participants were asked to provide a verbal explanation for their reasoning at the end of the first and sixth trial of each condition. Asking participants after a trial ensured their explanation did not affect their actual behaviour and decision-making. A maximum of two verbal justification per condition was collected to avoid participants from doubting or adjusting their reasoning process. All responses were audio-recorded and coded.

8.6.3 Language background

To assess multilingual participants' individual language history, they were asked to complete a digitised version of the LEAP-Q (Marian et al., 2007) before they attended the in-person session. The LEAP-Q is a tool for assessing the linguistic background of bilinguals or second language learners and for generating self-reported proficiency in multiple languages. We adapted the questionnaire, so participants were able to complete it on a web-based interface ahead of the in-person session. For this, we used the Qualtrics XM survey tool ('Qualtrics - Leading Experience Management and Survey Software'). Completing the questionnaire took between 15 to 30 minutes, depending on the extensiveness of language background. The questionnaire started by outlining the nature of the study, and participants were required to give informed consent.

In addition to the pre-session questionnaire, participants completed the LexTale task (Lemhöfer & Broersma, 2012), which a lexical test for advanced learners of English that is quick and whose validity was more objective compared to that of self-rated proficiency.

8.7 Results

8.7.1 Disambiguation performance

The dependent measure was the proportion of trials where participants selected the target. Responses towards target were coded as "1", and responses towards the distractor were coded as "0". We removed extreme values of reaction times longer than 10 seconds for the calculation of reaction time means. One-sample *t*-tests were conducted on the accuracy proportions to discern whether participants selected the target object above chance level (μ = 0.5). Alpha levels were adjusted to 0.0125 (Bonferroni correction) to account for multiple comparisons. This analysis revealed that participants selected the target object above chance in the expected label/label condition, as well as the fact/fact condition. The latter result is unexpected and was not found in previous studies. Furthermore, participants consistently selected the distractor in the label/fact condition, meaning that they assigned the probed fact to the item introduced with a label. In the fact/label condition participants performed at chance-level, and thus, it was henceforth considered the baseline. A logistic mixed-effects model with random intercepts for participants was computed. This model verified that performance in each condition was significantly different than in the fact/label condition (fact/fact: e^{β}= 1.78; 95% CI = 1.73, 1.83, p < 0.001; label/label: e^{β}= 4.66; 95% CI = 4.52, 4.81, p < 0.001; label/fact: e^{β}= 0.79, 95% CI = 0.77, 0.81, p < 0.001). To account for differences due to the language background variables, we entered condition as a predictor variable, as well as the following language background predictors as an interaction term with Condition: English proficiency (as measured by LexTale), current exposure to English, English as the first language (logical variable), age of acquisition of English, and the number of languages. This model yielded several significant interactions between the conditions and various language background variables (Table 8.7.2). To disentangle these interactions, we performed a by-condition sub-group analysis. To disentangle these interactions, we visualised those entailing continuous predictor variables (proficiency (LexTale), current English exposure, and age of English acquisition) in Figure 8.2. The interactions entailing categorical variables (English as L1, number of languages) can be broken down via Table 8.7.1.

Condition	Mean accuracy	t-statistic	English as L1	Mean accuracy	Number of Languages	N	Mean Accuracy	Std. Dev.
fact/fact	0.63	4.22, $p < 0.001$***	no	0.62	2	6	0.66	0.48
					3	13	0.67	0.47
					4	16	0.57	0.50
					5	9	0.59	0.49
			yes	0.66	2	6	0.67	0.47
					3	3	0.77	0.42
					4	4	0.71	0.45
					5	4	0.53	0.50
fact/label	0.50	-0.01, $p = 0.99$	no	0.47	2	6	0.46	0.50
					3	13	0.39	0.49
					4	16	0.53	0.50
					5	9	0.48	0.50
			yes	0.57	2	6	0.60	0.49
					3	3	0.51	0.50
					4	4	0.57	0.50
					5	4	0.55	0.50
label/fact	0.44	-2.58, $p < 0.0125$*	no	0.44	2	6	0.42	0.49
					3	13	0.45	0.50
					4	16	0.44	0.50
					5	9	0.45	0.50
			yes	0.44	2	6	0.46	0.50
					3	3	0.51	0.50
					4	4	0.40	0.49
					5	4	0.38	0.48
label/label	0.85	11.59, $p < 0.001$***	no	0.77	2	6	0.74	0.44
					3	13	0.87	0.34
					4	16	0.70	0.46
					5	9	0.82	0.39
			yes	0.84	2	6	0.89	0.31
					3	3	0.96	0.19
					4	4	0.80	0.40
					5	4	0.77	0.42

Table 8.7.1: Mean accuracy performances for each condition, and t-statistic for above-chance performance. Mean Accuracies (Standard deviations) by English as first language and number of languages.

	e^{β}	*Std. Error*	*z value*	*p-value*
(Intercept)	0.43	1.71	0.20	0.112
Condition - label/label	0.74	1.13	0.09	0.016*
Condition - fact/fact	0.57	1.12	0.01	< 0.001***
Condition - label/fact	3.03	1.11	37650.74	< 0.001***
Number of languages (NoL)	1.13	1.07	6.45	0.062
Age of acquisition English (AoA)	0.92	1.03	0.03	< 0.001***
Current exposure English (Exp)	1.01	1.00	10.40	0.019*
LexTale - proficiency	1.19	1.69	1.39	0.742
English as L1 (Eng_L1)	0.73	1.23	0.23	0.140
label/label : NoL	0.75	1.02	0.00	< 0.001***
fact/fact : NoL	0.77	1.01	0.00	< 0.001***
label/fact : NoL	0.82	1.01	0.00	< 0.001***
label/label : AoA	1.10	1.01	5104561.24	< 0.001***
fact/fact : AoA	1.09	1.01	9257394.37	< 0.001***
label/fact : AoA	1.09	1.01	46156291.15	< 0.001***
label/label : Exp	0.99	1.00	0.00	0.117
fact/fact : Exp	1.01	1.00	2024.59	0.002**
label/fact : Exp	0.97	1.00	0.00	< 0.001***
label/label : LexTale	47.92	1.12	266180948058367.00	< 0.001***
fact/fact : LexTale	4.00	1.11	376655.45	< 0.001***
label/fact : LexTale	2.95	1.11	31488.07	< 0.001***
label/label : Eng_L1	1.54	1.06	2010.21	< 0.001***
fact/fact : Eng_L1	0.94	1.05	0.28	0.008
label/fact : Eng_L1	1.91	1.04	3571449.13	< 0.001***

*Table 8.7.2: Estimates for model: Target look ~ Condition*NoL + Condition*AoA + Condition*Exp + Condition*LexTale + Condition*Eng_L1 + (1|Subject). L1 = first language*

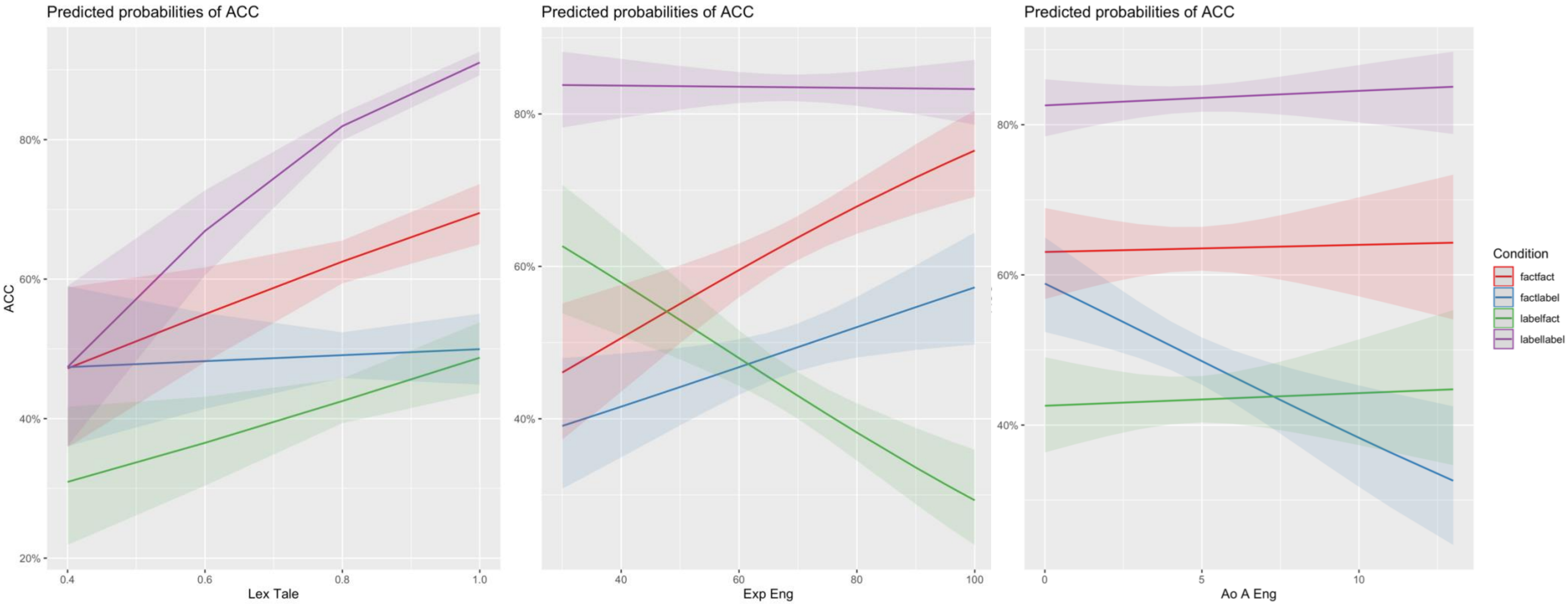


Figure 8.2: Predicted accuracies for interactions between condition and LexTale, condition and English exposure (Eng Exp), and condition and age of acquisition of English (AoA Eng). Estimates in Table 8.7.2.

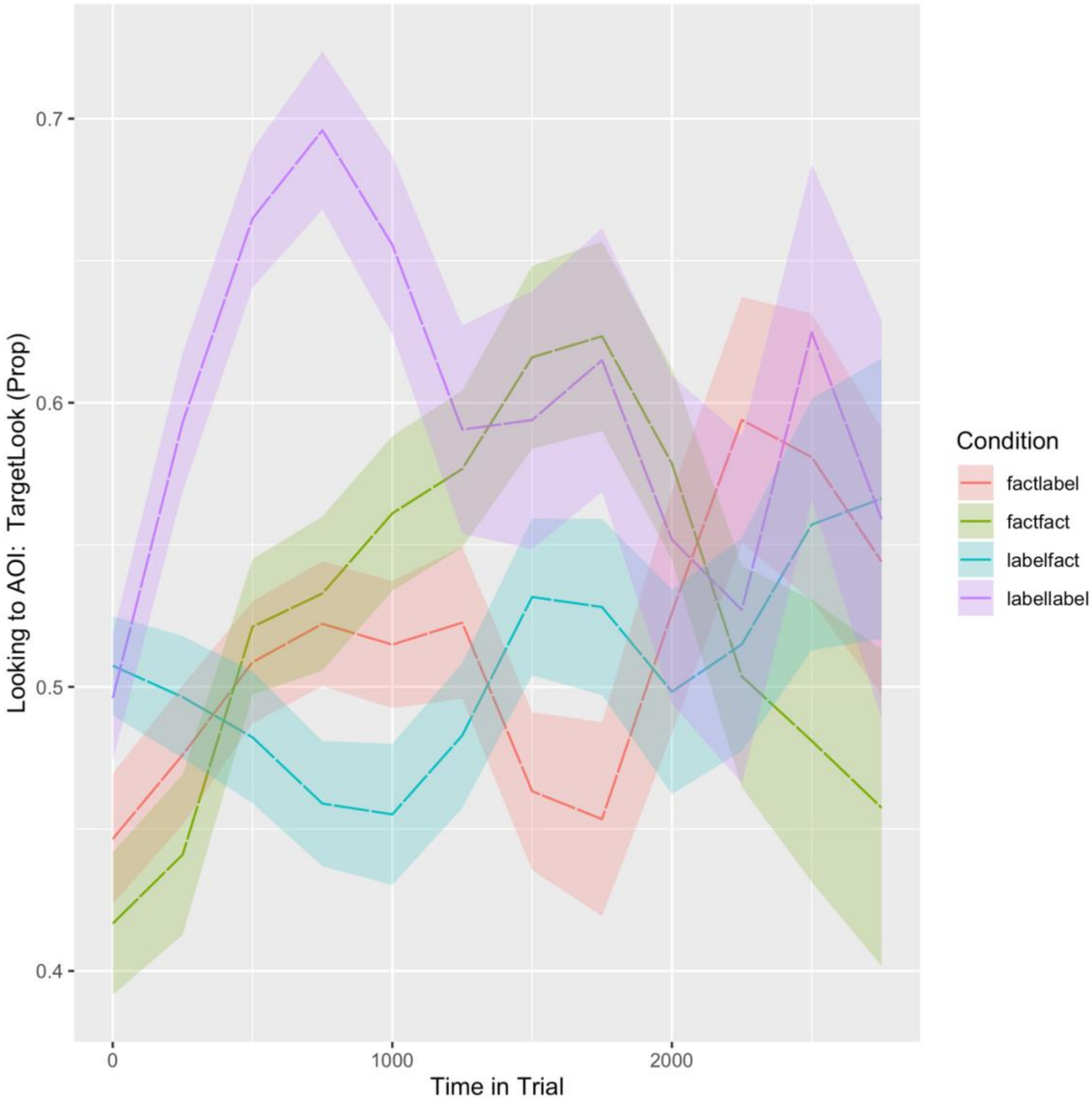


Figure 8.3: Time-course looking towards the target after target onset (in proportions) by condition

8.7.2 Time course looking

In order to explore how eye-gaze unfolded over the time of a trial, we analysed the time sequence data using the R package *EyetrackingR* (Dink & Ferguson, 2018). We defined time bins of 250ms, and a time analysis window of 0 to 3000ms after target word onset, choosing the upper limit based on the mean reaction times found in Table 8.7.1.

For the label/label condition, the instant gaze towards the target object was in line with our predictions. For the fact/fact condition, we expected gazes to fluctuate around the 50%-mark; however, participants were looking at the target item for a sustained period after 1000ms of target onset, indicating that they might be reasoning via mutual exclusivity. The fact/label conditions' eye-gaze fluctuated around the 50%-mark, which was expected, and are in line with the chance-performance (Table 8.7.1). The label/fact conditions' gaze pattern was also centred around the 50%-mark with a slightly opposite pattern to the fact/label condition within the first 1000ms after target word onset. A time-bin analysis revealed a significant effect of difference between the conditions from 250 to 1250ms and 1500 to 2000ms after target word onset indicating that eye-gazes varied according to condition (Table 8.7.3).

Estimate	Std. Err	Statistic	p-value	df	Time	Positive Runs	Negative Runs
0.05	0.03	1.59	0.114	240	0	NA	NA
0.12	0.04	3.34	<0.001***	240	250	1	NA
0.16	0.03	4.75	<0.001***	240	500	1	NA
0.17	0.04	4.93	<0.001***	240	750	1	NA
0.14	0.04	3.73	<0.001***	238	1000	1	NA
0.07	0.04	1.63	0.105	235	1250	NA	NA
0.13	0.05	2.71	0.007**	228	1500	2	NA
0.16	0.05	3.07	0.002**	218	1750	2	NA
0.03	0.06	0.41	0.681	206	2000	NA	NA
-0.07	0.07	-1.01	0.314	194	2250	NA	NA
0.04	0.08	0.57	0.566	176	2500	NA	NA
0.01	0.08	0.18	0.857	165	2750	NA	NA

Table 8.7.3: Estimates for time-bin analysis. Treatment level: Label/label condition. Critical Statistic = +/-1.97

8.7.3 Strategies

To further probe into the thought process behind participants' decision in a more explicit way, we asked participants about their reasoning twice per condition (post-trial). We first coded participants' verbal responses into strategies and then analysed how these strategies found application within the experiment conditions.

8.7.3.1 Verbal reports

In order to code participants' responses, we adapted the four major disambiguation strategies used by Malone et al. (2016) and added a 'Linguistic' strategy (Table 8.7.4). We added this strategy from our dataset in a bottom-up manner to better describe the strategies used in our data. The first author coded the entire data set, and an independent coder coded a subsample of 15%. The two ratings of the subsample matched to 91.9%. The ratings included an initial rating for each response and a secondary rating in cases when participants named two reasons which were used to discuss interrater discrepancies.

Strategy	Coding	Example
Contrast-based	reason by contrast	"Object on the right is the blicket because he already named the object on the left as the *toma*."
Logic-based	personal knowledge about the world, such as colour, shape	"Object on the left looks like a dog toy "
Linguistic	based on phonological, orthographical or other language-specific reasoning.	"This one sounded more Thai" *or* "This one sounded more what it looked like"
Topic-based	assumes that the two expressions are related to the same topic of conversation	"Because the speaker labelled the object on the left as *sibu*, he must know something about the object, and so maybe *kita* refers to something on that object."
Random	guessing or random choice	"Completely random guess. No idea why I chose that one."

Table 8.7.4: Coding scheme of strategies used to select the referent object

Each participant gave two verbal justifications for each condition (each 122 responses) which yielded a total of 488 responses. In the label/label condition, four responses were eliminated due to participants misunderstanding the trials leaving 484 verbal responses in the final sample. Each strategy was analysed individually to discern whether it found more application in some versus other conditions. The analysed data entailed the total number of occasions a particular strategy was used irrespective of whether it led to the selection of the target item (i.e. successful disambiguation) (Table 8.7.5). Responses falling under the "random" category were excluded (N = 76) from further analyses as they did not follow a particular strategy accounting for 15.6% of the responses given. The dependent variable was the strategy used (0 = not used; 1= used) and entered into four binary logistic regression analyses: (a) contrast-based, (b) logic-based, (c) linguistic, and (d) topic-based. The predictor variable was condition. For all models, fact/label was used as the reference category as performance here was at chance-level. In a second model (for each strategy), we checked how the language background variables, i.e. current English exposure, English proficiency, age of English acquisition, and the number of languages, might modulate the choice of strategy.

	Object selected	Contrast-based	Linguistic	Logic-based	Topic-based	Random
fact fact	Distractor	1	0	20	18	3
	Target	14	1	57	1	7
fact label	Distractor	2	27	13	6	9
	Target	7	26	11	2	19
label fact	Distractor	6	0	50	1	13
	Target	0	0	32	5	15
label label	Distractor	1	3	1	0	7
	Target	99	2	2	0	3

Table 8.7.5: Frequencies of used strategy by conditions and item

8.7.3.2 Contrast-based

A model, significantly better than the null model, $\chi^2(3) = 261.47, \mathrm{p} < 0.001$, Nagelkerke $\mathrm{R}^2 = 0.66$, indicated that the contrast-based strategy was used significantly more often in the label/label condition ($e^{\beta} = 118.06, SE = 1.66, p < 0.001$) than the reference condition. However, no significant effects were found for the use of this strategy within the fact/fact ($e^{\beta} = 1.46, SE = 1.56, p = 0.40$) or label/fact condition ($e^{\beta} = 0.64, SE = 1.73, p = 0.42$) in comparison to the reference condition. Hence, the contrast-based strategy found significantly more application when two new labels were provided for the items. These findings were expected as they are in line with previous research (Malone et al., 2016).

A second model including the aforementioned language variables improved the model significantly ($\chi^2(7) = 279.46, \mathrm{p} < 0.001$ compared to above model) and improved its fit to Nagelkerke $\mathrm{R}^2 = 0.69$. In addition to the same effect of label/label condition ($e^{\beta} = 191.84, SE = 1.78, p < 0.001$), this model also revealed an effect of current exposure of English ($e^{\beta} = 0.97, SE = 1.01, p < 0.05$), age of English acquisition ($e^{\beta} = 0.84, SE = 1.06, p < 0.01$), and English proficiency ($e^{\beta} = 70.40, SE = 5.41, p < 0.05$). Both, people with a later onset of English or more current English exposure used the contrast-based strategy to a lesser extent, whereas those with higher rates of proficiency used this strategy more often.

8.7.3.3 Logic-based

A model significantly better than the null model, $\chi^2(3) = 217.28, p < 0.001$, Nagelkerke $R^2 = 0.55$, indicated that the logic-based strategy was used significantly less often in the label/label condition ($e^{\beta} = 0.08, SE = 1.88, p < 0.001$), but more often in the fact/fact ($e^{\beta} = 6.42, SE = 1.37, p < 0.001$) and the label/fact condition ($e^{\beta} = 19.93, SE = 1.48, p < 0.001$) than the reference fact/label condition. These findings are in line with previous research (Malone et al., 2016), and indicate that the logic-based strategy found more application when the probe was a factual statement. A second regression adding the language background variables was modelled which did not improve the fit of the model ($\chi^2(4) = 6.03, p = 0.20$) compared to the simpler condition-only model indicating that the language variables did not contribute to the decision-making process as they did for the contrast-based strategy.

8.7.3.4 Linguistic strategy

For this analysis, the label/fact condition was excluded, as no use of the linguistic strategy was found amongst this condition (see Table 8.7.5). A model significantly better than the null model, $\chi^2(2) = 122.73, \mathrm{p} < 0.001$, Nagelkerke $\mathrm{R}^2 = 0.52$, indicated that the linguistic-based strategy was used significantly less often in the label/label condition ($e^{\beta} = 0.04, SE = 1.65, p < 0.001$) and the fact/fact ($e^{\beta} = 0.01, SE = 2.79, p < 0.001$). This strategy found most application in the reference condition fact/label with a high percentage of 43.44 % overall and was also more often used than a random strategy. In a second model, we added the language background variables as predictors; however, no effects were found indicating that the use of this strategy was not modulated by linguistic experience. Overall, this strategy accounted for only 12 % of verbal responses.

8.7.3.5 Topic-based

For this analysis, the label/label condition was excluded, as no use of the topic-based strategy was found amongst this condition (see Table 8.7.5). A model significantly better than the null model, $\chi^2(2) = 6.57, \mathrm{p} < 0.05$, Nagelkerke $\mathrm{R}^2 = 0.04$, indicated that the topic-based strategy not impacted by the condition which was in line with Malone et al. (2016). This strategy was only used 6.76 % of the time and found little application overall. A second model, including the language variables, revealed no improvement of model significance nor any effects indicating that these language variables had no impact on the use of this strategy.

8.8 Discussion

In an eye-tracking study examining the *disambiguation effect*, we investigated how multilingual adults performed in various contexts of referential ambiguity. Specifically, we were interested in how disambiguation was applied in a word-learning scenario (i.e. label/label), as opposed to situations that entailed referential facts about the unknown items, and how eye-gaze unfolded in these contexts. We predicted that participants would disambiguate only in the label/label condition should disambiguation adhere to domain-specificity and operate on a level of semantic arbitrariness. Conversely, should disambiguation be applicable across several domains, and thus adhere to domain-general accounts, we predicted that participants would disambiguate in all four conditions including those entailing factual information. Moreover, we examined whether variables modulating the multilingual experience, such as proficiency, exposure, age of acquisition, and the number of languages, impacted the use of disambiguation in the different mapping scenarios. We predicted that disambiguation in the label/label condition would be modulated by these language background variables replicating previous findings. With regards to the conditions entailing facts, we formulated two antithetic predictions depending on domain-specificity. Should disambiguation be domain-specific, we did not expect the above language variables to modulate performance within the factual conditions.

In contrast, should disambiguation be applicable in broader non-word learning contexts (i.e. domain-general), then we expected these language variables to have modulating effects on all the conditions. We predicted that gaze patterns varied based on condition. In the label/label condition, where the *disambiguation effect* is known to manifest, we predicted that participants' gazes would swiftly fixate on the target item. For the three remaining conditions comprising facts, we postulated two antithetic predictions analogous to above. If disambiguation operates more domain-specific, and therefore, not manifest in the facts condition, we expected the gaze patterns to be different, as participants' gazes would fluctuate equally between target and distractor item indicating no apparent fixation to the target item, and hence, no disambiguation effect. If disambiguation operates more domain-generally, we expected to find similar gaze patterns to the label/label condition in the other conditions comprising facts as well. Lastly, we explored which underlying strategies may have been at play during the decision-making process that manifested as a disambiguation effect (or not).

We expected the contrast-based strategy to be most prevalent in the label/label condition and modulated by the linguistic background variables, as this strategy adheres to the reasoning by exclusion (“not B, therefore A”) which adults use in word-mapping situations as found in label/label condition; the logic-based strategy most prevalent in the label/fact, fact/fact, and fact/label conditions and mildly modulated by the number of languages spoken, because parsing and integrating the factual information presented in these three conditions required logical knowledge about the world in order to create meaning ; the ‘linguistic’ strategy to be used to a lesser extent than the logic-based strategy in the factual conditions and modulated by the number of languages, as this strategy could be regarded as a sub-category of the logic-based strategy whereby participants attempted to match the factual information encountered with knowledge about phonological or semantic properties of words ; the topic-based strategy to find least application overall and not be impacted by the linguistic variables, as this strategy would be more suited in a coherent conversation in a naturalistic setting.

8.8.1 Does multilingualism impact disambiguation?

The present results corroborate previous findings that adults, with English as their L1 or L2 English speakers, reliably reason by exclusion when encountering a word-learning situation that presents two labels (label/label). Unexpectedly, the linguistic background as measured per current English exposure, age of English acquisition, English proficiency, number of languages, and English as L1, did not modulate adults’ performance in the label/label condition, although these factors were found to have modulating qualities in our previous study (Repnik et al., chapter 7). Fewer trials in the label/label may explain this discrepancy condition and the more elaborate and more prolonged trial procedure in the present study. In our previous study, disambiguation trials did not include introductory carrier phrases, and probes were prompted after a silent 3 seconds of baseline presentation.

Interestingly, the results around the remaining three factual conditions partially diverged from the predictions based on previous findings (Diesendruck & Markson, 2001; Malone et al., 2016), especially those in the fact/fact condition. Diesendruck &

Markson (2001) found that adults disambiguated in the label/label and label/fact, but not in the fact/fact and fact/label condition, which the authors considered supporting evidence for the domain-general account. In our study, however, multilingual adults disambiguated in the fact/fact condition, but not in the label/fact condition. Consulting how the proportion of looks unfolded over a trial (Figure 8.3), our behavioural findings were supported by the gaze patterns, as gazes towards the target were higher in both the label/label and fact/fact condition, albeit with a delay in the latter one. Thus, our results did not entirely reproduce the results by Diesendruck & Markson (2001). Similarly, our findings did also not entirely converge with a domain-specific view which regards the disambiguation effect as the manifestation of a lexical constraint, and should, therefore, not be observable when encountering the fact/fact condition (Malone et al., 2016). As these results were partly unexpected, we speculated that the multilingual background of the adults in our study might have contributed to the non-congruence with previous studies; however, based on our analyses this did not seem to be the case, as the language background variables did not seem to modulate participants' performance within each condition.

Nevertheless, it is essential to acknowledge that the mere observation and manifestation of the disambiguation effect do not explain what the underlying thought processes or strategies are, and these strategies may likely be context-specific. This is to say, had we used a different combination of items and stimuli, the presently observed disambiguation effect for the fact/fact condition may disappear, whereas the effect is stable and reproducible in the label/label condition. The tendency to choose the target item more often in the fact/fact condition may be context-/item specific where logic-based reasoning factored into the decision-making process, while the tendency to choose the target item more often in the label/label condition is based purely on contrast-based reasoning where no logic-based reasoning is required. Thus, it is possible to observe the same measurable effect, but the underlying mechanisms between these two conditions are different. It is for this reason that the accompanying verbal responses were of vital importance to the understanding of resolving referential ambiguity with facts.

8.8.2 Strategies: Contrast- over logic-based?

Verbal explanations were coded into five categories (contrast-based, logic-based, linguistic, topic-based, random/other), and we investigated how the differing contextual cues modulated each strategy.

The contrast-based strategy found extensive application in the label/label condition which is based on the *Disjunctive Syllogism* (i.e. “not A, therefore B”) and is in line with the principle of Contrast (Clark, 1990) which posits that a change of linguistic form implies a change in meaning. However, Contrast being a domain-general account, Clark (1990) also postulated that disambiguation applies to any type of referential cue, and therefore, also facts. Without a more in-depth look into participants’ strategies, it is easy to assume that the observed disambiguation effect in our fact/fact condition corroborates this domain-general view. A more in-depth analysis of the strategies revealed that the manifestation of the disambiguation effect was not significantly based on the use of a contrast-based strategy, but the use of a logic-based strategy. Applying the logic-based strategy in the factual conditions (fact/fact, label/fact, and fact/label) was in line with previous findings (Malone et al., 2016). Reasoning by contrast implies that adults adhere to the conventionality that each object only has one label and that a change in label usually results in the default assumption that words are mutually exclusive unless there is enough evidence to suspect otherwise. For referential cues that include facts about the item, however, adults are aware that many facts (fact/fact), or a label and a fact (fact/label; label/fact) can map onto the same referent object (Waxman & Booth, 2000).In this case, adults refer to their knowledge about the world, or the properties of the object, such as shape or colour, to discern the referent (i.e. logic-based strategy). For instance, several participants selected a more pet-friendly, chewable item upon hearing a probe that prompted them to “select the one my dog/cat likes to eat/play with”; or they assumed an object that happened to be green for some participants referred to “the one I got in Ireland”, due to an association of Ireland’s flag and a shamrock.

The logic-based strategy found most application in the label/fact condition, with the reasoning that would support the choice of the distractor item more often (50 compared to 32 times for the target item, see Table 8.7.5). An example of participants’ line of thinking was that if the speaker (presenting the introductions and probes) knows a fact about the item and uses it to ask for a referent, they would likely also know the name of this item. However, the opposite finding was encountered by Malone et al. (2016), whose adult participants disambiguated in the label/fact condition, i.e. chose the target item. Previous research with adults has revealed that they form referential pacts with their interlocutor, i.e. they form agreements about how a concept/item is referred to the first time, and thus, expect them to be consistent in their use of referential expressions (Kronmüller & Barr, 2015). Due to the speaker remaining the same throughout the experiment and sharing personal facts which could be considered authentic (by the listening participant), some of the participants may have established a connection and rapport with the speaker that resembled those of a natural conversation. If this is the case, then listeners are likely to establish referential pacts with the speaker and assume that a label precedent is followed by its factual definition (in the probe). Nonetheless, it is essential to acknowledge that a conversation in a naturalistic setting would still be very different, as it draws even more on shared experiences and common ground.

The linguistic strategy, although only seldomly used by the participants in our study found its predominant application in the fact/label condition, which was the baseline condition. All reasoning based on phonology, orthography, or semantics was classed as 'linguistic strategy'. Although using this strategy yielded chance-level performance, it was used over 90% in this condition. It is understandable why participants would use phonological features of the probe label to discern the referent. Some people found the label *posk* to sound "pointy and important", so they chose a referent that seemed pointier; others reasoned that the label entailed the round letter 'o' which led them to choose a rounder object (Morgenstern, Schmidt, & Fleming, 2019; Thompson & Estes, 2011). Linguistic reasoning was often paired with a logic-based strategy. Some people found that the word *deeba* sounded Thai, and hence chose the item that was paired with the information that it was "from Thailand". Doing so meant that they did not engage in the features about the object per se but believed the factual information about the item provided by the speaker.

Examining the contributions of the multilinguals' background variables, we found significant effects only within the use of the contrast-based strategy, but not within any of the others. The finding that linguistic variables of current exposure of

English, English proficiency and age of acquisition impacted on the use of the contrast-based strategy, but no other strategy, supports the idea that reasoning by exclusivity is rather language-specific than domain-general. Although multiculturalism likely increases knowledge about the world and may have positive effects in individual conversation settings, these will likely depend on the specific topic and shared common ground between speaker and interlocutor, whereas the communicative situation in our experiment employed generic facts with little to no cohesion between trials.

Using a contrast-based strategy or reasoning by exclusivity is only reliably used by adults when having to disambiguate the referents of new labels. However, similar studies with pre-school children (Diesendruck & Markson, 2001; Scofield & Behrend, 2007) found that children at this age consistently disambiguated facts and labels alike in an unrestricted manner. This means that at some point, reasoning by exclusivity becomes more constricted and specific to the domain of word learning, which seems to be caused with increasing linguistic experience (Kalashnikova et al., 2014). Children of such young ages are still developing their pragmatic skills and possess significantly less knowledge about the world for them to be successfully applying a logic-based strategy. In contrast, adults find the contrast-based strategy too limiting in specific contexts, especially when encoding factual information. One major caveat about our and previous adaptations of this study is the way of eliciting participants' responses. By asking them to explain their thinking process, they may encounter situations trying to communicate rather implicit strategies, which renders them less aware of what type of strategy they are using at all. Verbal response categorised as 'random' likely entail implicit strategies, which are not adequately captured by retrospective reports. Although Halberda's (2006) explanation of the *implicit* mental process-of-elimination that underlies the disambiguation effect, the logical mental computation ("not A, therefore B") may not be explicitly accessible by the subject when verbalising their answer. Due to this difficulty, participants tend to use logic-based justifications even if their underlying initial mechanisms were in line with the *Disjunctive Syllogism*. This becomes more obvious in the fact/fact condition, when participants looked more towards the target item, presenting the implicit process-of-elimination, but then showing a significantly higher proportion of logic-based responses in this condition.

8.9 Conclusion

In conclusion, the present study adds to our understanding of the different communicative contexts in which the disambiguation effect can be observed. We demonstrated that multilingual adults' linguistic background only modulated the use of the contrast-based strategy. Unlike children, adults do not use reasoning by exclusivity in an unrestricted manner making it more suitable for the solution of referential ambiguity of labels. That being said, more eye-tracking studies investigating the use of disambiguation of facts within children and adults are necessary to gain a deeper understanding of implicit processes, especially as findings are still diverging. Our study is neither in clear favour of the domain-general nor the domain-/language-specific account. One the one hand, our findings support the language-specific notion of the disambiguation of labels; on the other hand, they support the domain-general notion of the disambiguation of facts. However, these are not necessarily incompatible, and our findings confirm that facts and labels, although both linguistically mediated have different properties and are modulated by different processes. This means that it may well be the case that a more comprehensive approach is required to explaining our and previous findings and difference in between. The use of disambiguation, its implicit and explicit use, are likely interconnected with various communicative, cognitive, learning, linguistic, and pragmatic factors, as well as individual variability. To establish a theoretical account that encompasses all these modulations should be the aim of future research.

9 Conclusion

9.1 Summary

In this thesis, I investigated the role of multilingualism on disambiguation, which is a mechanism that helps language learners apply a name to an object. This research aimed to gain a deeper understanding of word learning and its association to disambiguation in multilingual children and adults.

I discussed the motivation for this research in chapters 2, 3 and 4. In chapter 2, I highlighted how multifaceted growing up and living with two languages can be. I outlined different types of bilingualism, and it became more evident that multilingualism is an experience with many modulating factors. These factors included current language exposure, age of acquisition, language proficiency, or the number of languages spoken. I concluded that due to this variability within multilingualism, people from this background should not be treated as one homogeneous group. Furthermore, I reviewed various models on executive functioning and working memory to elucidate that multilingualism not only impacts on the different linguistic variables but also executive functioning and working memory. Because multilinguals may perform differently on non-linguistic, it is also necessary to account for potential differences in these non-linguistic domains if possible.

In chapter 3, I reviewed the developmental steps involved in language acquisition. This showed that multilingualism could impact on any of the linguistic domains, not just the domain of word learning which was the focus of this thesis. I also reviewed how multilingualism may affect the mental lexicon; once multilinguals reach adulthood; their lexicon tends to be more consolidated in their languages. Several models on bilingual lexical access were reviewed to highlight the most prominent challenges when multilinguals retrieve words from their lexicon.

In chapter 4, I then considered specific concepts of word learning, namely fast mapping, and slow learning or retention, and how these two processes relate to each other. I then provided an in-depth review of the disambiguation effect, its computational processes, its underlying theoretical motivations according to different schools of thought, and its relationship to word mapping and retention. After reviewing three pivotal studies, it became apparent that disambiguation is not a fixed observable effect, but one that is malleable based on different language circumstances, such as growing up with two or more languages. I concluded this chapter by reviewing newer studies on how disambiguation was used in multilingual children and adults, and how disambiguation may be applicable in contexts that did not involve mapping a word to an object, but a fact.

Based on this discussion, I formulated three research questions (chapter 5), relative to the effects of multilingualism on children's use of disambiguation and their ability to retain a new word-object mapping; to the effects of multilingualism on adults' use of disambiguation and how it affected their processing speeds when engaging in the process-of-elimination; and to whether multilingual adults apply disambiguation in situations of referential ambiguity that entailed non-label referential expressions, such as a general fact about an item, and what their underlying thought processes were for decision-making. I addressed these questions in three experimental studies, of which the first was performed on children aged between 18 to 30 months and the remaining two on the same group of multilingual adults.

In the first study (chapter 6), I investigated if monolingual and multilingual children disambiguated a novel word-object mapping and retained it compared to one previously seen word-object mapping, and how age, English vocabulary size, and language background impacted on disambiguation and retention. I also examined if children who disambiguated would also retain better. For this, I adapted a looking-while-listening paradigm for use with eye-tracking. I collected data from 18- to 30-month-old monolingual and multilingual children. The data were analysed using binomial mixed-effects models. The analyses revealed that vocabulary size predicted the outcome of mapping and retention better than age. I also found that monolinguals' accuracy on disambiguation trials was high from the start, whereas multilinguals started to disambiguate later as their vocabulary grows. On retention trials, only monolingual children perform above chance level. The most exciting finding was that the use of disambiguation improved retention performance for the monolingual, but not for the multilingual children. This study illustrated and corroborated to the notion that disambiguation should first and foremost be regarded as a default fast mapping mechanism rather than a fully-fledged learning strategy. Vocabulary growth leading to an increase in disambiguation supported the idea that the disambiguation effect stems from previous learning as outlined by the associative network account.

In the second study (chapter 7), I studied the role of multilingual experience on the accuracy and processing times of adults in a word-learning task using English proficiency, age of acquisition of English, current English exposure, the number of languages, and English as the first language as modulating background variables. I determined whether multilinguals could retain fast-mapped word-object links from the disambiguation phase in three different retention conditions, and how the above variables modulated their retention performance. In each analysis, I controlled for working memory and executive function abilities using a counting recall and the AX-Continuous Performance task. The results showed that multilinguals' performance and processing speeds in disambiguation and retention trials were affected by their linguistic background, whereby English proficiency played the most influential role. Together, these findings also revealed a speed-accuracy trade-off which is modulated by English language proficiency and working memory ability. In other words, multilinguals with a better working memory performance performed faster, but at the expense of accuracy.

Finally, the last study (chapter 8) explored multilingual adults' use of disambiguation on referential expressions other than labels. Previous studies showed that adults, unlike children, do not extend reasoning by exclusivity to disambiguate other referential expressions, such as factual information about objects. This has led to an ongoing debate as to whether disambiguation is a process that is specific to word learning. In the second study (chapter 7), I found that multilingual experience variables modulated the use of disambiguation of words. If disambiguation were applicable in other referential contexts, such as facts, I would have expected these multilingual language variables to impact on the disambiguation of facts similarly. However, multilingualism did not seem to impact those condition entailing facts about items, and its modulating effect pertained solely to the label-only condition. This study partly supported to the idea that disambiguation is somewhat specific to word learning contexts; however, this study also revealed confounding results to those of previous research which challenges the dichotomous approach of wanting to class disambiguation as either language-specific or domain-general.

9.2 Discussion and implications

In this section, I discuss the findings of this research in two ways. First, I highlight more broadly this research's implications on multilingual research in general. Then I proceed to focus on how my research can impact how we view disambiguation and word learning.

Although research on people with multilingual backgrounds can be challenging in practice, it also presents a considerable advantage in furthering our understanding of how people process language; and this includes language processing and learning of monolinguals as well. Many theories or models of word learning were based initially on monolinguals, but no model is perfect in describing what happens when we learn words. Thus, every model is incomplete to some extent, and it is by researching various angles that these models are refined. Consider the language background variables mentioned earlier in this thesis, such as language proficiency, exposure, or the age of acquisition to name but a few. Research that samples and tests monolinguals are, for instance, limited in using exposure or age of acquisition as a modulating factor for behaviour, because monolinguals tend to be exposed to their one language close to 100 per cent of the time, and their age of acquisition also tends to be very early. This means, for these specific variables, the variation of the sample is limited, but for language proficiency, we would expect more variation as this is influenced by other variables again, such as education. However, if we test multilingual children and adults, all the data from these measurable variables can be gathered in each of their languages and used as predicting variables providing us with more range to explore what impacts on learning. More often than not, this leads to a revision of models in favour of more dynamicity. Multilingualism comprises many components are accompanied by linguistic, non-linguistic, and cultural differences, and all of these need to be examined in order to gain a more holistic perspective of the dynamic nature of language. Albeit the inclusion of these dynamic features poses practical challenges with regards to experimental design, statistical analyses, or recruitment, a strong effort should be made to do so, because the generalisability of research findings based on monolinguals and their consequences on linguistic theory is limited. Because of this, we need more multilingual research to devise models and theories more meaningful and inclusive of the different language circumstances and individual experiences. Two such models have recently been identified by Kremin and Byers-Heinlein (2020). The Factor Mixture Model and the Grade-of-membership model, both of which have been extensively used in the area of psychometrics, have the potential to be used within psycholinguistic studies revolving around multilingual populations. This is due to their ability to account for categorical and continuous variables simultaneously rendering it possible to add, for instance, categories such as 'monolingual vs. bilingual', **and** number of languages a continuous factor to a design.

The research of this thesis illustrates the aforementioned general implications more clearly. The three studies combined have shown that disambiguation is a dynamic process that presents itself in some, but not other situations that require the resolution of referential ambiguity. One way to look at this dynamic nature was to test multilingual children on their use of disambiguation and how their ability to use it may affect their ability to retain a newly formed word-object link within the scope of the experiment. We found that both monolingual and multilingual children exhibited the disambiguation effect, but that the use of disambiguation only impacted monolinguals' retention of the fast-mapped item. This overall result indicates that whilst multilingual children can disambiguate, they use it first and foremost as a 'default' mapping strategy, whereas monolinguals benefitted from it as a more refined learning strategy. This should not be interpreted as disadvantageous for the multilinguals but as an inherent quality of the disambiguation process which undergoes refinement and narrowing as a person matures. However, this refinement is modulated by certain variables, such as the number of languages or vocabulary size in the case of children. I emphasise that the more nuanced dynamics of disambiguation can be grasped more in-depth when testing multilinguals, which is further corroborated by the results of the two adult studies of this thesis.

The two studies conducted on a multilingual adult sample highlight the interactive nature of disambiguation in two ways. The first study (chapter 7) showed that real-time processing of engaging in disambiguation is modulated by multilingualism, as well as cognitive abilities. Moreover, this study provided strong evidence that viewing multilingualism as a continuum is necessary, because dichotomous categories of 'monolingual vs multilingual' do not provide a fine-grained enough picture. By including more modulating variables in the study design, we are enabled to gain an understanding of multilingualism that goes beyond calling it an 'advantage' or 'disadvantage'. The second study (chapter 8) illustrated that disambiguation undergoes a narrowing of applicability as people mature. This means that while it may find applications in particular, more general situations of referential ambiguity in childhood, this is not necessarily the case for the same situations in adulthood. Although the theoretical motivations of disambiguation had already been postulated by two opposing approaches, it is with the research on the multilingual adults in this research that I contributed to the debate of domain-specificity of disambiguation. Recall that the domain-specific accounts, such as mutual exclusivity or N3C, regard disambiguation as pertaining to specific situations of word learning. In contrast, the domain-general accounts, such as the principle of contrast or the pragmatic account, view it as a mechanism that is more widely applicable. By testing multilingual adults and using linguistic background variables, which would either affect their use of disambiguation in a specific situation of referential ambiguity or not, I was able to confront the dichotomy between the domain-specificity debate. My study illustrated that, again, the postulation of theories behind disambiguation needs to be more dynamic and that ascribing it to either of the two camps does not describe its reality.

From a theoretical perspective, I encountered some limitations with regards to the associative network account framed for word learning (Horst & Samuelson, 2008; Kucker et al., 2015). Whilst this model accounts for the dynamic interplay between the fast mapping of labels to referents and the slow learning of these mappings with regards to long-term retention, it was not formulated with multilingualism as a contributing factor in mind. The model acknowledges that long-term retention is reached by repeated exposures of correct word-object mappings which lead to the strengthening of these connections. Conversely, as co-occurrences of labels with incorrect referents reduce over time, wrong connections are pruned. This learning via co-occurrences is mediated by statistical learning, which in turn is heavily modulated by language input and exposure.

However, it is not clear how many-to-one mappings used by multilingual children are accounted for in this model; and further, how variations in language exposure (due to imbalanced input patterns) would be incorporated. A bilingual child who receives more exposure in one than the other language might not be able to track co-occurrences in the same way a monolingual child would for only one language. Because multiple languages are not represented in the model, it is unclear whether the different languages would be regarded as operating super-systems in which each language has its own interactive fast and slow mapping relationship, or whether languages are directly linked to the node of a lexical entry (i.e. one referent object has several word form connections). If we think of synonyms in a monolingual system, it becomes apparent that some words can have several referents, or a referent can have different names. Thus, strict one-to-one mappings are rare.

Nonetheless, the associative network account does not discuss many-to-one mappings even within monolingual word learning. Returning to the bilingual child with uneven input, they would eventually reach a point where the one-to-one mapping from the more dominant language needs to be updated to include the lexical representation of the less dominant language – that is if languages are represented at the level of the lexical entry. If, however, language operated in a top-down manner, then the vocabulary development of the different languages would have to be interactive in nature in order to operate in tandem, as translational equivalents would have to be linked in some way. Interestingly, this model views the use of disambiguation as evidence for an appropriately structured and pruned lexical network. How can this claim be transferred to multilingual children? This is where a disambiguation study investigating disambiguation across vs within languages could help to disentangle the issues around multiple language representation within the associative network model. Within this model, word learning is regarded as dynamic relationship between two major processes, fast mapping and slow learning, and their sub-processes. Thus, it is one of the few models that already allows for a lot fluidity and malleability based on cognitive and environmental factors. Nonetheless, the model fails to explicitly include multilingualism which, as we have seen, has the ability to modulate disambiguation processes significantly. Because the associative network model accounts for ‘environmental factors’, the multilingual experience could be added to the picture here, especially if Hirosh & Degani’s (2008) model were to be superimposed, as the latter includes predictions of how direct and indirect effects of multilingualism affects learning. The associative network account describes the process of fast mapping from a developmental point of view; however, knowing that adults make use of disambiguation when facing novel words leads to the question as to how one might extend this model to an adult learner population. Here, one option might lie in the synthesis between the associative network account (Horst & Samuelson, 2008; Kucker & Samuelson, 2012) and elements of the declarative/procedural model (Gupta & Tisdale, 2009). The former model was not conceptualised with adults, and the latter not specifically with word learning in mind; however, both models complement each other as the underlying processes are based on the same principles. Despite these possible extensions, the modelling of one all-explaining theory remains unrealistic due to the inherent complexity of cognitive, individual and societal systems.

9.3 Limitations

I encountered several limitations throughout this research. Research with young children is often very challenging because of their attentional constraints and their inability to sit still for more extended periods. The first study (chapter 6) was partly aimed at replicating and combining the experimental designs by Byers-Heinlein & Werker (2009) and Bion, Borovsky & Fernald (2013). The experiment procedure and stimuli were modelled as closely as possible to their original, and for this reason, trials could not be designed to be more engaging or attention-grabbing, which was the feedback reported by parents. They thought that animate items or characters from cartoons would help keep the children’s attention.

During experimentation, it became apparent that most children started to get distracted towards the second half of the study. This often meant taking a break and allowing the child to play with some toys in the play area of the lab. However, due to the experimental setup, there was no recalibration after the children sat back down;

however, everything possible was done to minimise this by taking extreme care to position the child on their caregiver's lap in as similar a position as before. The attention of children could probably be sustained for longer if filler items with animate items had been introduced. However, this would have meant a trade-off with regards to the total experiment time. With the current experiment being already at ten to twelve minutes, introducing filler items could have led to attention loss, nonetheless. All of these challenges make it difficult to reach large sample sizes when testing children. Thus, the hope lies in future collaborative multi-lab projects and/or Open Science projects as a way of sharing data not only in terms of numbers, but also with regards to adding more languages than may be feasible in certain geographical locations.

Moreover, it was not possible to test children's working memory or executive functions at this young age. Although suitable tests that study precursors of WM and EF are available, including them in the battery would have been counterproductive with respect to study duration. Thus, I was unable to statistically control for these variables, as I have done for my first adult study. Unlike in the adult studies, I grouped children into monolingual and multilingual groups to be able to draw direct comparisons. Although I did collect data on their language background, such as current exposure or quality of input, I did not explicitly use it as a predictor variable in the models on multilingual children. This was omitted because it was beyond the scope for the specific research questions, I addressed in the formatted journal article, but also because this type of data was unavailable for the monolingual group. However, in a follow-up analysis on precisely the multilingual sample I tested, it would be more than possible and very insightful to use more of the language background data collected on children as predicting variables. Unfortunately, due to the pivoting of the entire research (see below) this was no longer feasible because of time limitations.

The actual coding of the experiment also caused several problems. Using E-Prime with Tobii Extensions as experimental software resulted in the observation that E-Prime slowed down during writing of the SaveGazeData file, which is the file that records all the data output. Through streamlined coding, this effect could be minimised, but even at a low sampling rate of 60 Hz, E-Prime seemed to struggle often. The situation was significantly improved once the lab manager acquired a new desktop computer with more RAM working memory capacity.

The original plan of this research was to conduct a follow-up study based on that of chapter 6. The aim was to discern whether bilingual children would disambiguate differently should they find themselves in a 'monolingual' vs 'bilingual mode', as this could have contributed to finding out whether disambiguation was used within and across languages. In order to run robust statistical analysis, one must collect data from a group of children who spoke the same first and second languages. I had started recruiting English-Polish speaking bilinguals aged between 24 and 30 months. The decision to use Polish as the other language was made based on the fact that it is the most widely spoken language in the area other than English. Although being widely spoken, the very narrow age inclusion criteria meant that I had to abort this study after having been able to test only fourteen children that fit the criteria. Because of this, I decided to pivot the research towards multilingual adult users of disambiguation.

With regards to the two studies conducted on adults, I encountered fewer restrictions. One of the main limitations posed in these studies was the language history questionnaire that participants had to complete in advance. Completing it for one language was already relatively lengthy, which meant it had the potential to consume much time for some participants who had to list all of their languages. However, most participants had no problems completing the form, or if they did, they were able to discuss questions with me. Only one person failed to include English in the questionnaire, which was the language that all participants had to mention, and thus, resulted in the disqualification of further data analysis.

9.4 Conclusion

This thesis examined the effects of multilingualism on the development and application of disambiguation, which is a process-of-elimination, on word mapping and retention in children and adults. Overall, I found that vocabulary size for children and language proficiency for adults were crucially affecting their performances.

With regards to studying the use of disambiguation within multilingual children, it can be said that instead of age, it is their size of vocabulary that seems to be a better predictor of the developmental trajectory of disambiguation. This means that when comparing children on potential differences in the use of disambiguation, one might consider matching children on vocabulary size rather than age as is often done. By doing so, the role of other modulating factors, such as language exposure or quality of language input, can be teased apart further.

Studying a multilingual adult sample on the use of disambiguation and retention of new word-object mappings whilst also controlling for differences in cognitive abilities showed that disambiguation is impacted by the mutual effects of linguistic and non-linguistic factors. My findings propose that future avenues of research should dynamically include these modulatory and mutual effects of language and cognition.

Examining disambiguation in non-traditional contexts, such as in its application with factual expressions, together with a multilingual sample exacerbated that the addition of multilinguals could be insightful in many study designs. This addition may also lead to more understanding in other studies even if these do not specifically look at differences between monolingual and multilinguals.

Together, these studies identify at least two dimensions of the multilingual experience in which disambiguation may be affected, thereby furthering our appreciation of the multifariousness of multilingualism. In other words, my work demonstrates that incorporating multilingualism into the empirical rationale of a study helps to get granular on the mind, instead of furthering debates on whether multilingualism is ‘good or bad’.

References

Abrahamsson, N., & Hyltenstam, K. (2009). Age of onset and nativelikeness in a second language: Listener perception versus linguistic scrutiny. *Language Learning*, *59*(2), 249–306. https://doi.org/10.1111/j.1467-9922.2009.00507.x

Abutalebi, J., & Green, D. W. (2016). Neuroimaging of language control in bilinguals: Neural adaptation and reserve. *Bilingualism*, *19*(4), 689–698. https://doi.org/10.1017/S1366728916000225

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the Time Course of Spoken Word Recognition Using Eye Movements: Evidence for Continuous Mapping Models. *Journal of Memory and Language*, *38*, 419–439.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–412. https://doi.org/10.1016/j.jml.2007.12.005

Babino, A., & Stewart, M. A. (2017). "I Like English Better": Latino Dual Language Students' Investment in Spanish, English, and Bilingualism. *Journal of Latinos and Education*, *16*(1), 18–29. https://doi.org/10.1080/15348431.2016.1179186

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The Phonological Loop as a Language Learning Device. *Psychological Review*, *105*(1), 158–173. https://doi.org/10.1037/0033-295X.105.1.158

Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Irwin, J. M., & Tidball, G. (1996). Infants' Reliance on a Social Criterion for Establishing Word-Object Relations. *Child Development*, *67*, 3135–3153. https://doi.org/10.1111/j.1467-8624.1996.tb01906.x

Barr, D. J. (2013). Random effects structure for testing interactions in linear mixed-effects models. *Frontiers in Psychology*, *4*(June), 3–4. https://doi.org/10.3389/fpsyg.2013.00328

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bartolotti, J., & Marian, V. (2012). Language Learning and Control in Monolinguals and Bilinguals. *Cognitive Science*, *36*(6), 1129–1147. https://doi.org/10.1111/j.1551-6709.2012.01243.x

Bartolotti, J., Marian, V., Schroeder, S. R., & Shook, A. (2011). Bilingualism and inhibitory control influence statistical learning of novel word forms. *Frontiers in Psychology*, *2*(NOV), 1–10. https://doi.org/10.3389/fpsyg.2011.00324

Bates, D. (2005). *Fitting linear mixed models in R*. *R News* (Vol. 5).

Bates, D. M., & Sarkar, D. (2007). lme4: Linear mixed-effects models using S4 classes. R package.

Bates, E., Thal, D., & Marchman, V. (1991). Symbols and syntax: A Darwinian approach to language development. In N. Krasnegor, D. Rumbaugh, R. Schiefelbush, & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development* (pp. 29–65). Hillsdale, NJ: Erlbaum.

Baum, S., & Titone, D. (2014). Moving toward a neuroplasticity view of bilingualism, executive control, and aging. *Applied Psycholinguistics*, *35*(5), 857–894. https://doi.org/10.1017/S0142716414000174

Bell, A., Fairbrother, M., & Jones, K. (2019). Fixed and random effects models: making an informed choice. *Quality and Quantity*, *53*(2), 1051–1074. https://doi.org/10.1007/s11135-018-0802-x

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition*, *12*(01), 3. https://doi.org/10.1017/S1366728908003477

Bialystok, E. (2011). Coordination of executive functions in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *110*(3), 461–468. https://doi.org/10.1016/j.jecp.2011.05.005

Bialystok, E. (2017). The bilingual adaptation: How minds accommodate experience. *Psychological Bulletin*, *143*(3), 233–262. https://doi.org/10.1037/bul0000099

Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development*, *11*(4), 485–508. https://doi.org/10.1080/15248372.2010.516420

Bialystok, E., & DePape, A. M. (2009). Musical Expertise, Bilingualism, and Executive Functioning. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(2), 565–574. https://doi.org/10.1037/a0012735

Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism*, *13*(4), 525–531. https://doi.org/10.1017/S1366728909990423

Bion, R. a H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: disambiguation of novel word-object mappings in relation to vocabulary learning at 18, 24, and 30months. *Cognition*, *126*(1), 39–53. https://doi.org/10.1016/j.cognition.2012.08.008

Birdsong, D. (2005). Interpreting age effects in second language acquisition. In J. F. Kroll & A. M. B De Groot (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches* (pp. 109–127). New York: Oxford University Press.

Bloom, P. (2002). *How children learn the meanings of words*. MIT press.

Bonfieni, M., Branigan, H. P., Pickering, M. J., & Sorace, A. (2019). Cognitive control in bilinguals: Effects of language experience and individual variability. *Bilingualism*. https://doi.org/10.1017/S1366728918001086

Bosch, L., Figueras, M., Teixidó, M., & Ramon-Casas, M. (2013). Rapid gains in segmenting fluent speech when words match the rhythmic unit: Evidence from infants acquiring syllable-timed languages. *Frontiers in Psychology*, *4*(MAR), 106. https://doi.org/10.3389/fpsyg.2013.00106

Braver, T. S. (2012). The variable nature of cognitive control: a dual mechanisms framework. *Trends in Cognitive Sciences*, *16*(2), 106–113. https://doi.org/10.1016/j.tics.2011.12.010

Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In *Variation in working memory*. (pp. 76–106). New York, NY, US: Oxford University Press.

Braver, T. S., Paxton, J. L., Locke, H. S., & Barch, D. M. (2009). Flexible neural mechanisms of cognitive control within human prefrontal cortex. *Proceedings of the National Academy of Sciences*, *106*(18), 7351–7356. https://doi.org/10.1073/pnas.0808187106

Byers-Heinlein, K., Chen, K. H., & Xu, F. (2014). Surmounting the Tower of Babel: Monolingual and bilingual 2-year-olds' understanding of the nature of foreign language words. *Journal of Experimental Child Psychology*, *119*, 87–100. https://doi.org/10.1016/j.jecp.2013.09.011

Byers-Heinlein, K., & Fennell, C. T. (2014). Perceptual narrowing in the context of increased variation: Insights from bilingual infants. *Developmental Psychobiology*, *56*(2), 274–

291. https://doi.org/10.1002/dev.21167

Byers-Heinlein, K., Fennell, C. T., & Werker, J. F. (2013). The development of associative word learning in monolingual and bilingual infants. *Bilingualism*, *16*(1), 198–205. https://doi.org/10.1017/S1366728912000417

Byers-Heinlein, K., & Werker, J. F. (2009). Monolingual, bilingual, trilingual: Infants' language experience influences the development of a word-learning heuristic. *Developmental Science*, *12*(5), 815–823. https://doi.org/10.1111/j.1467-7687.2009.00902.x

Byers-Heinlein, K., & Werker, J. F. (2013). Lexicon structure and the disambiguation of novel words: Evidence from bilingual infants. *Cognition*, *128*(3), 407–416. https://doi.org/10.1016/j.cognition.2013.05.010

Calvo, N., Ibáñez, A., & García, A. M. (2016). The Impact of Bilingualism on Working Memory: A Null Effect on the Whole May Not Be So on the Parts. *Frontiers in Psychology*, *7*, 265. https://doi.org/10.3389/fpsyg.2016.00265

Carey, S. (1978). The child as word learner. In G. A. Halle, M.; Bresnan, J., Miller (Ed.), *Linguistic theory and psychological reality* (pp. 264–293). Cambridge, MA: MIT Press.

Chamorro, G., & Sorace, A. (2019). The Interface Hypothesis as a framework for studying L1 attrition. In M. S. Schmid & B. Köpke (Eds.), *The Oxford Handbook of Language Attrition*. Oxford University Press.

Chan, J. (2018). Attitudes and identities in learning English and Chinese as a lingua franca: a bilingual learners' perspective. *Journal of Multilingual and Multicultural Development*, *39*(9), 759–775. https://doi.org/10.1080/01434632.2018.1438446

Chan, Jacky, & Monaghan, P. (2019). Simulating Bilingual Word Learning: Monolingual and Bilingual Adults' Use of Cross-Situational Statistics. In *Proceedings of the 41st Annual Meeting of the Cognitive Science Society* (pp. 1472–1478).

Clark, E. V. (1983). Meanings and concepts. In J. H. Flavell, E. M. Markman, & P. H. Mussen (Eds.), *Handbook of child psychology: Vol. 3* (pp. 787–840). New York: Wiley.

Clark, E. V. (1993). *The Lexicon in Acquisition*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511554377

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language*, *17*, 417–431.

Clark, E. V, & Hecht, B. F. (1983). Comprehension, production, and language acquisition.

Ann. Rev. PsychoL, 34, 325–349.

Cockcroft, K., Wigdorowitz, M., & Liversage, L. (2019). A multilingual advantage in the components of working memory. *Bilingualism*, *22*(1), 15–29. https://doi.org/10.1017/S1366728917000475

Coco, M. I., & Keller, F. (2015). Integrating mechanisms of visual guidance in naturalistic language production. *Cognitive Processing*, *16*(2), 131–150. https://doi.org/10.1007/s10339-014-0642-0

Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language*, *50*(4), 491–511. https://doi.org/10.1016/j.jml.2004.02.002

Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning Memory and Cognition*, *32*(5), 1057–1074. https://doi.org/10.1037/0278-7393.32.5.1057

Dahan, D., Swingley, D., Tanenhaus, M. K., & Magnuson, J. S. (2000). Linguistic Gender and Spoken-Word Recognition in French. *Journal of Memory and Language*, *42*(4), 465–480. https://doi.org/10.1006/jmla.1999.2688

Davidson, D., & Tell, D. (2005). Monolingual and bilingual children’s use of mutual exclusivity in the naming of whole objects. *Journal of Experimental Child Psychology*, *92*(1), 25–45. https://doi.org/10.1016/j.jecp.2005.03.007

de Bruin, A., Treccani, B., & Della Sala, S. (2015). Cognitive Advantage in Bilingualism: An Example of Publication Bias? *Psychological Science*, *26*(1), 99–107. https://doi.org/10.1177/0956797614557866

De Houwer, A. (2007). Parental language input patterns and children’s bilingual use. *Applied Psycholinguistics*, *28*(3), 411–424. https://doi.org/10.1017/S0142716407070221

de Saussure, F. (1914). *Course in General Linguistics: Ferdinand de Saussure*. *Language*. https://doi.org/10.1037/0021-9010.60.6.742

de Saussure, F., & Baskin, W. (2011). *Course in General Linguistics*. (P. Meisel & H. Saussy, Eds.). Columbia University Press. https://doi.org/10.7312/saus15726

DeKeyser, R. M. (2000). The robustness of critical period effects in second language acquisition. *Studies in Second Language Acquisition*, *22*(4), 499–533. https://doi.org/10.1017/s0272263100004022

Diesendruck, G., & Markson, L. (2001). Children’s avoidance of lexical overlap: a pragmatic account. *Developmental Psychology*, *37*(5), 630–641. https://doi.org/10.1037/0012-1649.37.5.630

Diesendruck, G., Markson, L., Akhtar, N., & Reudor, A. (2004). Two-year-olds’ sensitivity to speakers’ intent: An alternative account of Samuelson and Smith. *Developmental Science*, *7*(1), 33–41. https://doi.org/10.1111/j.1467-7687.2004.00320.x

Dijkstra, T. (2005). Bilingual Visual Word Recognition and Lexical Access. In *Handbook of bilingualism: Psycholinguistic approaches.* (pp. 179–201). Nijmegen: Oxford University Press.

Dink, J., & Ferguson, B. (2018). eyetrackingR.

Dong, Y., & Li, P. (2015). The cognitive science of bilingualism. *Language and Linguistics Compass*, *9*(1), 1–13. https://doi.org/10.1111/lnc3.12099

Eilers, R. E., Pearson, B. Z., & Cobo-Lewis, A. B. (2006). Social factors in bilingual development: The Miami experience. In *Childhood bilingualism: Research on infancy through school age* (pp. 68–90).

Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking Innateness: A Connectionist Perspective on Development*. Cambridge, MA: MIT Press.

Escudero, P., Mulak, K. E., Fu, C. S. L., & Singh, L. (2016). More limitations to monolingualism: Bilinguals outperform monolinguals in implicit word learning. *Frontiers in Psychology*, *7*(AUG), 1218. https://doi.org/10.3389/fpsyg.2016.01218

Fantz, R. L. (1963). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science*, *140*(3564), 296–297. https://doi.org/10.1126/science.140.3564.296

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., … Reilly, J. S. (1993). *The MacArthur Communicative Development Inventories: User’s Guide and Technical Manual.* Baltimore: Paul H. Brokes Publishing Co.

Fenson, Larry, Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). MacArthur-Bates Communicative Development Inventories (2nd ed.). Paul H. Brookes Publishing Co.

Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental*

Psychology, *42*(1), 98–116. https://doi.org/10.1037/0012-1649.42.1.98

Frank, I., & Poulin-Dubois, D. (2002). Young monolingual and bilingual children's responses to violation of the Mutual Exclusivity Principle. *International Journal of Bilingualism*, *6*(2), 125–146. https://doi.org/10.1177/13670069020060020201

Ganger, J., & Brent, M. R. (2004). Reexamining the vocabulary spurt. *Developmental Psychology*. https://doi.org/10.1037/0012-1649.40.4.621

Gaskell, G. M., & Ellis, A. W. (2009). Word learning and lexical development across the lifespan. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1536), 3607–3615. https://doi.org/10.1098/rstb.2009.0213

Gathercole, V. C. (1989). Contrast: A semantic constraint? *Journal of Child Language*, *16*(3), 685–702. https://doi.org/10.1017/S0305000900010795

Goldenberg, E. R., & Sandhofer, C. M. (2013). Same, varied, or both? Contextual support aids young children in generalizing category labels. *Journal of Experimental Child Psychology*, *115*(1), 150–162. https://doi.org/10.1016/j.jecp.2012.11.011

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L. M., & Wenger, N. R. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology*. https://doi.org/10.1037//0012-1649.28.1.99

Golinkoff, R. M., Mervis, C. B., & Hirsh-Pasek, K. (1994). Early object labels: the case for a developmental lexical principles framework. *Journal of Child Language*, *21*(01), 125–155. https://doi.org/10.1017/S0305000900008692

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language*, *58*(3), 787–814. https://doi.org/10.1016/j.jml.2007.07.001

Gollan, T. H., Starr, J., & Ferreira, V. S. (2014). *More than use it or lose it: The number-of-speakers effect on heritage language proficiency*. *Psychonomic Bulletin and Review* (Vol. 22). Gathercole & Thomas. https://doi.org/10.3758/s13423-014-0649-7

Grassmann, S., & Tomasello, M. (2010). Young children follow pointing over words in interpreting acts of reference. *Developmental Science*, *13*(1), 252–263. https://doi.org/10.1111/j.1467-7687.2009.00871.x

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, *1*(2), 67–81. https://doi.org/10.1017/s1366728998000133

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology*, *25*(5), 515–530. https://doi.org/10.1080/20445911.2013.796377

Grice, H. (1975). Logic and Conversation. In P. Cole & J. Morgan (Eds.), *Syntax and Semantics: Vol 3, Speech Acts* (pp. 41–58). New York: Academic Press. https://doi.org/10.1057/9780230005853_5

Grosjean, F. (1998). Studying bilinguals: Methodological and conceptual issues. *Bilingualism: Language and Cognition*, *1*(2), 131–149. https://doi.org/10.1017/s136672899800025x

Grosjean, F. (2001). The bilingual's language mode. In J. Nicol (Ed.), *One mind, Two Languages: Bilingual Langauge Processing* (pp. 1–22). Oxford: Blackwell Publishing.

Gupta, P., & Cohen, N. J. (2002). Theoretical and computational analysis of skill learning, repetition priming, and procedural memory. *Psychological Review*, *109*(2), 401.

Gupta, P., & Dell, G. S. (1999). The emergence of language from serial order and procedural memory. *The Emergence of Language*, 447–481.

Gupta, P., & Tisdale, J. (2009). Word learning, phonological short-term memory, phonotactic probability and long-term memory: Towards an integrated framework. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1536), 3755–3771. https://doi.org/10.1098/rstb.2009.0132

Halberda, J. (2003). The development of a word-learning strategy. *Brain and Development*, *87*, 23–34. https://doi.org/10.1016/S0

Halberda, J. (2006). Is this a dax which I see before me? Use of the logical argument disjunctive syllogism supports word-learning in children and adults. *Cognitive Psychology*, *53*(4), 310–344. https://doi.org/10.1016/j.cogpsych.2006.04.003

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children.* Baltimore, MD, US: Paul H Brookes Publishing.

Hedden, T., Ketay, S., Aron, A., Markus, H. R., & Gabrieli, J. D. E. (2008). Cultural influences on neural substrates of attentional control. *Psychological Science*, *19*(1), 12–17. https://doi.org/10.1111/j.1467-9280.2008.02038.x

Hirosh, Z., & Degani, T. (2018). Direct and indirect effects of multilingualism on novel language learning: An integrative review. *Psychonomic Bulletin and Review*, *25*(3), 892–916. https://doi.org/10.3758/s13423-017-1315-7

Hollich, G. J., Hirsh-Pasek, K., & Golinkoff, R. M. (1998). Introducing the 3-D intermodal preferential looking paradigm: A new method to answer an age-old question. *Advances in Infancy Research*, *12*, 355–374.

Hoover, M. A., & Richardson, D. C. (2008). When facts go down the rabbit hole: Contrasting features and objecthood as indexes to memory. *Cognition*, *108*(2), 533–542. https://doi.org/10.1016/j.cognition.2008.02.011

Horst, J. S., & Hout, M. C. (2016). The Novel Object and Unusual Name (NOUN) Database: A collection of novel images for use in experimental research. *Behavior Research Methods*, *48*(4), 1393–1409. https://doi.org/10.3758/s13428-015-0647-3

Horst, J. S., Parsons, K. L., & Bryan, N. M. (2011). Get the story straight: Contextual repetition promotes word learning from storybooks. *Frontiers in Psychology*, *2*(FEB), 17. https://doi.org/10.3389/fpsyg.2011.00017

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy*, *13*(2), 128–157. https://doi.org/10.1080/15250000701795598

Horst, J. S., Samuelson, L. K., Kucker, S. C., & McMurray, B. (2011). What’s new? Children prefer novelty in referent selection. *Cognition*, *118*(2), 234–244. https://doi.org/10.1016/j.cognition.2010.10.015

Houston-Price, C., Caloghiris, Z., & Raviglione, E. (2010). Language experience shapes the development of the mutual exclusivity bias. *Infancy*, *15*(2), 125–150. https://doi.org/10.1111/j.1532-7078.2009.00009.x

Hull, R., & Vaid, J. (2007, January 1). Bilingual language lateralization: A meta-analytic tale of two hemispheres. *Neuropsychologia*. Pergamon. https://doi.org/10.1016/j.neuropsychologia.2007.03.002

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. *Advances in Infancy Research*, *5*, 69–95.

Hurtado, N., Grüter, T., Marchman, V. A., & Fernald, A. (2014). Relative language exposure, processing efficiency and vocabulary in Spanish-English bilingual toddlers. *Bilingualism*, *17*(1), 189–202. https://doi.org/10.1017/S136672891300014X

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*(4), 434–446. https://doi.org/10.1016/j.jml.2007.11.007

Jaswal, V. K., & Hansen, M. B. (2006). Learning words: Children disregard some pragmatic information that conflicts with mutual exclusivity. *Developmental Science*, *9*(2), 158–165. https://doi.org/10.1111/j.1467-7687.2006.00475.x

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, *21*(1), 60–99. https://doi.org/10.1016/0010-0285(89)90003-0

Junker, D. A., & Stockman, I. J. (2002). Expressive vocabulary of German-English bilingual toddlers. *American Journal of Speech-Language Pathology*, *11*(4), 381–394. https://doi.org/10.1044/1058-0360(2002/042)

Kalashnikova, M., Escudero, P., & Kidd, E. (2018). The development of fast-mapping and novel word retention strategies in monolingual and bilingual infants. *Developmental Science*, *21*(6). https://doi.org/10.1111/desc.12674

Kalashnikova, M., Mattock, K., & Monaghan, P. (2014). Disambiguation of novel labels and referential facts: A developmental perspective. *First Language*, *34*(2), 125–135. https://doi.org/10.1177/0142723714525946

Kalashnikova, M., Mattock, K., & Monaghan, P. (2015). The effects of linguistic experience on the flexible use of mutual exclusivity in word learning. *Bilingualism*, *18*(4), 626–638. https://doi.org/10.1017/S1366728914000364

Kalashnikova, M., Mattock, K., & Monaghan, P. (2016). Mutual exclusivity develops as a consequence of abstract rather than particular vocabulary knowledge. *First Language*, *36*(5), 451–464. https://doi.org/10.1177/0142723716648850

Kalashnikova, M., Oliveri, A., & Mattock, K. (2018). Acceptance of lexical overlap by monolingual and bilingual toddlers. *International Journal of Bilingualism*, 136700691880804. https://doi.org/10.1177/1367006918808041

Kandhadai, P., Hall, D. G., & Werker, J. F. (2017). Second label learning in bilingual and monolingual infants. In *Developmental Science* (Vol. 20). https://doi.org/10.1111/desc.12429

Kaushanskaya, M. (2012). Cognitive mechanisms of word learning in bilingual and monolingual adults: The role of phonological memory. *Bilingualism*, *15*(3), 470–489. https://doi.org/10.1017/S1366728911000472

Kaushanskaya, M., Gross, M., & Buac, M. (2014). Effects of classroom bilingualism on task-shifting, verbal memory, and word learning in children. *Developmental Science*, *17*(4), 564–583. https://doi.org/10.1111/desc.12142

Kaushanskaya, M., & Marian, V. (2009). Bilingualism Reduces Native-Language Interference During Novel-Word Learning. *Journal of Experimental Psychology: Learning Memory and Cognition*, *35*(3), 829–835. https://doi.org/10.1037/a0015275

Kaushanskaya, M., & Rechtzigel, K. (2012). Concreteness effects in bilingual and monolingual word learning. *Psychonomic Bulletin and Review*, *19*(5), 935–941. https://doi.org/10.3758/s13423-012-0271-5

Kaushanskaya, M., Yoo, J., & Van Hecke, S. (2013). Word learning in adults with second-language experience: Effects of phonological and referent familiarity. *Journal of Speech, Language, and Hearing Research*, *56*(2), 667–678. https://doi.org/10.1044/1092-4388(2012/11-0084)

Klein, D., Mok, K., Chen, J. K., & Watkins, K. E. (2014). Age of language learning shapes brain structure: A cortical thickness study of bilingual and monolingual individuals. *Brain and Language*, *131*, 20–24. https://doi.org/10.1016/j.bandl.2013.05.014

Klein, E. C. (1995). Second versus Third Language Acquisition: Is There a Difference? *Language Learning*, *45*(3), 419–466. https://doi.org/10.1111/j.1467-1770.1995.tb00448.x

Kohnert, K. J., & Bates, E. (2002). Balancing bilinguals II: Lexical comprehension and cognitive processing in children learning Spanish and English. *Journal of Speech, Language, and Hearing Research*, *45*(2), 347–359. https://doi.org/10.1044/1092-4388(2002/027)

Kremin, L., & Byers-Heinlein, K. (2020). Why not both? Rethinking categorical and continuous approaches to bilingualism, 1–27. https://doi.org/10.31234/osf.io/nkvap

Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology*, *25*(5), 497–514. https://doi.org/10.1080/20445911.2013.799170

Kronmüller, E., & Barr, D. J. (2015). Referential precedents in spoken language comprehension: A review and meta-analysis. *Journal of Memory and Language*, *83*, 1–19. https://doi.org/10.1016/j.jml.2015.03.008

Kucker, S. C., Mcmurray, B., & Samuelson, L. K. (2015). Slowing Down Fast Mapping: Redefining the Dynamics of Word Learning. *Child Development Perspectives*, *9*(2), 74–78. https://doi.org/10.1111/cdep.12110

Kucker, S. C., & Samuelson, L. K. (2012). The First Slow Step: Differential Effects of Object and Word-Form Familiarization on Retention of Fast-Mapped Words. *Infancy*, *17*(3), 295–323. https://doi.org/10.1111/j.1532-7078.2011.00081.x

Kuhl, P. K., Tsao, F. M., & Liu, H. M. (2003). Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(15), 9096–9101. https://doi.org/10.1073/pnas.1532872100

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods*, *44*(2), 325–343. https://doi.org/10.3758/s13428-011-0146-0

Lenneberg, E. H. (1967). The Biological Foundations of Language. *Hospital Practice*, *2*(12), 59–67. https://doi.org/10.1080/21548331.1967.11707799

Liittschwager, J. C., & Markman, E. M. (1994). Sixteen- and 24-month-olds' use of mutual exclusivity as a default assumption in second-label learning. *Developmental Psychology*, *30*(6), 955–968. https://doi.org/10.1037/0012-1649.30.6.955

Malone, S. A., Kalashnikova, M., & Davis, E. M. (2016). Is It a Name or a Fact? Disambiguation of Reference Via Exclusivity and Pragmatic Reasoning. *Cognitive Science*, *40*(8), 2095–2107. https://doi.org/10.1111/cogs.12321

Marchman, V. A., Fernald, A., & Hurtado, N. (2010). How vocabulary size in two languages relates to efficiency in spoken word recognition by young Spanish-English bilinguals. *Journal of Child Language*, *37*(4), 817–840. https://doi.org/10.1017/S0305000909990055

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940–967. https://doi.org/10.1044/1092-4388(2007/067)

Markman, E. M. (1990). Constraints children place on word meanings. *Cognitive Science*, *14*(1), 57–77. https://doi.org/10.1016/0364-0213(90)90026-S

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. *Cognitive Psychology*, *16*(1), 1–27. https://doi.org/10.1016/0010-0285(84)90002-1

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive Psychology*, *20*(2), 121–157.

https://doi.org/10.1016/0010-0285(88)90017-5

Markman, E. M., Wasow, J. L., & Hansen, M. B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology*, *47*(3), 241–275. https://doi.org/10.1016/S0010-0285(03)00034-3

Markson, L., & Bloom, P. (1997). Evidence against a dedicated system for word learning in children. *Nature*, *385*(6619), 813–815. https://doi.org/10.1038/385813a0

Mather, E., & Plunkett, K. (2010). Novel labels support 10-month-olds' attention to novel objects. *Journal of Experimental Child Psychology*, *105*(3), 232–242. https://doi.org/10.1016/j.jecp.2009.11.004

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing Type I error and power in linear mixed models. *Journal of Memory and Language*, *94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001

Mayor, J., & Plunkett, K. (2010). A Neurocomputational Account of Taxonomic Responding and Fast Mapping in Early Word Learning. *Psychological Review*, *117*(1), 1–31. https://doi.org/10.1037/a0018130

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, *102*(3), 419–457. https://doi.org/10.1037/0033-295X.102.3.419

McMurray, B. (2007). Defusing the childhood vocabulary explosion. *Science*, *317*(5838), 631. https://doi.org/10.1126/science.1144073

McMurray, B., Horst, J. S., & Samuelson, L. K. (2012). Word learning emerges from the interaction of online referent selection and slow associative learning. *Psychological Review*, *119*(4), 831–877. https://doi.org/10.1037/a0029872

McMurray, B., Horst, J. S., Toscano, J. C., & Samuelson, L. K. (2009). Integrating Connectionist Learning and Dynamical Systems Processing: Case Studies in Speech and Lexical Development. In *Toward a Unified Theory of Development Connectionism and Dynamic System Theory Re-Consider*. New York: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195300598.003.0011

Merriman, W. E., Bowman, L. L., & MacWhinney, B. (1989). The Mutual Exclusivity Bias in Children's Word Learning. *Monographs of the Society for Research in Child Development*, *54*(3/4), i. https://doi.org/10.2307/1166130

Mervis, C. B., & Bertrand, J. (1994). Acquisition of the Novel Name–Nameless Category (N3C) Principle. *Child Development*, *65*(6), 1646–1662. https://doi.org/10.1111/j.1467-8624.1994.tb00840.x

Miller, L. (2017). The relationship between language proficiency and language attitudes. *Spanish in Context*, *14*(1), 99–123. https://doi.org/10.1075/sic.14.1.05mil

Mitchell, C., & McMurray, B. (2009). On leveraged learning in lexical acquisition and its relationship to acceleration. *Cognitive Science*, *33*(8), 1503–1523. https://doi.org/10.1111/j.1551-6709.2009.01071.x

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex 'Frontal Lobe' Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Montgomery, J. W. (2003). Working memory and comprehension in children with specific language impairment: What we know so far. In *Journal of Communication Disorders* (Vol. 36, pp. 221–231). Elsevier. https://doi.org/10.1016/S0021-9924(03)00021-2

Morales, J., Gómez-Ariza, C. J., & Bajo, M. T. (2013). Dual mechanisms of cognitive control in bilinguals and monolinguals. *Journal of Cognitive Psychology*, *25*(5), 531–546. https://doi.org/10.1080/20445911.2013.807812

Morgenstern, Y., Schmidt, F., & Fleming, R. W. (2019). One-shot categorization of novel object classes in humans. *Vision Research*, *165*, 98–108. https://doi.org/10.1016/j.visres.2019.09.005

Moss, K. K. H. (1996). Word Monitoring. *Language and Cognitive Processes*, *11*(6), 689–694. https://doi.org/10.1080/016909696387105

Myers-Scotton, C. (2017). Code-Switching. In *The Handbook of Sociolinguistics* (pp. 217–237). Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1002/9781405166256.ch13

Paap, K. R. (2018). Bilingualism in Cognitive Science: The Characteristics and Consequences of Bilingual Language Control. In A. De Houwer & L. Ortega (Eds.), *The Cambridge Handbook of Bilingualism* (pp. 435–465). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781316831922.023

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology*, *66*(2), 232–258.

https://doi.org/10.1016/j.cogpsych.2012.12.002

Papagno, C., & Vallar, G. (1995). Verbal Short-term Memory and Vocabulary Learning in Polyglots. *The Quarterly Journal of Experimental Psychology Section A*, *48*(1), 98–107. https://doi.org/10.1080/14640749508401378

Pearson, B. Z., Fernandez, S. C., Lewedeg, V., & Oller, D. K. (1997). The relation of input factors to lexical learning by bilingual infants. *Applied Psycholinguistics*, *18*(1), 41–58. https://doi.org/10.1017/s0142716400009863

Perani, D., Abutalebi, J., Paulesu, E., Brambati, S., Scifo, P., Cappa, S. F., & Fazio, F. (2003). The role of age of acquisition and language usage in early, high-proficient bilinguals: An fMRI study during verbal fluency. *Human Brain Mapping*, *19*(3), 170–182. https://doi.org/10.1002/hbm.10110

Pereira, A. F., Smith, L. B., & Yu, C. (2014). A bottom-up view of toddler word learning. *Psychonomic Bulletin and Review*, *21*(1), 178–185. https://doi.org/10.3758/s13423-013-0466-4

Place, S., & Hoff, E. (2011). Properties of Dual Language Exposure That Influence 2-Year-Olds' Bilingual Proficiency. *Child Development*, *82*(6), 1834–1849. https://doi.org/10.1111/j.1467-8624.2011.01660.x

Plunkett, K. (1997). Theories of early language acquisition. *Trends in Cognitive Sciences*, *1*(4), 146–153.

Polka, L., Orena, A. J., Sundara, M., & Worrall, J. (2017). Segmenting words from fluent speech during infancy – challenges and opportunities in a bilingual context. *Developmental Science*, *20*(1), e12419. https://doi.org/10.1111/desc.12419

Portocarrero, J. S., Burright, R. G., & Donovick, P. J. (2007). Vocabulary and verbal fluency of bilingual and monolingual college students. *Archives of Clinical Neuropsychology*, *22*(3), 415–422. https://doi.org/10.1016/j.acn.2007.01.015

Qualtrics - Leading Experience Management and Survey Software. (n.d.). Retrieved 22 July 2020, from https://www.qualtrics.com/uk/?rid=ip&prevsite=en&newsite=uk&geo=GB&geomatch=uk

Quine, W. V. O. (1960). *Word and Object*. *Word and Object: An inquiry into the linguistic mechanisms of objective reference*. Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/9636.001.0001

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception*, *22*(4), 463–475. https://doi.org/10.1068/p220463

R Core Team. (2019). R: A language and environment fo statistical computing. Vienna, Austria.

Regier, T. (2005). Cognitive Science : A Multidisciplinary The Emergence of Words : Attentional Learning in Form and Meaning. *Cognitive Science*, *29*, 819–865. https://doi.org/10.1207/s15516709cog0000

Repnik, K. M., Chondrogianni, V., & Sorace, A. (2021). Linking disambiguation and retention in a developmental eye-tracking study with monolingual and multilingual children. *Journal of Experimental Child Psychology*, *206*, 105072. https://doi.org/10.1016/j.jecp.2020.105072

Roder, B. J., Bushnell, E. W., & Sasseville, A. M. (2000). Infants' Preferences for Familiarity and Novelty during the Course of Visual Processing. *Infancy*, *1*(4), 491–507. https://doi.org/10.1207/S15327078IN0104_9

Runnqvist, E., Strijkers, K., Alario, F. X., & Costa, A. (2012). Cumulative semantic interference is blind to language: Implications for models of bilingual speech production. *Journal of Memory and Language*, *66*(4), 850–869. https://doi.org/10.1016/j.jml.2012.02.007

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical Learning by 8-Month-Old Infants. *Science*, *274*(5294), 1926 LP – 1928. https://doi.org/10.1126/science.274.5294.1926

Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15-20-month-olds. *Developmental Psychology*, *38*(6), 1016–1037. https://doi.org/10.1037/0012-1649.38.6.1016

Samuelson, L. K., Kucker, S. C., & Spencer, J. P. (2017). Moving Word Learning to a Novel Space: A Dynamic Systems View of Referent Selection and Retention. *Cognitive Science*, *41*, 52–72. https://doi.org/10.1111/cogs.12369

Sanz, C. (2000). Bilingual education enhances third language acquisition: Evidence from Catalonia. *Applied Psycholinguistics*, *21*(1), 23–44. https://doi.org/10.1017/s0142716400001028

Sanz, C. (2007). Predicting enhanced l3 learning in bilingual contexts: The role of biliteracy.

In *A Portrait of the Young in the New Multilingual Spain* (pp. 220–240).

Sanz, C. (2019). Multilingualism and Metalinguistic Awareness. In *The Encyclopedia of Applied Linguistics* (pp. 1–10). Wiley. https://doi.org/10.1002/9781405198431.wbeal0802.pub2

Schafer, G., Plunkett, K., & Harris, P. L. (1999). What's in a name? Lexical knowledge drives infants' visual preferences in the absence of referential input. *Developmental Science*, *2*(2), 187–194. https://doi.org/10.1111/1467-7687.00067

Scofield, J., & Behrend, D. A. (2007). Two-year-olds differentially disambiguate novel words and facts. *Journal of Child Language*, *34*(4), 875–889. https://doi.org/10.1017/S0305000907008100

Shinskey, J. L., & Munakata, Y. (2005). Familiarity breeds searching- Infants reverse their novelty preferences when reaching for hidden objects. *Psychological Science*, *16*(8), 596–600. https://doi.org/10.1111/j.1467-9280.2005.01581.x

SIMD - Scottish index of multiple deprivation [database]. (n.d.). Retrieved 1 September 2019, from https://simd.scot

Smith, L., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition*, *106*(3), 1558–1568. https://doi.org/10.1016/j.cognition.2007.06.010

Squire, L., Knowlton, B., & Musen, G. (1993). The Structure and Organization of Memory. *Annual Review of Psychology*, *44*(1), 453–495. https://doi.org/10.1146/annurev.psych.44.1.453

Struys, E., Duyck, W., & Woumans, E. (2018). The role of cognitive development and strategic task tendencies in the bilingual advantage controversy. *Frontiers in Psychology*, *9*(SEP), 1790. https://doi.org/10.3389/fpsyg.2018.01790

Swingley, D., & Fernald, A. (2002). Recognition of words referring to present and absent objects by 24-month-olds. *Journal of Memory and Language*, *46*(1), 39–56. https://doi.org/10.1006/jmla.2001.2799

TarrLab. (1996). Object Data Bank. Retrieved 26 August 2020, from https://www.cmu.edu/dietrich/psychology/tarrlab/stimuli/index.html

Thompson, P. D., & Estes, Z. (2011). Sound symbolic naming of novel objects is a graded function. *Quarterly Journal of Experimental Psychology*, *64*(12), 2392–2404. https://doi.org/10.1080/17470218.2011.605898

Tincoff, R., & Jusczyk, P. W. (1999). Some Beginnings of Word Comprehension. *Psychological Science*, *10*(2), 172–175.

Tomasello, M. (2000). The social-pragmatic theory of word learning. *Pragmatics*, *10*(4), 401–413. https://doi.org/10.1075/prag.10.4.01tom

Tomasello, M. (2001). The item-based nature of children's early syntactic development. In *Language development: The essential readings.* (pp. 169–186). Malden: Blackwell Publishing.

Tomasello, M., & Barton, M. E. (1994). Learning words in nonostensive contexts. *Developmental Psychology*, *30*(5), 639.

Unsworth, S. (2013). Assessing the role of current and cumulative exposure in simultaneous bilingual acquisition: The case of Dutch gender. *Bilingualism: Language and Cognition*, *16*(01), 86–110. https://doi.org/10.1017/S1366728912000284

Unsworth, S. (2015). Amount of exposure as a proxy for dominance in bilingual language acquisition. In J. Treffers-Daller & C. Silva-Corvalán (Eds.), *Language dominance in bilinguals: Issues of measurement and operationalization* (pp. 156–173). Cambridge, UK: Cambridge University Press.

Unsworth, S. (2016). Quantity and quality of language input in bilingual language development. In E. Nicoladis & S. Montanari (Eds.), *Bilingualism across the lifespan: Factors moderating language proficiency.* (pp. 103–121). Washington: American Psychological Association. https://doi.org/10.1037/14939-007

Unsworth, S., Argyri, F., Cornips, L., Hulk, A., Sorace, A., & Tsimpli, I. (2014). The role of age of onset and input in early child bilingualism in Greek and Dutch. *Applied Psycholinguistics*, *35*(4), 765–805. https://doi.org/10.1017/S0142716412000574

Valian, V. (2015). Bilingualism and cognition. *Bilingualism*, *18*(1), 3–24. https://doi.org/10.1017/S1366728914000522

Van Geert, P. (1991). A dynamic systems model of cognitive and language growth. *Psychological Review*, *98*(1), 3–53. https://doi.org/10.1037/0033-295X.98.1.3

Vihman, M. M., Thierry, G., Lum, J., Keren-Portnoy, T., & Martin, P. (2007). Onset of word form recognition in English, Welsh, and English-Welsh bilingual infants. *Applied Psycholinguistics*, *28*(3), 475–493. https://doi.org/10.1017/S0142716407070269

Vlach, H. A., & Johnson, S. P. (2013). Memory constraints on infants' cross-situational statistical learning. *Cognition*. https://doi.org/10.1016/j.cognition.2013.02.015

Vouloumanos, A., & Werker, J. F. (2009). Infants' Learning of Novel Words in a Stochastic Environment. *Developmental Psychology*. https://doi.org/10.1037/a0016134

Wang, T., & Saffran, J. R. (2014). Statistical learning of a tonal language: The influence of bilingualism and previous linguistic experience. *Frontiers in Psychology*, *5*(AUG), 953. https://doi.org/10.3389/fpsyg.2014.00953

Waxman, S. R., & Booth, A. E. (2000). Principles that are invoked in the acquisition of words, but not facts. *Cognition*, *77*(2), B33–B43. https://doi.org/10.1016/S0010-0277(00)00103-7

Wojcik, E. H., & Saffran, J. R. (2013). The Ontogeny of Lexical Networks: Toddlers Encode the Relationships Among Referents When Learning Novel Words. *Psychological Science*, *24*(10), 1898–1905. https://doi.org/10.1177/0956797613478198

Woodward, A. L., & Markman, E. M. (1991). 'Constraints on learning as default assumptions: Comments on Merriman and Bowman's 'The mutual exclusivity bias in children's word learning': Reply. *Developmental Review*, *11*(2), 137–163. https://doi.org/0273-2297/91

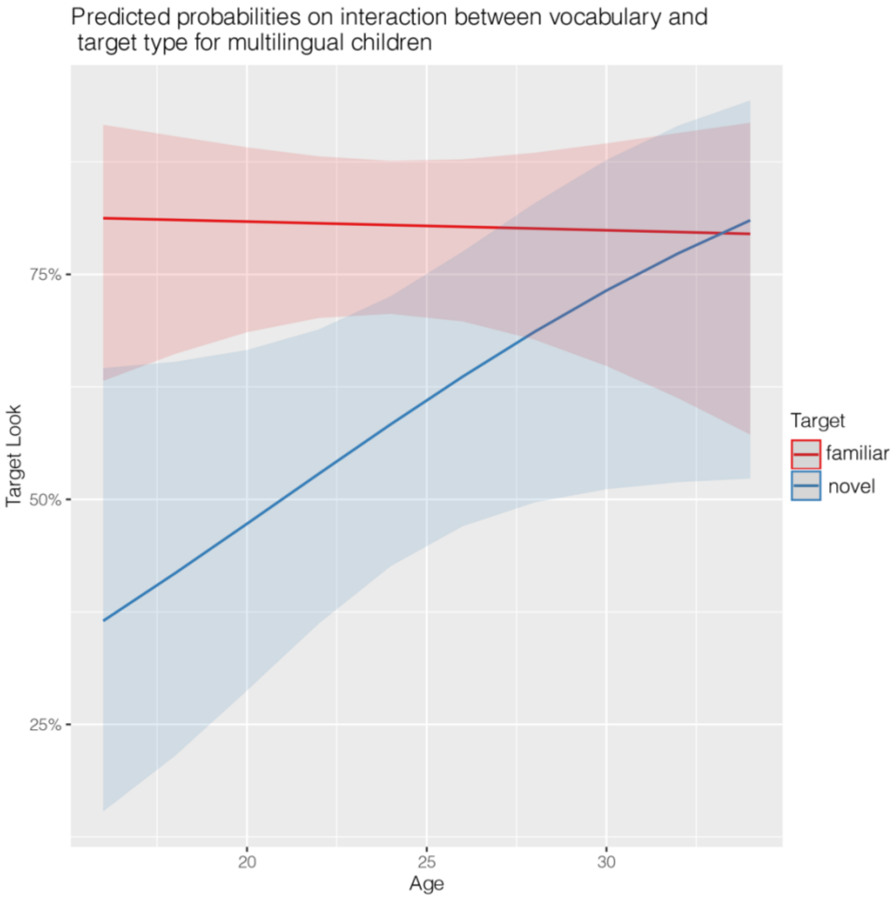
Xu, F., & Tenenbaum, J. B. (2007). Sensitivity to sampling in Bayesian word learning. *Developmental Science*, *10*(3), 288–297. https://doi.org/10.1111/j.1467-7687.2007.00590.x

Yow, W. Q., Li, X., Lam, S., Gliga, T., Chong, Y. S., Kwek, K., & Broekman, B. F. P. (2017). A bilingual advantage in 54-month-olds' use of referential cues in fast mapping. In *Developmental Science* (Vol. 20). https://doi.org/10.1111/desc.12482

Zhou, B., & Krott, A. (2016). Data trimming procedure can eliminate bilingual cognitive advantage. *Psychonomic Bulletin and Review*, *23*(4), 1221–1230. https://doi.org/10.3758/s13423-015-0981-6

Appendices

A. Appendix for Chapter 6



B. Appendix for Chapter 7

Disambiguation	**ACC**	**RT**	**Exposure English**	**Proficiency English (self-rated)**	**LexTale**	**Working memory**	**pro-/reactive control**	**Age of acquisition English**	**Number of languages**	**English as L1**
ACC	1	-0.146	0.134	0.042	0.162	-0.021	-0.097	-0.02	0.014	0.083
RT	-0.146	1	-0.001	-0.158	-0.235	0.04	0.149	-0.077	-0.174	0.037
Exposure English	0.134	-0.001	1	**0.469**	**0.522**	-0.069	-0.223	**-0.593**	**-0.423**	**0.681**
Proficiency English (self-rated)	0.042	-0.158	0.469	1	**0.637**	-0.198	-0.189	**-0.573**	-0.044	**0.488**
LexTale	0.162	*-0.235*	0.522	0.637	1	-0.115	-0.203	**-0.382**	-0.177	**0.353**
Working memory	-0.021	0.04	-0.069	-0.198	-0.115	1	0.161	0.061	-0.024	0.002
pro-/reactive control	-0.097	0.149	-0.223	-0.189	-0.203	0.161	1	0.157	0.232	-0.12
Age of acquisition English	-0.02	-0.077	-0.593	-0.573	-0.382	0.061	0.157	1	**0.309**	**-0.769**
Number of languages	0.014	-0.174	-0.423	-0.044	-0.177	-0.024	0.232	0.309	1	**-0.308**
English as L1	0.083	0.037	0.681	0.488	0.353	0.002	-0.12	-0.769	-0.308	1

Table B.1: Correlations between language experience variables and cognitive functioning variables within the Disambiguation condition. Numbers in bold indicate significant correlations.

Easy retention	**ACC**	**RT**	**Exposure English**	**Proficiency English (self-rated)**	**LexTale**	**Working memory**	**pro-/reactive control**	**Age of acquisition English**	**Number of languages**	**English as L1**
ACC	1	-0.071	0.23	0.217	**0.298**	-0.013	-0.066	-0.056	-0.088	0.186
RT	-0.071	1	-0.067	-0.238	**-0.305**	-0.056	0.212	-0.038	-0.032	0.041
Exposure English	*0.23*	-0.067	1	**0.469**	**0.522**	-0.069	-0.223	**-0.593**	**-0.423**	**0.681**
Proficiency English (self-rated)	*0.217*	*-0.238*	0.469	1	**0.637**	-0.198	-0.189	**-0.573**	-0.044	**0.488**
LexTale	***0.298***	***-0.305***	0.522	0.637	1	-0.115	-0.203	**-0.382**	-0.177	**0.353**
Working memory	-0.013	-0.056	-0.069	-0.198	-0.115	1	0.161	0.061	-0.024	0.002
pro-/ reactive control	-0.066	0.212	-0.223	-0.189	-0.203	0.161	1	0.157	0.232	-0.12
Age of acquisition English	-0.056	-0.038	-0.593	-0.573	-0.382	0.061	0.157	1	**0.309**	**-0.769**
Number of languages	-0.088	-0.032	-0.423	-0.044	-0.177	-0.024	0.232	0.309	1	**-0.308**
English as L1	0.186	0.041	0.681	0.488	0.353	0.002	-0.12	-0.769	-0.308	1

Table B.2: Correlations between language experience variables and cognitive functioning variables within the Easy Retention condition. Numbers in bold indicate significant correlations.

Hard retention	**ACC**	**RT**	**Exposure English**	**Proficiency English (self-rated)**	**LexTale**	**Working memory**	**pro-/reactive control**	**Age of acquisition English**	**Number of languages**	**English as L1**
ACC	1	**-0.381**	0.171	0.203	0.239	-0.087	-0.07	-0.089	-0.004	0.228
RT	-0.381	1	0.018	-0.206	**-0.3**	-0.142	0.108	-0.057	-0.125	0.073
Exposure English	0.171	0.018	1	**0.469**	**0.522**	-0.069	-0.223	**-0.593**	**-0.423**	**0.681**
Proficiency English (self-rated)	*0.203*	*-0.206*	0.469	1	**0.637**	-0.198	-0.189	**-0.573**	-0.044	**0.488**
LexTale	*0.239*	***-0.3***	0.522	0.637	1	-0.115	-0.203	**-0.382**	-0.177	**0.353**
Working memory	-0.087	-0.142	-0.069	-0.198	-0.115	1	0.161	0.061	-0.024	0.002
pro-/ reactive control	-0.07	0.108	-0.223	-0.189	-0.203	0.161	1	0.157	0.232	-0.12
Age of acquisition English	-0.089	-0.057	-0.593	-0.573	-0.382	0.061	0.157	1	**0.309**	**-0.769**
Number of languages	-0.004	-0.125	-0.423	-0.044	-0.177	-0.024	0.232	0.309	1	**-0.308**
English as L1	*0.228*	0.073	0.681	0.488	0.353	0.002	-0.12	-0.769	-0.308	1

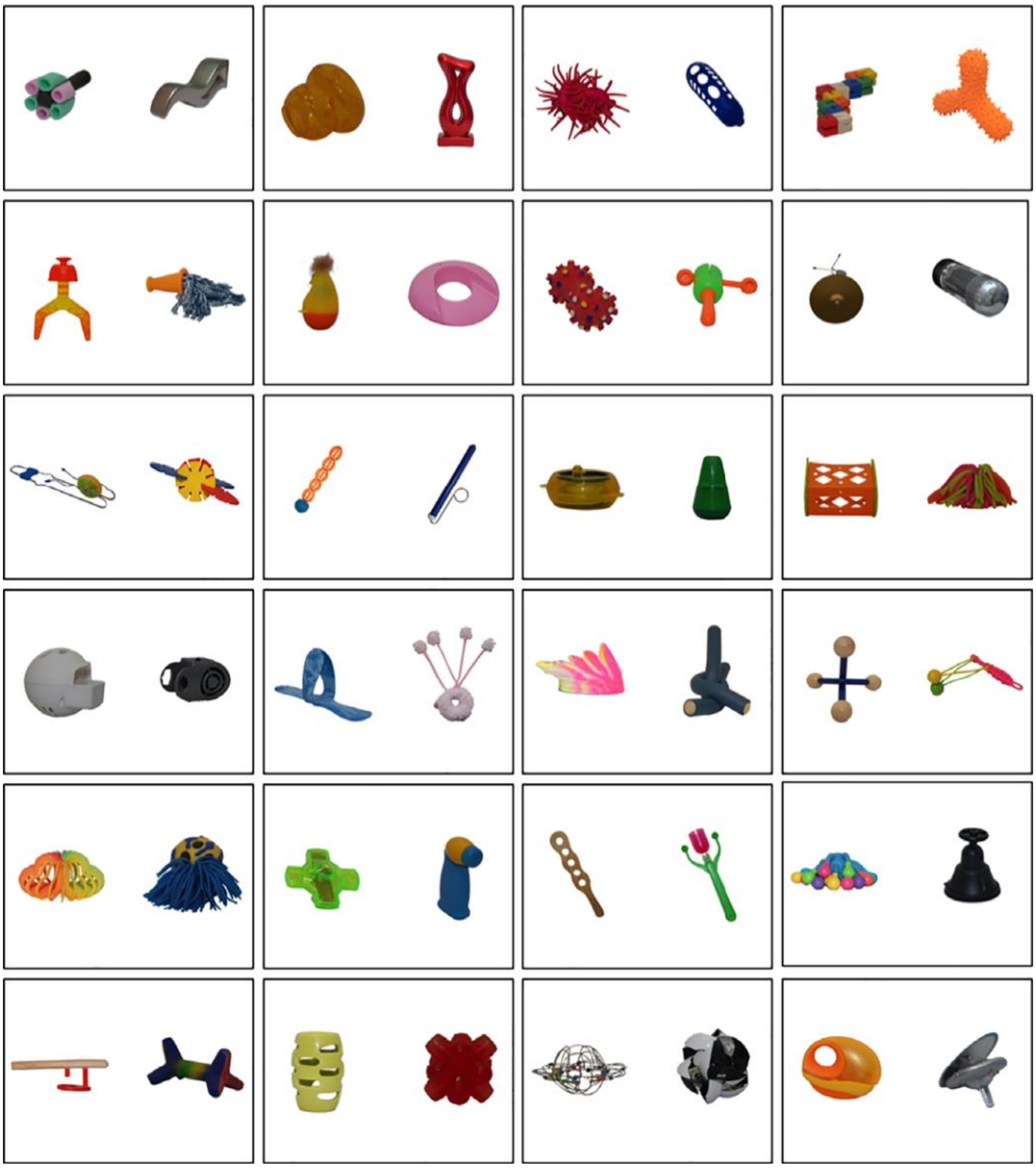
Table B.3: Correlations between language experience variables and cognitive functioning variables within the Hard Retention condition. Numbers in bold indicate significant correlations.

Reverse retention	**ACC**	**RT**	**Exposure English**	**Proficiency English (self-rated)**	**LexTale**	**Working memory**	**pro-/reactive control**	**Age of acquisition English**	**Number of languages**	**English as L1**
ACC	1	-0.223	**0.242**	0.215	0.202	-0.144	-0.15	-0.082	-0.1	0.108
RT	-0.223	1	-0.051	-0.126	**-0.287**	-0.133	0.222	0.001	-0.105	0.044
Exposure English	***0.242***	-0.051	1	**0.469**	**0.522**	-0.069	-0.223	**-0.593**	**-0.423**	**0.681**
Proficiency English (self-rated)	*0.215*	-0.126	0.469	1	**0.637**	-0.198	-0.189	**-0.573**	-0.044	**0.488**
LexTale	*0.202*	***-0.287***	0.522	0.637	1	-0.115	-0.203	**-0.382**	-0.177	**0.353**
Working memory	-0.144	-0.133	-0.069	-0.198	-0.115	1	0.161	0.061	-0.024	0.002
pro-/ reactive control	-0.15	*0.222*	-0.223	-0.189	-0.203	0.161	1	0.157	0.232	-0.12
Age of acquisition English	-0.082	0.001	-0.593	-0.573	-0.382	0.061	0.157	1	**0.309**	**-0.769**
Number of languages	-0.1	-0.105	-0.423	-0.044	-0.177	-0.024	0.232	0.309	1	**-0.308**
English as L1	0.108	0.044	0.681	0.488	0.353	0.002	-0.12	-0.769	-0.308	1

Table B.4: Correlations between language experience variables and cognitive functioning variables within the Reverse Retention condition. Numbers in bold indicate significant correlations.

C. Appendix for Chapter 8

Novel object pairings – Examples



Verbal Stimuli

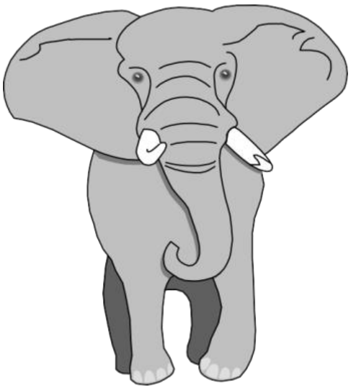
Labels		
toma	mido	zepper
dawnoo	coodle	tulver
wuggy	teega	sibu
kita	smope	posk
wiso	fimp	juff
vab	mensey	deeba
yok	hux	koba
pabey	mido	kinch
bink	coodle	zepper
Facts		
I got for Christmas.	from London.	from Aberdeen.
I bought in a department store.	I got last week.	my dad bought.
I keep in my living room.	my sister gave to me.	I keep in my car.
I keep at home.	I got from a friend.	I keep in my wardrobe.
I keep in my bedroom.	from Ireland.	I got for graduation.
I use at work.	I got in the supermarket.	I got from Thailand
I got online.	I got for my birthday.	I got last year.
my dog likes to play with.	my cat likes to eat.	my aunty loves.

D. Language Background Questionnaires

MacArthur Communicative Development Inventory

Child's Name:___________________________________Sex: ___________

Date of Birth:___________Age:____________Today's Date: ____________



The MacArthur Communicative Development

British English Adaptation

A. VOCABULARY CHECKLIST
Children understand many more words than they say. We are particularly interested in the words your child SAYS. Please go through the list and mark the words you have heard your child use. If your child uses a different pronunciation of a word (for example, "raffe" instead of "giraffe" or "sketti" for "spaghetti"), mark the word anyway. Remember that this is a "catalogue"

1. SOUND EFFECTS AND ANIMAL SOUNDS		
baa baa	meow	uh oh
choo choo	moo	vroom
cockadoodledoo	ouch	woof woof
grr	quack quack	yum yum

2. ANIMALS (Real or Toy)		
animal	duck	owl
ant	elephant	penguin
bear	fish	pig
bee	frog	pony
bird	giraffe	puppy
bunny	goose	sheep
butterfly	hen	squirrel
cat	horse	teddybear
chicken	insect/fly	tiger
cockerel	kitty	turkey
cow	lamb	turtle
crocodile	lion	wolf
deer	monkey	zebra
dog	moose	
donkey	mouse	

3. VEHICLES (Real or Toy)

aeroplane	fire-engine	sledge
bicycle	helicopter	tractor
boat	lorry	train
bus	motorbike	tricycle
car	pram	

4. TOYS

ball	chalk	pen
balloon	crayon	pencil
bat	doll	play dough
block	game	present
book	glue	story
bubbles	jigsaw	toy

5. FOOD AND DRINK

apple	fish	pickle
applesauce	food	pizza
banana	grapes	popcorn
beans	green beans	potato
biscuit	hamburger	pretzel
bread	ice	pudding
butter	ice cream	pumpkin
cake	icepop/icelolly	raisin
carrots	jam	salt
cereal	jelly	sandwich
cheese	juice/fizzy juice	sauce
chewing gum	lollipop	soup
chicken	meat	spaghetti
chips	melon	strawberry
chocolate	milk	sweetcorn
coffee	muffin	sweets
coke	noodles	toast
cracker	nuts	tuna
crisps	orange	vanilla
doughnut	pancake	vitamins
drink	peanut butter	water
egg	peas	yogurt

6. CLOTHING

beads	jeans	slipper
belt	jumper	sock
bib	mittens	sweatshirt
boots	nappy	tights
button	necklace	trainers
coat	pyjamas	trousers
dress	scarf	underpants
gloves	shirt	zip
hat	shoe	
jacket	shorts	

7. BODY PARTS		
ankle ☐	feet ☐	nose ☐
arm ☐	finger ☐	penis* ☐
belly button ☐	hair ☐	shoulder ☐
buttocks/bottom* ☐	hand ☐	tooth ☐
cheek ☐	head ☐	toe ☐
chin ☐	knee ☐	tongue ☐
ear ☐	leg ☐	tummy ☐
eye ☐	lips ☐	vagina* ☐
face ☐	mouth ☐	

*or word used in

8. SMALL HOUSEHOLD ITEMS		
basket ☐	hammer ☐	plant ☐
blanket ☐	hoover ☐	plate ☐
bottle ☐	jar ☐	purse ☐
bowl ☐	keys ☐	radio ☐
box ☐	knife ☐	rubbish ☐
brush ☐	lamp ☐	scissors ☐
bucket ☐	light ☐	soap ☐
camera ☐	medicine ☐	spoon ☐
can ☐	money ☐	tape ☐
clock ☐	mop ☐	telephone ☐
comb ☐	nail ☐	tissue/kleenex ☐
cup ☐	napkin ☐	toothbrush ☐
dish ☐	paper ☐	towel ☐
fork ☐	penny ☐	watch ☐
glass ☐	picture ☐	
glasses ☐	pillow ☐	

9. FURNITURE AND ROOMS		
bath ☐	garage ☐	shower ☐
bathroom ☐	high chair ☐	sink ☐
bed ☐	kitchen ☐	sofa ☐
bedroom ☐	living room ☐	stairs ☐
bench ☐	oven ☐	stove ☐
cellar ☐	playpen ☐	table ☐
chair ☐	porch ☐	TV ☐
cot ☐	potty ☐	wardrobe ☐
door ☐	refrigerator ☐	washing machine ☐
drawer ☐	rocking chair ☐	window ☐
dryer ☐	room ☐	

10. OUTSIDE THINGS		
backyard ☐	pool ☐	star ☐
cloud ☐	rain ☐	stick ☐
flag ☐	rock ☐	stone ☐
flower ☐	roof ☐	street ☐
garden ☐	sandpit ☐	sun ☐
grass ☐	sky ☐	swing ☐
hose ☐	slide ☐	tree ☐
ladder ☐	snow ☐	water ☐
lawn mower ☐	snowman ☐	wind ☐
moon ☐	spade ☐	
pavement ☐	sprinkler ☐	

11. PLACES TO GO		
beach	home	school
camping	house	shop
church*	outside	woods
circus	park	work
city centre, town	party	yard
country	petrol station	zoo
farm	picnic	
film	playground	

*or word used in

12. PEOPLE		
aunt	doctor	child's own name
baby	fireman	people
babysitter	friend	person
babysitter's name	girl	pet's name
boy	grandma*	police
brother	grandpa*	postman
child	lady	sister
clown	man	teacher
cowboy	mummy*	uncle
daddy*	nurse	

*or word used in

13. GAMES AND ROUTINES		
bath	lunch	shopping
breakfast	nap	snack
bye	night night	so big!
dinner	no	thank you
give me five!	patty cake	this little piggy
gonna get you!	peekaboo	turn around
go potty	phone	yes
hi	please	
hello	shh/shush/hush	

14. ACTION WORDS				
bite	drink	hold	read	swim
blow	drive	hurry	ride	swing
break	drop	jump	rip	take
bring	dry	kick	run	talk
build	dump	kiss	say	taste
bump	eat	knock	see	tear
buy	fall	lick	shake	think
carry	feed	like	share	throw
catch	find	listen	show	tickle
chase	finish	look	sing	touch
clap	fit	love	sit	wait
clean	fix	make	skate	wake
climb	get	open	sleep	walk
close	give	paint	slide	wash
cook	go	pick	smile	watch
cover	hate	play	spill	wipe
cry	have	pour	splash	wish
cuddle	hear	pretend	stand	work
cut	help	pull	stay	write
dance	hide	push	stop	
draw	hit	put	sweep	

15. DESCRIPTIVE WORDS		
allgone	full	orange
asleep	gentle	poor
awake	good	pretty
bad	green	quiet
better	happy	red
big	hard	sad
black	heavy	scared
blue	high	sick
broken	hot	sleepy
brown	hungry	slow
careful	hurt	soft
clean	last	sticky
cold	little	stuck
cute	long	thirsty
dark	loud	tiny
dirty	mad	tired
dry	naughty	wet
empty	new	white
fast	nice	windy
fine	noisy	yellow
first	old	yucky

16. WORDS ABOUT TIME		
after	morning	today
before	night	tomorrow
day	now	tonight
later	time	yesterday

17. PRONOUNS			
he	me	their	we
her	mine	them	you
hers	my	these	your
him	myself	they	yourself
his	our	this	
I	she	those	
it	that	us	

18. QUESTION WORDS			
how	when	which	why
what	where	who	

19. PREPOSITIONS AND LOCATIONS		
about	down	on top of
above	for	out
around	here	over
at	inside/in	there
away	into	to
back	next to	under
behind	of	up
beside	off	with
by	on	

20. QUANTIFIERS AND ARTICLES					
a	☐	each	☐	other	☐
all	☐	every	☐	same	☐
a lot	☐	more	☐	some	☐
an	☐	much	☐	the	☐
another	☐	not	☐	too	☐
any	☐	none	☐		

21. HELPING VERBS					
am	☐	does	☐	need/need to	☐
are	☐	don't	☐	try/try to	☐
be	☐	gonna/going to	☐	want to	☐
can	☐	gotta/got to	☐	was	☐
could	☐	hafta/have to	☐	were	☐
did/did you	☐	is	☐	will	☐
do	☐	lemme/let me	☐	would	☐

22. CONNECTING WORDS					
and	☐	but	☐	so	☐
because	☐	if	☐	then	☐

B. HOW CHILDREN USE WORDS	Not Yet	Sometimes	Often
1. Does your child ever talk about past events or people who are not present? For example, a child who went to the circus last week might later say circus, clown or band			
2. Does your child ever talk about something that's going to happen in the future, for example, saying "choo choo" or "aeroplane" before you leave the house for a trip, or saying "swing" when you are going			
3. Does your child talk about objects that are not present such as asking about a missing or absent toy, referring to a pet out of view, or asking about someone not present?			
4. Does your child understand if you ask for something that is not in the room, for example, by going to the bedroom to get a teddy bear when you say "where's the bear?"			
5. Does your child ever pick up or point to an object and name an absent person to whom the object belongs? For example, a child might point to mammy's shoe and say "mammy".			

PART II – SENTENCES AND GRAMMAR

A. WORD ENDINGS/PART I	Not Yet	Sometimes	Often
1. To talk about more than one thing, we add an 's' to many words. Examples include cars (for more than one car), shoes, dogs and keys. Has your child begun to do this?			
2. To talk about ownership, we add an 's', for example, Daddy's key, kitten's dish and baby's bottle. Has your child begun to do this?			
3. To talk about activities, we sometimes add 'ing' to verbs. Examples include looking, running and crying. Has your child begun to do this?			
4. To talk about things that happened in the past, we often add 'ed' to the verb. Examples include kissed, opened and pushed. Has your child begun to do this?			

B. WORD FORMS

Following are some other words children learn. Please mark any of these words that your child uses.

NOUNS

children ☐	men ☐	teeth ☐
feet ☐	mice ☐	

VERBS

ate ☐	fell ☐	made ☐
blew ☐	flew ☐	ran ☐
bought ☐	got ☐	sat ☐
broke ☐	had ☐	saw ☐
came ☐	heard ☐	took ☐
drank ☐	held ☐	went ☐
drove ☐	lost ☐	

C. WORD ENDINGS/PART 2

Young children often place the wrong endings on words, for example, a child might say "Auntie goed home". Mistakes like this are often a sign of progress in language. In the following lists, please mark all the mistakes of this kind you have heard your child say recently.

NOUNS

blockses ☐	mans ☐	sockses ☐
childrens ☐	mens ☐	teeths ☐
childs ☐	mices ☐	toeses ☐
feets ☐	mouses ☐	tooths ☐
foots ☐	shoeses ☐	

VERBS

ated ☐	comed ☐	goed ☐	ranned ☐
blewed ☐	doed ☐	gotted ☐	runned ☐
blowed ☐	dranked ☐	haved ☐	seed ☐
bringed ☐	drinked ☐	heared ☐	satted ☐
buyed ☐	eated ☐	holded ☐	sitted ☐
breaked ☐	falled ☐	losed ☐	taked ☐
broked ☐	flied ☐	losted ☐	wented ☐
camed ☐	getted ☐	maked ☐	

HAS YOUR CHILD BEGUN TO COMBINE WORDS YET, SUCH AS "NOTHER BISCUIT", OR "DOGGIE BITE"?

So

IF YOU ANSWERED NOT YET, PLEASE STOP HERE. IF YOU ANSWERED SOMETIMES OR OFTEN, PLEASE CONTINUE.

D. EXAMPLES: Please list three of the longest sentences you have heard your child say recently.

E. COMPLEXITY

In each of the following pairs, please mark the one that sounds MOST like the way your child talks right now. If your child is saying sentences even longer or more complicated than the two provided, just pick the second one.

Two shoe. ☐
Two shoes. ☐

Two foot. ☐
Two feet. ☐

Daddy car. ☐
Daddy's car ☐

(Talking about something happening right now)
Kitten sleep. ☐
Kitten sleeping. ☐

(Talking about something happening right now)
I make tower. ☐
I making tower. ☐

(Talking about something that already happened)
I fall down. ☐
I fell down. ☐

More biscuit! ☐
More biscuits! ☐

These my tooth. ☐
These my teeth. ☐

I want that. ☐
I want that one you got. ☐

Turn on light. ☐
Turn on the light so ☐

Baby blanket. ☐
Baby's blanket. ☐

Doggie table. ☐
Doggie on table. ☐

That my lorry. ☐
That's my lorry. ☐

(Talking about something that already happened)
Daddy pick me up. ☐
Daddy picked me up. ☐

(Talking about something that already happened)
Kitten go away. ☐
Kitten went away. ☐

(Talking about something that already happened)
Doggie kiss me. ☐
Doggie kissed me. ☐

Baby crying. ☐
Baby is crying. ☐

You fix it. ☐
Can you fix it? ☐

Baby want eat. ☐
Baby want to eat. ☐

Read me story, ma/ummy. ☐
Read me a story, ma/ummy. ☐

No wash dolly. ☐
Don't wash dolly. ☐

Want more juice. ☐
Want juice in there. ☐

There a kitten. ☐
There's a kitten. ☐

Go bye-bye. ☐
Want go bye-bye. ☐

Where ma/ummy go? ☐
Where did ma/ummy go? ☐

Coffee hot. ☐
That coffee hot. ☐

I no do it. ☐
I can't do it. ☐

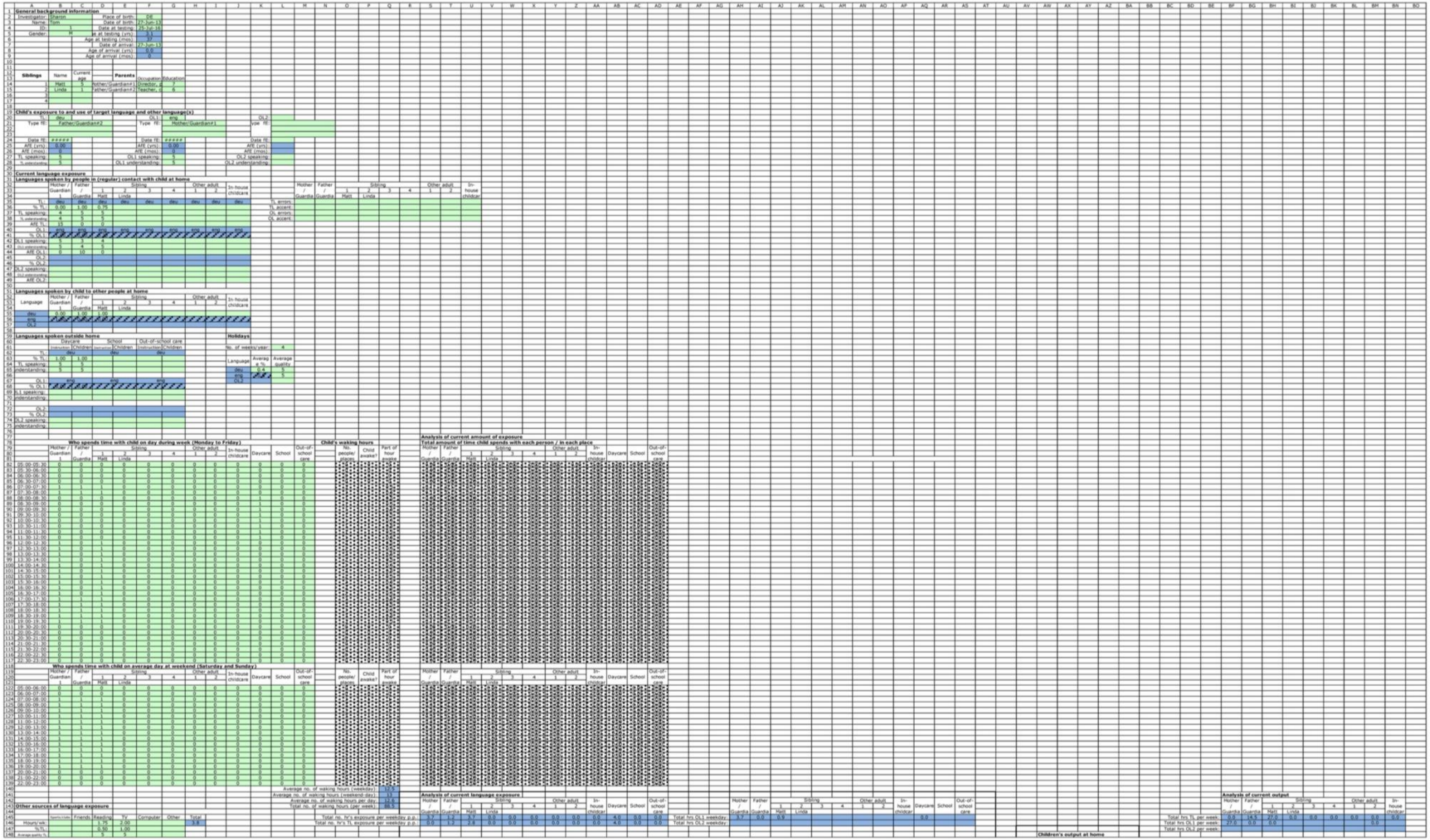
I like read stories. ☐
I like to read stories. ☐

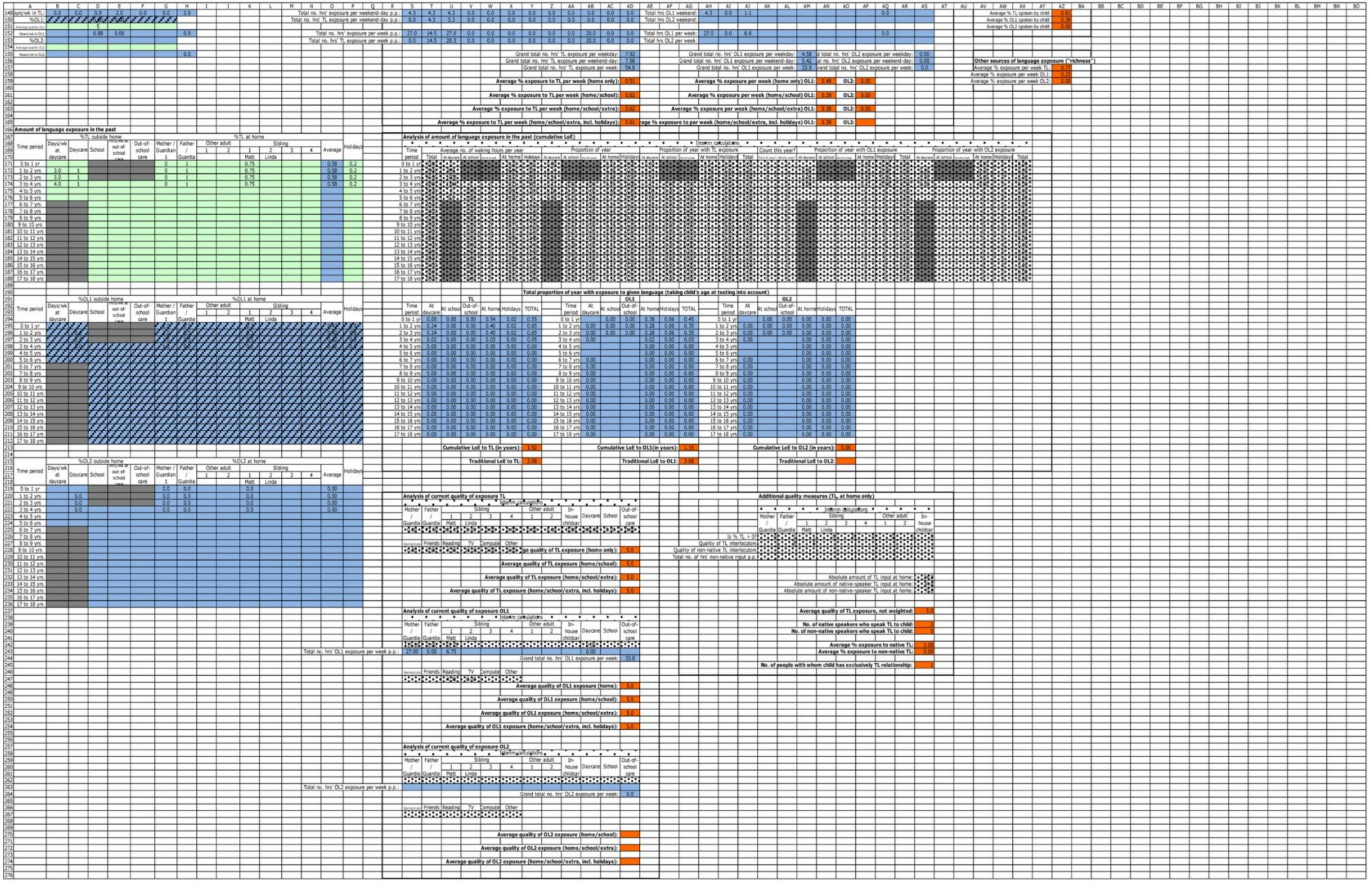
Don't read book. ☐
Don't want you read that book. ☐

We made this. ☐
Me and Paul made this ☐

OTHER COMMENTS:

Bilingual Experience Language Calculator




Amount of language exposure in the past
Analysis of amount of language exposure in the past (cumulative LoE)
Total proportion of year with exposure to given language (taking child's age at testing into account)
Cumulative LoE to TL (in years):
Traditional LoE to TL:
Cumulative LoE to OL1(in years):
Traditional LoE to OL1:
Cumulative LoE to OL2 (in years):
Traditional LoE to OL2:
Average % exposure to TL per week (home only):
Average % exposure to TL per week (home/school):
Average % exposure to TL per week (home/school/extra):
Average % exposure to TL per week (home/school/extra, incl. holidays):
Other sources of language exposure ("richness")
Analysis of current quality of exposure TL
Analysis of current quality of exposure OL1
Analysis of current quality of exposure OL2
Additional quality measures (TL, at home only)
Average quality of TL exposure (home only):
Average quality of TL exposure (home/school):
Average quality of TL exposure (home/school/extra):
Average quality of TL exposure (home/school/extra, incl. holidays):
Average quality of OL1 exposure (home):
Average quality of OL1 exposure (home/school):
Average quality of OL1 exposure (home/school/extra):
Average quality of OL1 exposure (home/school/extra, incl. holidays):
Average quality of OL2 exposure (home/school):
Average quality of OL2 exposure (home/school/extra):
Average quality of OL2 exposure (home/school/extra, incl. holidays):
Average quality of TL exposure, not weighted:
No. of native speakers who speak TL to child:
No. of non-native speakers who speak TL to child:
Average % exposure to native TL:
Average % exposure to non-native TL:
No. of people with whom child has exclusively TL relationship:

LEAP-Q (online adaptation with additional questions)

Hello!

Thank you for signing up to our language learning study.
Soon you will be asked to tell us more about your language experience.
The experiment consists of two sessions:

an **online** questionnaire about your language background which you are about to fill out.

an **in-person** session scheduled individually between you and the experimenter.

NB: No matter how many languages you speak or know, everyone is asked to fill in this questionnaire if they want to proceed to the in-person session. This will take between 10-15 minutes. We know this is a significant amount of time and we really appreciate your effort. Make sure you will be undisturbed when you answer these questions, as it will speed up things.

The next page will detail what kind of study we're doing, what your rights are, and what will be done with your data. You should print or save this page for your records.

Nature of the study. You are invited to participate in a study which involves a series of tasks: first you will be asked to fill out an online questionnaire about your language background. During your scheduled session, you are asked to participate in two experiments where you look at pairs of images whilst listening to sentences, and respond via button press. Your answers will be recorded. Furthermore, you will sometimes be asked why you have chosen certain answers; your response will be audio recorded. In addition, you are asked to perform three short tasks: (1) one measures your English proficiency, (2) one measures your working memory, and (3) one measures a variety of cognitive functions. All your responses will be recorded. Your session should last for up to 60 minutes. You will be given full instructions shortly.

Compensation. You will be compensated with £7.50.

Risks and benefits. There are no known risks to participation in this study. Other than the compensation mentioned, there are no tangible benefits to you, however you will be contributing to our knowledge about language.

Confidentiality and use of data. All the information we collect during the course of the research will be processed in accordance with Data Protection Law. In order to safeguard your privacy, we will never share personal information (like your name) with anyone outside the research team. Your data will be referred to by a unique participant number rather than by name). Please note that we will temporarily collect your student ID/email address to prevent repeat participation, however we will never share this information with anyone outside the research team. We will store any personal data (i.e., name, student ID, email address, audio recordings) using a password protected, encrypted hard drive/laptop. The anonymised data collected during this study will be used for research purposes. With your permission, identifiable data such as recordings may also be used for research or teaching purposes, and may be shared with other researchers.

What are my data protection rights? The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Voluntary participation and right to withdraw. Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you withdraw from the study during or after data gathering, we will delete your data and there is no penalty or loss of benefits to which you are otherwise entitled. If you have any questions about what you've just read, please feel free to ask, or contact us later. You can contact us by email at. This project has been approved by PPLS Ethics committee. If you have questions or comments regarding your rights as a participant, they can be contacted at 0131 650 4020 or ppls.ethics@ed.ac.uk.

By clicking **I ACCEPT,** you consent to the following:

I agree to participate in this study. I confirm that I have read and understood **how my data will be stored and used**. I understand that only by filling in the online section of this study will I be eligible to attend the in-person session. I understand that I have the **right to terminate this online-session or the in-person session** at any point. If I choose to **withdraw after completing the study**, my data will be deleted at that time.

○ I ACCEPT (1)

○ I DO NOT ACCEPT (2)

Please enter your date of birth (DD/MM/YYYY):

____

Please enter your gender:

○ Male (1)

○ Female (2)

○ Other (3)

Is your first language English?

- ◯ Yes (5)
- ◯ No (6)

Please check your highest COMPLETED education level (or the approximate UK equivalent to a degree obtained in another country):

- ◯ Less than secondary education (1)
- ◯ Nat5/GCSE (Year 11) (2)
- ◯ Highers/A-levels (Year 13) (3)
- ◯ International Baccalaureate (IB) (4)
- ◯ College (e.g. HNC/HND) (5)
- ◯ Apprenticeship (6)
- ◯ Undergraduate (e.g. BSc/MA(hons)/BA) (7)
- ◯ Post-graduate diploma (below Master-level) (8)
- ◯ Master's (e.g. MSc, MPhil) (9)
- ◯ Doctorate (e.g. PhD, MD, JD) (10)

Date when you came to the UK (if applicable)

____

If you have ever immigrated to another country, please provide name of country and date of immigration here.

____

Have you ever had any of the following? (Tick all that apply - if yes, please specify in next question)

☐ Vision impairment (1)

☐ language disability (2)

☐ Hearing impairment (3)

☐ Learning disability (4)

Please specify any disabilities or impairments and their correction:

Please list all the languages you know (in any order):

○ Language 1 ____

○ Language 2 ____

○ Language 3 ____

○ Language 4 ____

○ Language 5 ____

Please rank the languages you know **in order of dominance:**

______ Language 1 (1)

______ Language 2 (2)

______ Language 3 (3)

______ Language 4 (4)

______ Language 5 (5)

Please rank the languages you know in **order of acquisition** (starting with your native/earliest language):

______ Language 1 (1)

______ Language 2 (2)

______ Language 3 (3)

______ Language 4 (4)

______ Language 5 (5)

Please list what percentage of time you are *currently* and *on average* exposed to each language (your percentage should add up to 100%):

Language 1 : _______ (1)

Language 2 : _______ (2)

Language 3 : _______ (3)

Language 4 : _______ (4)

Language 5 : _______ (5)

Total : ________

When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you.
(Your percentages should add up to 100%):

Language 1 : _______ (1)

Language 2 : _______ (2)

Language 3 : _______ (3)

Language 4 : _______ (4)

Language 5 : _______ (5)

Total : ________

When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time. (Your percentages should add up to 100%):

Language 1 : _______ (1)

Language 2 : _______ (2)

Language 3 : _______ (3)

Language 4 : _______ (4)

Language 5 : _______ (5)

Total : ________

Please name the cultures with which you identify. (Examples of possible cultures include Scottish, Welsh, English, European, US-American, Chinese, Jewish-Orthodox, etc):

- ○ Culture (1) ________________________________
- ○ Culture (2) ________________________________
- ○ Culture (3) ________________________________
- ○ Culture (4) ________________________________
- ○ Culture (5) ________________________________

On a scale from 0 to 10, please rate the extent to which you identify with each culture.

	0 - No identification	1- Very low identification	2	3	4	5- moderate identification	6	7	8	9	10 - Complete identification
Culture	○	○				○					○
Culture	○	○				○					○
Culture	○	○				○					○
Culture	○	○				○					○
Culture	○	○				○					○

How many years of formal education do you have? (Please include tertiary education, such as university, etc.)

____

The following questions refer to your knowledge of Language 1 (the below block was repeated for each entered language)

Ages when you ... (if you're not fluent speaking and/or reading, please set the value to ZERO)

	-1 4 9 14 20 25 30 35
began acquiring Language 1 ()	
became fluent speaking in Language 1 ()	
began reading in Language 1 ()	
became fluent reading in Language 1 ()	

Please list the number of years and months you spent in each language environment:

	Years (1)	Months (2)
A country where Language 1 is spoken (1)		
A family where Language 1 is spoken (2)		
A school/ or working environment where Language 1 is spoken (3)		

On a scale from 1 to 10, please select your ***level of <u>proficiency</u>*** in speaking, understanding, and reading Language 1:

	1 - none	2 - very low	3 - low	4 - fair	5 - slightly less than adequate	6 - adequate	7 - slightly more than adequate	8 - good	9 - very good	10 - excellent
Speaking			○		○	○	○	○	○	○
Understanding			○		○	○	○	○	○	○
Reading			○		○	○	○	○	○	○

Please select how much the following factors contributed to you learning Language 1:

	A great deal (1)	A lot (2)	A moderate amount (3)	A little (4)	None at all (5)
Interacting with family (1)	○	○	○	○	○
Interacting with friends (2)	○	○	○	○	○
Reading (3)	○	○	○	○	○
Watching TV/films/series (4)	○	○	○	○	○
Language tapes/self instruction/ apps (5)	○	○	○	○	○
Listening to the radio/music (6)	○	○	○	○	○

Please rate to what extent you are currently exposed to Language 1 in the following contexts:

	Always (1)	Most of the time (2)	About half the time (3)	Sometimes (4)	Never (5)
Interacting with family (1)	○	○	○	○	○
Interacting with friends (2)	○	○	○	○	○
Reading (3)	○	○	○	○	○
Watching TV/films/series (4)	○	○	○	○	○
Language tapes/self instruction/ apps (5)	○	○	○	○	○
Listening to the radio/music (6)	○	○	○	○	○

In your perception, how much of a foreign accent do you have in Language 1:

	none (1)	almost none (2)	very light (3)	light (4)	some (5)	moderate (6)	considerable (7)	heavy (8)	very heavy (9)	extremely heavy (10)	pervasive (11)
Accent in Language 1 (1)	○	○	○	○	○	○	○	○	○	○	○

Please rate how frequently others identify you as a non-native speaker based on your accent in Language 1

	Always (1)	Most of the time (2)	About half the time (3)	Sometimes (4)	Never (5)
being identified as non-native (1)	○	○	○	○	○