The lifelong interplay between language and cognition:
from language learning to perspective-taking, new insights
into the ageing mind

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Declaration

I declare that the thesis has been composed by myself and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work which has formed part of jointly-authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

Madeleine Long
Edinburgh, February 9, 2018

Abstract

A fundamental question in language research is the extent to which linguistic and cognitive systems interact. The aim of this thesis is to explore that relationship across new contexts and over the entire adult lifespan. This work centers on two branches of empirical research: the first is an investigation into the impact of later-life language learning on cognitive ageing (**chapters 2-4**), and the second examines the cognitive mechanisms underlying communicative perspective-taking from young adulthood into old age (**chapter 5**). The results of these chapters demonstrate that changes to one's linguistic environment can affect cognitive functions at any age, and similarly age-related changes to cognition can affect linguistic abilities, shedding light on the extent to which language and the brain are intricately connected over the lifespan. In the discussion (**chapter 6**), I consider how this work contributes new insights to the field, opening the door for future research to explore methods of improving cognitive abilities and linguistic behavior in old age.

Lay summary

Psycholinguistic research examines how mechanisms in our brain allow us to carry out the complex processes involved in acquiring, interpreting, and producing language. While our understanding of language and cognition continues to expand, more work is needed to address the extent to which linguistic and cognitive systems influence each other over the lifespan. This thesis delves into that relationship by examining: i.) how later-life language learning affects cognitive ageing and ii.) how age-related changes to the brain affect language use.

To address the first inquiry, I tested adult language learners before and after intensive one-week language courses using tasks measuring attentional functions. I found that language learners' attention improved following the course, and that those who continued practicing for five or more hours per week maintained this improvement nine months later. While older and younger adults differed in their overall attentional performance, the positive impact of language learning on attention was detectable across all ages. I also found that those in higher-level courses initially exhibited better attentional control, whereas those in lower levels improved the most, likely due to the novelty and challenge associated with learning a completely foreign language. Attentional improvement was found in learners of a wide range of spoken languages including Gaelic, Norwegian, and Turkish as well as British Sign Language.

To address the second inquiry, I tested adults using tasks measuring attention and the ability to consider a partner's perspective in conversation. Results showed that older adults were less likely to consider their partner's perspective than

younger adults, and that attentional functions predicted this ability. Interestingly, younger and older adults showed distinct patterns which suggest that as we age we may rely on different attentional mechanisms to guide our ability to consider another's perspective in conversation.

Overall, this thesis demonstrates that changes to one's linguistic environment (e.g. learning a language) can affect brain functions, and similarly age-related changes to the brain can affect linguistic abilities, shedding light on the extent to which language and the brain are intricately connected. These insights pave the way for future studies to explore methods of improving brain functions and linguistic behavior in old age.

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Publications

Each of the following chapters has been adapted from a paper that was published or submitted for publication.

The work in **Chapter 2** was adapted from a paper published in PLoS One as:

Novelty, challenge, and practice: the impact of intensive language learning on attentional functions, by Thomas Bak (supervisor), Madeleine Long, Mariana Vega-Mendoza (collaborator), and Antonella Sorace (supervisor).

Summary of contribution: This study was conceived by all of the authors. I collected the data, performed the statistical analyses along with Mariana Vega-Mendoza, and created the tables and graphs. All authors contributed to writing the paper.

The work presented in **Chapter 3** was adapted from a paper submitted for publication as:

The role of novelty and familiarity in the impact of language learning on cognitive performance, by Madeleine Long, Mariana Vega-Mendoza (collaborator), Hannah Rohde (supervisor), Antonella Sorace (supervisor), and Thomas Bak (supervisor).

Summary of contribution: This study was conceived by all of the authors. I collected the data and along with Hannah Rohde I performed the statistical analyses, and created the tables and graphs. All authors contributed to writing the paper.

The work presented in **Chapter 4** was adapted from a paper submitted for publication as:

Cognitive psychology meets sociolinguistics: effects of brief intensive language learning on attentional functions and language attitudes, by Madeleine Long, Graham Turner (collaborator), Mariana Vega-Mendoza (collaborator), Antonella Sorace (supervisor), and Thomas Bak (supervisor).

Summary of contribution: This study was conceived by all of the authors. Mariana Vega-Mendoza and I collected the data. I performed the statistical analyses, and created the tables and graphs. All authors contributed to writing the paper.

The work presented in **Chapter 5** was adapted from a paper published in Cognition as:

Individual differences in switching and inhibition predict perspective-taking across the lifespan, by Madeleine Long, William (Sid) Horton (collaborator), Hannah Rohde (supervisor), and Antonella Sorace (supervisor).

This study was conceived by all of the authors. I collected and coded the data, and along with Sid Horton and Hannah Rohde I performed the statistical analyses, and created the tables and graphs. All authors contributed to writing the paper.

Chapter 1

Chapter overview

This thesis investigates the relationship between language and cognition over the lifespan. In the introduction, I establish the background for each of the four studies presented in this thesis. The first three studies examine the effects of language learning on cognitive ageing (chapters 2-4) and the last study examines the effects of cognitive ageing on perspective-taking (chapter 5).

I begin this chapter by providing a brief history of research on language learning within bilingualism (**section 1.1**) and cognitive ageing (**section 1.2**). Subsequently, I discuss the relationship between bilingualism and cognitive control (**section 1.3**), by outlining influential models surrounding bilingualism and attention. Based on these models, I provide general predictions for chapters 2-4. Further, I provide an overview of key literature, from studies on early balanced bilinguals to language learning in young adulthood, leading directly into descriptions of the work carried out in chapters 2-4 and specific predictions for each chapter. In **section 1.4**, I review models of perspective-taking and cognitive functions and make general predictions for chapter 5 based on these models. In addition, I outline key literature on perspective-taking, from children to young adults and clinical populations, identifying a set of questions raised by prior studies that are subsequently addressed in chapter 5. Finally, in **section 1.5**, I provide a brief outline of the thesis.

1.1 Bilingualism research: a brief history

Dating back to the turn of the century, early literature on bilingualism was dominated by the view that knowledge of more than one language negatively impacted intelligence and proficiency levels (Hakuta, 1985). This view was partly based on the notion that bilingual code switching was indicative of mental confusion and linguistic deficiency (Saer, 1923). However, during the birth of cognitive science, in which linguists, psychologists, and neuroscientists came together to study the mind and brain, a seminal study by Peal & Lambert (1962) was published. In the study, researchers found that bilingual children experienced enhanced mental flexibility compared to their monolingual counterparts, including better performance on both verbal and non-verbal intelligence tests and a more diversified set of mental abilities. These results not only challenged the status quo of that era, demonstrating for the first time that code switching may in fact contribute to better developmental skills, but paved the way for a surge in research on bilingualism and cognition for decades to come.

1.2. Cognitive ageing research: a brief history

At around the same time that perceptions of bilingualism swung from one end of the pendulum to the other, a perspective shift in the field of cognitive neuroscience was also taking place. Scientists went from a previously widespread view of the brain as fundamentally static to an understanding that the brain is continuously changing throughout the lifetime, including in old age.

The idea of a fixed state became popularized by Broca's influential 1861 studies on aphasia, in which he linked deficits in language production to the left hemisphere of the brain, supporting the notion that cognitive functions could be

localized to specific areas. Over the next 100 years, this localization theory led to the widely held belief that there was no long-term potential for cognitive recovery following brain damage, disregarding the possibility of an adaptive brain (Bach-y-Rita, 1990). However, in the 1970s, modern lesion studies found that Broca's aphasia was not always confined to a specific region (Dronkers, Plaisant, Iba-Zizen, & Cabanis, 2007), suggesting that other parts of the brain may also played a role in language production. Indeed, subsequent work revealed that human language does not exist in isolation but rather works concurrently with complex cognitive and neural machinery including attentional mechanisms, sensory and motor systems, and memory to allow for efficient production (e.g. Federenko, 2014). As such, our understanding of the brain moved towards a less rigid, more plastic system, able to recruit different networks to promote cognitive recovery following brain damage (Bach-y-Rita, 1990).

Currently, a large body of evidence suggests that the brain is capable of structural and functional modification in response to changes in the environment, whether work-related, exercise-related, or taking up novel, mentally challenging activities which stimulate the brain (Wan & Schlaug, 2010). Over the past decade, investigations into lifestyle factors and their cognitive correlates have become more widespread, including a greater use of behavioral interventions to examine whether different activities could mitigate the effects of cognitive decline with ageing and help delay the onset of age-related diseases (Kramer, Erickson & Colcombe, 2006).

Against this background, **chapters 2-4** investigate whether a mentally stimulating activity such as later-life language learning could yield similar cognitive effects as those found in bilinguals, promoting healthy cognitive ageing. In the

following sections, I discuss theoretical models surrounding bilingualism and cognitive control including their predictions for the studies presented in this thesis. I also give an overview of the literature leading up to this research inquiry, from early bilingualism work to recent studies on language learning in young adults, transitioning into **chapters 2-4** and explaining how each chapter addresses a novel theoretical question about this complex interaction between language and cognitive capacity.

1.3. Bilingualism and cognitive control

The finding that bilinguals exhibit enhanced mental flexibility, as reported in Peal & Lambert (1962) and subsequent studies (Kovács & Mehler, 2008; Bialystok & Viswanathan, 2009), has been associated with the discovery that bilinguals experience a parallel activation of both languages during comprehension and production (Beauvillain & Grainger, 1987; Brysbaert, Van Dyck, & Van de Poel, 1999; Colome, 2001; Costa, 2005; De Groot, Delmaar, & Lupker, 2000; Kroll, Bobb, Misra & Guo, 2008). In order to manage these competing linguistic systems, it has been theorized that bilinguals recruit domain general cognitive functions (i.e. attentional processes which work in conjunction to effectively plan and coordinate behavior) to monitor the linguistic environment and select the appropriate language while suppressing the other (Kroll, Bob, & Hoshino, 2014). In turn, these functions may adapt to become more efficient, leading to better cognitive performance. Nevertheless, questions remain regarding the exact nature of this enhancement and the specific conditions of the bilingual experience that give rise to these cognitive adaptations.

1.3.1. Theoretical background

1.3.1.1. Models of bilingualism and attention

Early models of bilingualism attributed better cognitive performance to the role of inhibitory control, emphasizing its importance in managing cross-linguistic interference through top-down suppression of non-target language representations (Green, 1998; Dijkstra, van Heuven, Grainger 1998; Abutalebi & Green, 2007). According to Green's influential Inhibitory Control (IC) model, inhibition can be viewed as a reactive mechanism executed by a higher level of control, namely a supervisory attentional system (SAS), which regulates 'language task schemas' (i.e. mental devices constructed or adapted on the spot to achieve a specific linguistic task, such as translation or word production). This concept of task schemas originates from a model of cognitive control proposed by Norman and Shallice (1986), which accounts for the way in which we control routine and non-routine behavior: the model posits that when a task has been previously performed, the relevant schema (or action sequences) can be retrieved from memory, allowing for automatic performance of that task. However, where automaticity is insufficient (e.g. a novel task), the SAS is recruited to construct new task schemas and monitor their performance in relation to the specified task goals. In the context of bilingual language processing, the IC model proposes that task schemas associated with different languages are activated by perceptual or cognitive cues, and are thus often in direct competition with one another; reactive inhibition adapts to resolve this conflict, triggered by the activation of lexical nodes in the irrelevant language and modulated by the degree of that activation (i.e. the greater the activation, the more inhibition is applied). As such, inhibitory processes of the SAS are theorized to become more efficient in the presence of that competition.

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A further prediction of the IC model relates to the process of switching between languages and the associated cost of doing so. Previous studies have shown a reduction in speed when transitioning from trials in one language to trials in another (e.g. Thomas and Allport, 1995; Von Studnitz and Green 1997). The IC model posits that these transitional delays are brought about by the twofold challenge of having to change the language task schema as well as apply inhibition to active lemmas from the previous language. Moreover, the IC model predicts that in the case of unbalanced bilinguals, the costs associated with switching languages may be asymmetrical relative to language dominance. That is, switching from a weaker language to a more dominant language should incur more processing delays than switching in the opposite direction, as the magnitude of inhibition required to suppress the dominant language is greater. As such, reconstructing the task schema to activate the strongly inhibited language may be more cognitively taxing, leading to greater switching latencies.

Taken together, the IC model and its predictions focus primarily on the role of reactive inhibition in controlling and switching between two language systems. Indeed, numerous studies support this inhibition-focused model, with evidence demonstrating that bilinguals experience smaller interference effects than monolinguals on measures of attentional control involving task-relevant and task-irrelevant dimensions, such as Flanker, Simon, and Stroop tasks (e.g. Blumenfeld and Marian, 2011; Tao et al., 2011; Bialystok et al., 2004). Moreover, recent studies have confirmed the asymmetrical costs when switching from a weaker to a dominant language, demonstrating that strong inhibition of the dominant language can result in subsequent negative priming of that language (e.g. Mueter & Allport,

1999; Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al., 2012).

Nevertheless, as the literature on bilingualism and cognition expanded over the last two decades, new findings emerged which cannot be explained by the IC model alone, namely faster reaction times for bilinguals in both congruent and incongruent trials (Martin-Rhee & Bialystok, 2008; Costa et al., 2008) and in high but not low monitoring conditions (i.e. conditions where the distribution of congruent and incongruent trials are similar—requiring continuous monitoring of trial type—versus conditions when the majority of trials are either congruent or incongruent) (Costa, et al., 2009). Additionally, work has shown that bilinguals may experience larger inhibition of return effects than monolinguals even when response suppression capacity does not differ across groups, indicating mechanisms beyond inhibition are at work (Colzato et al., 2008). Finally, research on unbalanced bilinguals has found longer naming latencies in the dominant language as opposed the to weaker language(s), which has been interpreted as an effect of inhibition at the global level (Costa & Santestaban, 2004). This type of global inhibition would likely require additional mechanisms of control to allow for a proactive (as opposed to reactive) inhibition of the dominant language (Wu & Thierry, 2017). Together, these studies suggest that monitoring processes and goal-maintenance also play a critical important role in bilingual language processing. Consequently, researchers have elaborated on inhibitory-focused models to account for additional cognitive mechanisms in regulating competing linguistic systems.

Recent interdisciplinary work has drawn a parallel between models of cognitive control in attentional research (particularly Braver's 2012 dual-mechanisms

framework) with theories surrounding bilingual language control (Colzato et al., 2008; Costa et al., 2009). The dual-mechanisms framework postulates that the ability to coordinate, regulate, and maintain goal-directed behavior is operationalized through the dynamic use of two semi-independent yet complementary modes of cognitive control: a proactive mode which optimally biases attention to a given goal, and a reactive mode in which a response is triggered after interference is detected. Applying this model to bilingual language control, the proactive mode can be viewed as sustaining the goal of communicating in the appropriate language until contextual cues indicate otherwise (Costa et al., 2006; Finkbeiner et al., 2006), while the reactive mode can be viewed as a response to the activation of inappropriate linguistic candidates through the inhibition of that interference (Morales, et al., 2015). From this perspective, the locus of the bilingual advantage may originate from the complex interplay between parallel modes of cognitive control involving numerous aspects of attention, from sustained attention to attentional switching, and inhibition (Costa et al., 2006; De Groot and Christoffels, 2006; Festman and Münte, 2012; Green and Abutalebi, 2013; Kroll and Bialystok, 2013; Morales et al., 2013). Indeed, bilinguals may adapt to optimally balance between proactive and reactive modes of control depending on the conditions of the environment (e.g. high versus low interference), a theory recently developed by Green and Abutalebi (2013) in the Adaptive Control Hypothesis.

In their model, Green and Abutalebi argue that distinct interactional contexts such as single language, dual language, and dense code-switching vary in the demands imposed on bilingual control processes. Of specific relevance to this thesis is the dual-language context in which switching between languages typically

occurs within a conversation but not within an utterance and where different languages may be used with different partners; this context is most similar to the language-learning environment of **chapters 2-4**, therefore I will focus on the predictions associated with this context in particular.

In the dual-language context, demands on control processes are highly complex as either language could become the target or non-target language at any moment. Thus effective communication in this environment requires a careful balance of proactive and reactive modes of control to allow for the selection and continuous activation of the intended language of use (otherwise known as *goal maintenance*), as well as the reactive inhibiting of representations from competing task schemas (i.e. *interference control*). Beyond this, speakers must also be able to efficiently disengage from goal-directed behavior and interference control to switch into another language (e.g. upon detecting a new addressee enter the scene). This involves an additional mechanism of cognitive control: *salient cue detection*. According to Green and Abutalebi, salient cue detection triggers a cascade of other processes to allow for a smooth transition into the other language. These processes include *selective response inhibition,* which halts a speaker's production in the current language, *task disengagement,* which disengages control mechanisms from that language, and *task engagement*, which engages control mechanisms in another language. Altogether, the dual-language context is hypothesized to increase demands on six specific cognitive mechanisms: goal maintenance, interference control, salient cue detection, selective response inhibition, task disengagement, and task engagement; as a result, these processes are theorized to adapt and become more efficient to meet the conditions of that environment.

In **chapters 2-4** of this thesis, I assess whether these processes improve in adult second language learners immersed in a dual-language environment. I test this through the use of three attentional measures that specifically tap into these processes. The first measure assesses participants' sustained attention abilities, which can be viewed as an index of continuous goal maintenance. The second measure assesses inhibitory control/selective attention (depending on the strategy used by the participant), which can be viewed as an index of interference control. Interestingly, while it cannot be determined whether participants in this task adopt a strategy of ignoring distracting cues or focusing exclusively on the target cue, a similar conundrum exists in theories of bilingual language processing. That is, the precise mechanisms behind interference suppression could either be the direct inhibition of non-target competition, or conversely, a strong activation of the target language which inadvertently suppresses the competitor (Green & Abutalebi, 2013). (This will be discussed in more detail in the discussion section in chapter 6.) Lastly, the third measure assesses attentional switching which can be viewed as an index of the flow of processes that are salient cue detection, selective response inhibition, task disengagement, and task engagement.

1.3.1.2. General predictions based on these models

Applying the predictions of the Adaptive Control Hypothesis from the dual-language bilingual context to adults acquiring a foreign language, the same areas of attentional control would be expected to experience increased demands (i.e. sustained attention, inhibition, and attentional switching); thus this model would predict language learning-related improvement would be found in those specific attentional mechanisms. However, an important distinction should be made: unlike

balanced bilinguals, language learners in the early stages of acquisition must switch between using the dominant native language and a much weaker foreign language. According to the IC model, shifting from a weaker language to a dominant language is especially difficult, as it requires strong inhibition of the dominant language as well as efficient release of that inhibition to switch back into it. Based on this account, the demands placed on language learners' attentional switching abilities (in having to disengage strong inhibition and refocus attention to the previously inhibited language) would be especially taxing, and therefore attentional switching skills may adapt the most from the start to the end of the course, resulting in the largest improvement.

A final prediction based on these models can be made in relation to the comparison of language learners with active controls enrolled in art, film, and English courses. As discussed earlier in this section, the IC model was influenced by Norman and Shallice's 1986 theory of cognitive control which accounts for routine and non-routine behavior. The theory holds that when a sequence of actions has previously been performed, the task schema can be retrieved from memory and applied again to carry out the task. This type of retrieval relies on contention scheduling, which is an automatic process that ensures proper schema is activated while supressing non-target schema.

However, for non-routine actions, there is no previous task schema that can be retrieved to perform the task, therefore attentional mechanisms are recruited to construct new schemas while monitoring and managing the co-activation of other task schema. Applying this theory to language learners and active controls, it is plausible that those in the art, film, and English teaching courses are taught more

routine action sequences over the course (e.g. preparing a camera for filming). This allows those students to gradually build memory representations of specific task schema, and rely on contention scheduling to automatically carry out the process and inhibit any interference. Conversely, learning a language may involve less routine action sequences given the unpredictability involved in having to switch between co-activated languages based on social or linguistic cues (or instructions from the teacher to translate new information from one language to the other). Based on this account, automaticity would be less sufficient for language learners and attentional mechanisms would be recruited to a larger extent to manage interference from competing language task schemas while allowing for efficient shifting between languages.

Together, the above predictions map out the general hypotheses for **chapters 2-4** based on influential models of bilingualism and cognitive control. In the following sections, I outline the specific research questions presented in those chapters and provide a brief history and background to the literature leading up to the investigations. I also provide further detailed predictions for the outcomes of those specific chapters.

1.3.2. Historical background

1.3.2.1 From childhood bilingualism to lifespan studies

Much of the initial work following Peal & Lambert's 1962 study focuses on 'classic' bilinguals: children exposed to more than one language from birth or shortly thereafter. However, over the past fifteen years, the general definition of bilingualism has expanded to include those who have acquired another language after childhood and without reaching full proficiency, offering a more representative picture of the

general population (Kroll, Dussias, Bice & Perrotti, 2015). Along with this shift, researchers began exploring bilingualism in its many forms, and started to look beyond the early years to examine whether the cognitive effects of bilingualism are detectable across the lifespan.

To date, the findings are inconclusive. Some studies have found that the same enhanced mental flexibility documented in bilingual children also extends to young adults (Costa, Hernández, Costa-Faidella & Sebastián-Gallés, 2009; Bak, Vega-Mendoza, & Sorace, 2014; Vega-Mendoza, West, Sorace & Bak, 2015), and continues into later life (Bialystok et al, 2004). There is even evidence that bilinguals may experience a delayed onset of dementia (Bialystok, Craik & Freedman, 2007; Alladi et al, 2013; Woumans et al, 2015) and better cognitive recovery following stroke (Alladi et al, 2015). Notably, however, other studies have found no differences between bilinguals and monolinguals (Paap & Greenberg, 2013; Clare et al., 2016), calling into question the very notion of a bilingual cognitive advantage (Hilchey & Klein, 2011). Moreover, some have proposed that a publication bias is responsible for inflating an otherwise small or non-existent effect (de Bruin, Treccani & Della Sala, 2015).

While this debate is on-going, it is important to consider that there are many social, environmental, and educational factors at play in these studies (Bak, 2016a). To shed light on what drives these divergent findings, a new approach is to look beyond simple group comparisons (e.g. bilinguals versus monolinguals) and more intricately explore the particular features of a population or specified group of participants, a methodological point I discuss and investigate in **chapter 3**.

1.3.3. Current work: language learning and ageing

The majority of research on adult language learners centers on proficiency and attainment in the foreign language. It wasn't until recently that studies began examining the impact of adult language learning on cognition. In a 2014 study, university students were tested before and after a six-month intensive introductory Spanish course (Sullivan, Janis, Moreno, Astheimer & Bialystok, 2014). Unlike the control group (of introductory psychology students), language students experienced modulation in electrophysiological signalling for verbal and nonverbal conflict tasks, resembling patterns displayed by lifelong bilinguals. These findings suggest that changes to neuronal processes in response to attentional tasks can begin to occur after a relatively short period of intensive language learning. Similarly, a 2015 study also compared university students studying different subjects, this time foreign language versus literature majors (Vega-Mendoza, West, Sorace & Bak, 2015). No differences were found between first year language and literature students on attentional tasks, however fourth year language students significantly outperformed their first year counterparts on attentional switching, an effect which was not present in literature students.

Building upon these findings, **chapter 2** investigates whether older adults experience similar attentional improvement following language learning, and whether the effects emerge as early as one week after an intensive language course. In the study, 33 Gaelic learners (aged 18-78) were tested before and after a week-long residential course on the Isle of Skye and compared to active controls enrolled in courses of the same duration and intensity but not involving foreign language learning, and passive controls who followed their regular routines.

I predicted that the three groups would be indistinguishable from baseline, but that both the Gaelic learners and active controls would improve by the end of the week due to the intensity and challenge of the courses. Given the distinct cognitive demands of a dual-language environment, I hypothesized that Gaelic learners would experience the greatest attentional improvement, while active controls would take an intermediate position; I did not expect passive controls to improve as they were not enrolled in a course. I also predicted that continued language practice following the Gaelic course could help to maintain cognitive improvement. Further, I hypothesized that age would influence performance: given the large body of work on age-related cognitive decline in healthy older adults (e.g. Craik & Byrd, 1982; Deary et al., 2009), I predicted that elderly participants would perform worse on the attentional tasks than younger participants. However, in light of recent work on the efficacy of cognitive interventions in old age (e.g. Wan & Schlaug, 2010), I predicted that improvement in attentional functions would be found irrespective of participant age.

Results revealed that proportionally language learners experienced the most improvement in attentional switching, followed by active controls, then passive controls. A nine-month follow-up revealed that all language learners who continued to study Gaelic for five hours or more per week maintained that improvement, whereas those who studied less than that experienced inconsistent results: some improved while others maintained or deteriorated. These findings are the first to demonstrate longitudinal language learning-related attentional improvement within the same participants and across the lifespan.

In **chapter 3** I expand on these results by assessing a much larger sample of Gaelic language learners (n=105) aged 21-85 to tease apart understudied factors affecting individual differences in cognitive outcomes following language learning. In this study, I examined cognitive performance and its relationship to level of attainment in the target language (i.e. novelty versus familiarity with Gaelic), previous language experience, participant age, and gender. While the role of novelty and familiarity has been studied extensively in memory research (Kirchhoff et al., 2000; Danckert et al., 2007; Poppenk, Köhler, & Moscovitch, 2010), and novelty alone has been implicated in the cognitive effects of language learning (Bak, Long, Vega-Mendoza & Sorace, 2016), this is the first study to focus on the differential effects of novelty and familiarity on cognitive performance following language learning.

I predicted that those enrolled in the more advanced Gaelic courses would initially outperform those in the lower level courses, while those in the lower level courses would experience the greatest cognitive improvement (based on work by Bjork & Kroll, 2015 and the direction of the results from the previous chapter). I also predicted that younger adults would outperform older adults but that age would not interact with session (as observed in the previous chapter). Finally, I did not have a strong prediction as to whether knowledge of more than two languages (in this case English and Gaelic plus additional ones) would confer any additive benefits due to the fact that prior work on this topic is inconclusive (Kavé et al., 2008; Chertkow et al., 2010; Alladi et al., 2013; Freedman et al., 2014).

The results of this chapter confirmed findings from the previous chapter: adults of all ages experienced significant attentional improvement after the one-week Gaelic course. Interestingly, there was an effect of both novelty and familiarity

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on attentional switching: those in higher level Gaelic courses initially outperformed those in lower levels, whereas those in lower levels improved the most after the course. Age also played a role: although younger and older adults' performance differed on switching and sustained attention, age did not interaction with session (pre-/post-course) on any attentional measure, highlighting the robustness of the cognitive effects of Gaelic language learning as well as the brain's adaptability over the lifespan.

While these effects emerged in learners of Gaelic, it is important to consider that languages differ in the way that they are produced (spoken/sign modalities). To examine whether modality plays a role in the type of cognitive changes observed in the previous chapters, **chapter 4** reports on an intervention study in which 35 adults aged 23-85 were randomly assigned to one of three week-long language courses, two of which were spoken languages (Norwegian and Turkish) and one sign language (British Sign Language). The random allocation controlled for potential selection bias from the previous chapters and the two unrelated spoken languages minimized the influence of language typology on spoken language results. These efforts allowed for a careful comparison of the effects of language learning across spoken and sign modalities using the same attentional tasks as in previous chapters in addition to visuospatial working memory tasks which were included based on predictions from studies on bimodal bilinguals (discussed below). Further, the participants in this study were residents of Edinburgh (rather than week-long visitors to the Isle of Skye), allowing us to remove the influence of certain environmental factors on cognitive outcomes.

An important distinction should be made between bimodal bilinguals (i.e. those fluent in a spoken and sign language) and unimodal bilinguals (those fluent in languages of the same modality). That is, perceptual and motor systems allow bimodal bilinguals to process and produce both languages simultaneously, whereas this is not possible for unimodal bilinguals who only have one means of articulation (Emmorey, Borinstein, Thompson & Gollan, 2008). Interestingly, research comparing bimodal and unimodal bilinguals has shown divergent results with regards to cognitive control: bimodal bilinguals appear to rely less on attentional mechanisms (and thus do not show the same enhancement found in unimodal bilinguals), which has been attributed to the fact that their two languages access distinct sensory-motor systems during comprehension and production (Giezen, Blumenfeld, Shook, Marian, & Emmorey, 2015; Emmorey, Luk, Pyers, & Bialystok, 2008). On the other hand, a large body of work has found that signers outperform non-signers in dynamic spatial tasks (Rettenbach, Diller, & Sireteanu, 1999; Emmorey, Kosslyn, & Bellugi, 1993; Emmorey, Klima, & Hickok, 1998), an effect which has extended to non-native hearing signers with one to five years of regular signing experience (Keehner & Gathercole, 2007).

Based on these results, I predicted that spoken language learners would experience the greatest improvement in attention due to the competition for articulation between languages in the same perceptual system, but that both spoken language learners and sign language learners would improve in attentional functions given the intensive learning environment. In contrast, due to the spatial challenges of sign languages (i.e. the need to mentally rotate locations from the perspective of the signer), I predicted that sign language learners would experience

the greatest improvement in visuospatial working memory, especially on the Reverse Corsi spatial task which involves 180° rotation (directly mimicking spatial transformations that occur during sign discourse). I did not expect spoken language learners to improve on the visuospatial tasks as learning a spoken language does not impose any specific demands on visuospatial working memory.

The findings of this chapter revealed that spoken and sign language learners of all ages experienced attentional switching improvement and that there was no difference in improvement between the two groups. Moreover, contrary to my predictions, no effects were found for either of the visuospatial tasks. In addition to the cognitive assessment, participants completed questionnaires about their attitudes towards the randomly assigned language and its impact on cognition. This allowed for the merging of research in two major disciplines -cognitive psychology and sociolinguistics- to address the complex interaction between attitudes to language learning and its cognitive effects.

Participants in spoken languages initially overestimated the difficulty of their course, however by the end of the course, attitudes towards both spoken and sign languages improved. Further, those who increased their endorsement of the cognitive impact of the course also experienced a larger improvement in attention switching, suggesting that participants may have actually felt that they performed better following the course.

Collectively, the results from **chapters 2-4** demonstrate that language and attention are intricately connected over the lifespan. Each study highlights the strength of this relationship by showing that changes to one's linguistic environment can have a measureable impact on attentional control, irrespective of age.

Nevertheless, it is important to note that until now, I have only tested this relationship in one direction: that is, how language affects cognitive ageing. I have yet to account for the other side of the coin: how age-related attentional changes could have a measurable impact on language. In **chapter 5** I set out to address this question in the context of language production, where questions remain regarding the role of attention in regulating communicative perspective-taking over the lifespan.

1.4. Communicative perspective-taking and cognitive control

Throughout development, we acquire the ability to conceptualize others' thoughts and feelings as distinct from our own. This allows us to engage in meaningful social interactions in which our understanding of another's perspective, including their knowledge and beliefs, directly shapes our use of language. During discourse, we often make judgements about what knowledge is shared with a specific partner (common ground) and what referents must be introduced (privileged ground), requiring constant integration and updating of information. This complex process by which we tailor our interpretations and speech to meet the knowledge and assumptions held of our partner is essential to effective communication, yet the cognitive mechanisms underlying this process have yet to be defined.

1.4.1. Theoretical background

1.4.1.1. Models of perspective-taking and attention

In order to process perspective, individuals must first compute or infer differences in perspective (e.g. what information is common or privileged knowledge), then integrate that information and adapt linguistic behavior accordingly (Clark & Marshall, 1981). Current theories on the mechanisms underlying this process

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suggest that domain general cognitive functions may play a role in inhibiting privileged information when considering common ground. Indeed, a number of studies have found that perspective-taking abilities are modulated by non-linguistic cognitive functions (i.e. inhibitory control and working memory), such that individuals who exhibit superior functioning are more adept at anticipating the correct referent based on their partner's perspective (Brown-Schmidt, 2009; Lin, Keysar, & Epley, 2010), and are more likely to appropriately tailor utterances to a partner's point of view (Wardlow, 2013). Findings from neuroimaging studies also support the involvement of domain general control by demonstrating that the ability to self-project (i.e. imagine oneself in hypothetical situations based on past or future events or the upcoming actions of another person) is regulated by the same type of higher order cognitive functions (Wagner, Shannon, Kahn, & Buckner, 2005, Saxe & Kanwisher, 2003).

Nevertheless, how exactly domain general functions regulate perspective-taking abilities is still undetermined. Indeed, two of the most influential models of perspective-taking (the constraint satisfaction model and the dual process model) would make different predictions in relation to how domain general mechanisms influence perspective. The constraint satisfaction model posits that the formulation of an utterance involves a series of contextual constraints which are weighed in relation to their salience and reliability; distinguishing between common or privileged knowledge is considered one of these constraints (Hanna, Tanenhaus & Trueswell, 2003; Nadig & Sedivy, 2002). A prediction based on this model would suggest that attentional mechanisms are recruited early in production to reduce the representation of a specific feature (e.g. the size of an object) when that representation violates perspective differences (Wardlow, 2013). The dual process model, on the other

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hand, proposes a two-stage process for considering perspective: the first stage is automatic, and involves interlocutors formulating or interpreting a message from their own perspective, while the second stage is more effortful as it involves monitoring for the appropriate perspective (Keysar, Barr, Balin & Paek, 1998; Keysar, Lin & Barr, 2003). This model would therefore predict that attentional mechanisms are recruited during the later stages of production as a means of correcting for the egocentric perspective when appropriate.

Interestingly, both of these models and their predictions could be integrated into a single model of attentional control based on Braver's dual-mechanisms framework (2012). As detailed earlier, Braver's model involves two semi-independent modes of control: a proactive mode and a reactive mode. Similar to the bilingual experience of managing competing linguistic systems, speakers in the midst of a conversation must manage competition between distinct perspective representations by balancing the salience of their own perspectives against the need to attend to the interlocutor's. These pressures may require both the inhibition of salient-but-irrelevant information along with the readiness to refocus attention on appropriate contextual information, and the strategic mode of control that individuals rely on could vary across individuals. In this context, the proactive (goal maintenance) mode could be viewed as the ability to consistently inhibit privileged context from the early stages of production (in line with the constraint satisfaction model), whereas the reactive (background monitoring) mode would allow for enhanced sensitivity to contextual cues, allowing for the modulation of inhibition when a speaker switches perspectives (in line with the dual process model).

1.4.1.2. General predictions based on these models

According to Braver's dual-mechanims framework (and the integrated model

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of the constraint satisfaction model and dual process model presented above), perspective-taking may rely on a combination of proactive and reactive control and there may be individual differences for the type of cognitive strategy used. For example, individuals who prefer a proactive mode of control might adopt a strategy of inhibiting privileged ground early in production whereas those who prefer a reactive mode of control may rely on cues to guide perspective shifts and respond according to the need to engage and disengage attention from one perspective to the other.

1.4.2. Historical background

1.4.2.1. From childhood perspective-taking to young adult and clinical populations

Early work on perspective-taking focused on children's ability to conceptualize that other individuals have knowledge and beliefs that may differ from their own. Findings from this work have demonstrated that perspective-taking may take years to develop. For example, one study showed that children under four years old fail to appreciate others' perspectives when prompted through verbal tasks (Wimmer & Perner, 1983). Interestingly, however, implicit measures of perspective-taking have shown that children much younger than four may already form representations of others' perspectives (Onishi & Baillargeon, 2005). Thus a child's inability to articulate this knowledge may result from insufficient cognitive control. In line with this interpretation is work that demonstrates children's inhibitory control is negatively correlated with communicative egocentrism (Nilsen & Graham, 2009), suggesting a role of domain general cognitive control in the development and use of perspective-taking in language production.

Recent work on young adults has shown a similar pattern of results whereby inhibition and working memory predict perspective-taking abilities (Brown-Schmidt, 2009; Lin, Keysar, & Epley, 2010; Wardlow, 2013). Nevertheless, other studies have failed to replicate this effect in young adults (Brown-Schmidt & Fraundorf, 2015; Ryskin, Benjamin, Tullis, & Brown-Schmidt, 2015; Ryskin, Brown-Schmidt, Canseco-Gonzalez, Yiu, & Nguyen, 2014), which suggests that domain general mechanisms might not influence perspective-taking abilities. In addition to these studies on young adults, research has been carried out on adults at the other end of the lifespan: Wardlow, Ivanova, and Gollan (2014) observed that perspective-taking correlates more strongly with attentional functions in a clinical population than in healthy age-matched controls. (However, it should be noted that those measures were simplified for the patients, leading to ceiling-level performance in controls and possibly obscuring individual differences.)

Based on these results, I argue that there are two understudied factors in the literature that may explain this disparity. First, the majority of perspective-taking studies focus exclusively on working memory and inhibition. Attentional switching (i.e. the ability to disengage inhibition and refocus attention) has been overlooked as a potential mechanism responsible for efficient shifting of perspectives over the course of a conversation. Indeed, similar to the costs associated with switching languages, evidence from perspective-taking tasks show latencies when shifting trials from one perspective to another compared to trials which do not require perspective shifts (Bradford, Jentszch & Gomez, 2015; Ryskin et al., 2014; Ryskin, Wang & Brown-Schmidt, 2016). This suggests attentional switching may play an important role in persepective-taking, in addition to inhibition. Second, as reported above, adults in these studies tend to be either young adults (who operate at peak

cognitive and linguistic capacity) or clinical populations (who do not represent healthy cognitive ageing); missing from this work is the study of adults across the entire lifespan, where age-related cognitive changes may affect language production.

1.4.3 Current work: perspective-taking and ageing

In order to address these gaps, I set out to examine whether the same range of attentional functions modulated by language learning – *sustained attention, inhibition,* and *attentional switching* – would predict communicative perspective-taking over the adult lifespan in a sample of 100 adults aged 17-84. Given that previous work has shown age-related decline in communicative abilities (Bortfeld, Leon, Bloom, Schober & Brennan, 2001; Healey & Grossman, 2016; Horton & Spieler, 2007; Lysander & Horton, 2012) and in attentional abilities (e.g. Deary et al., 2009), I predicted that attentional functions and perspective-taking would vary by age (i.e. that older adults would perform worse than younger adults). Further, as recent work has shown potential age-related differences in preferences for proactive versus reactive control strategies (Braver, 2012), I predicted that perspective-taking and attentional control might interact with the age of participants, such that different attentional mechanisms might predict older and younger adult perspective-taking performance.

Results from this study revealed that older adults were less sensitive to perspective differences than younger adults, as they were less likely to adjust their speech to reflect what their partner knew. Importantly, results revealed that attentional functions predicted perspective-taking abilities, and that these patterns differed across younger and older adults; for younger adults, inhibitory control

predicted how well they considered their partner's point of view, whereas for older adults it was attentional switching. This is in line with work suggesting that younger adults prefer a more proactive mode of control whereas older adults may prefer a more reactive mode (Braver, 2012). Therefore the findings of this study suggest that not only do attentional functions impact language production, but there also may be an age-related shift in the type of attentional mechanisms recruited to regulate this communicative ability over the lifespan.

Taken together, the results of this thesis demonstrate that changes to one's linguistic environment can have a significant impact on attentional functions (**chapters 2-4**), and that changes to one's attentional functions can likewise have a significant impact on language (**chapter 5**), revealing just how intricately connected our linguistic and cognitive systems are over the course of adulthood. I discuss this further in **chapter 6**, by reflecting on how this body of work contributes to the advancement of the field and paves the way for future intervention studies.

1.5. Brief outline of the thesis

To summarize, the aim of the thesis is to give a multifaceted picture of the lifelong interplay between language and cognition. Each study builds on previous work to advance our understanding of this relationship. The following topics are addressed: the impact of brief intensive language learning on cognitive ageing (chapter 2), the role of novelty and familiarity in the impact of language learning on cognitive ageing (chapter 3), the role of language modality in the impact of language learning on cognitive ageing (chapter 4), and the impact of cognitive ageing on communicative perspective-taking (chapter 5).

Chapter 2: Novelty, challenge, and practice: the impact of intensive language learning on attentional functions

Chapter overview

This chapter contributes to our understanding of the lifelong relationship between language and cognition through an exploratory study investigating whether changes to one's linguistic environment, specifically learning a new language, modulates cognitive functions over the lifespan. Using attentional tests measuring *sustained attention, inhibition, and attentional switching*, I tested 33 early stage learners of Gaelic aged 18-78 before and after one-week intensive courses and compared their performance to active controls (enrolled in courses of the same intensity and duration but not language-related) and passive controls (following their regular routines). Nine months later, I re-tested half of the language learners to examine whether continuous language practice would have a lasting effect on cognitive performance. The results of this study provide new insights into the extent to which language influences cognitive ageing.

Abstract

We investigated the impact of a short intensive language course on attentional functions. We examined 33 participants of a one-week Scottish Gaelic course and compared them to 34 controls: 16 active controls who participated in courses of comparable duration and intensity but not involving foreign language learning and 18 passive controls who followed their usual routines. Participants completed auditory tests of attentional inhibition and switching. There was no difference between the groups in any measures at the beginning of the course. At the end of the course, a significant improvement in attention switching was observed in the language group ($p<.001$), and active controls ($p<0.05$), but not in the passive control group ($p>.05$). A linear trend revealed that language learners improved the most, followed by active, then passive controls. Further, while younger adults performed better than older adults, the beneficial impact of the courses was found across the lifespan. Half of the language participants ($n=17$) were retested nine months after their course. All those who practiced Gaelic five hours or more per week improved from their baseline performance. In contrast, those who practiced four hours or fewer showed an inconsistent pattern: some improved while others stayed the same or deteriorated. Our results suggest that even a short period of intensive language learning can modulate attentional functions and that all age groups can benefit from this effect. Moreover, improvement can be maintained through continuous practice.

2.1. Introduction

Few topics have recently generated as much controversy as the question of possible cognitive benefits associated with bilingualism, particularly in areas such as executive functions and attention. The evidence is inconsistent. Some studies show better results in bilinguals, from childhood (Bialystok & Viswanathan, 2009) to old age (Kavé, Eyal, Shorek, & Cohen-Mansfield, 2008) and dementia (Alladi et al., 2013); others find no difference (Paap & Greenberg, 2013). However, as documented by de Bruin et al (2014), very few studies show an opposite effect, namely a bilingual disadvantage.

Most studies thus far have examined "classic" bilingualism: early acquisition and balanced command of different languages. However, recent research into people who have learned languages in adulthood and without reaching native-like proficiency suggests similar cognitive effects as in the classic bilinguals (Bak, Nissan, Allerhand & Deary, 2014; Bak, Vega-Mendoza & Sorace A, 2014; Tao, Marzecová, Taft, Asanowicz & Wodniecka, 2011; Sullivan, Janus, Moreno, Astheimer & Bialystok, 2014). These findings open a new set of questions: How much language learning is necessary before the first cognitive changes become detectable? How much practice is needed to sustain them? Do they occur in people of all ages, even in the elderly?

In this study, we set out to determine whether learning a new language would lead to an improvement in cognitive performance as early as one week after an intensive course. We examined learners of Scottish Gaelic: a Celtic language different from English in phonology, vocabulary, and word order, with a complex grammar and unfamiliar spelling (Gillies, 2008) posing considerable challenges to its

learners. The control group consisted of two subgroups: *active controls* who participated in courses of comparable duration and intensity but not involving foreign language learning and *passive controls* who followed their usual routines.

To assess cognitive functions we used subtests from the Test of Everyday Attention (Robertson, Ward, Ridgeway & Nimmo-Smith, 1994), measuring attentional inhibition and switching, functions which play a central role in the current understanding of cognitive processing in bilinguals (Abutalebi et al., 2013; Costa, Hernández, Costa-Faidella & Sebastián-Gallés, 2009). In a recent study using these tests (Vega-Mendoza, West, Sorace & Bak, 2015), fourth year language (but not literature) students outperformed their first year counterparts, suggesting a positive effect of intensive language learning on attentional performance. However, while Vega-Mendoza et al examined different students at two different stages of their academic career, the present study investigates potential differences *within* the same participants.

We predicted that all three groups would be indistinguishable from each other in their baseline performance. Since the parallel versions of the Test of Everyday Attention (Robertson et al., 1994) were designed to avoid practice effects, so that the test can be used in longitudinal studies and in monitoring the effects of neuro-rehabilitation, we did not expect to find any changes in performance between the first and the second assessment in the passive control group. In contrast, given the growing evidence for beneficial cognitive effects of different types of mental exercise (Park et al., 2014; Valenzuela & Sachdev, 2009), we predicted that both the active controls and the language group would improve after one week of their respective intensive courses. In view of the particular challenges associated with

learning an unfamiliar language, we hypothesized that the improvement would be more pronounced in language learners (Janus, Lee, Moreno & Bialystok, 2016). We also speculated that long-term language practice could help to maintain cognitive improvement. Finally, we predicted that younger adults would perform better than older adults, but that age would not interact with session.

2.2. Methodology

2.2.1. Participants

A total of 76 volunteers participated in the study: 36 language learners and 40 controls. Language learners were recruited from Sabhal Mòr Ostaig, a Gaelic college on the Isle of Skye, Scotland, and were tested before and after a one-week intensive Gaelic course. The testing was conducted over three weeks in Summer 2014. Everyone enrolled in language courses was invited via email to participate in the study. All those who agreed were tested. The students had an average of 14 hours of language classes between the first and second testing and were offered Gaelic entertainment in the evening (e.g. concerts, films, conversation circle).

The control group consisted of 40 individuals not enrolled in a language course. Recruitment was comparable to that of the language learners in that the controls received a written invitation and all those who signed up were tested. The group was further subdivided into active and passive controls to examine whether any potential cognitive changes in language learning were course-specific or due to general stimulation in an intensive course environment. Active controls (n=16) were enrolled in intensive courses with a similar schedule to those of the Gaelic students, but were not learning an unfamiliar language. The courses included CELTA training (an English language teaching qualification for those fluent in English) at the

Randolph School of English (*m*=19.5 hours between testing), art courses at Leith School of Art (*m*=12 hours between testing), and a documentary film course offered by the University of Edinburgh (*m*=15 hours between testing). Both language and non-language courses were taught by multiple tutors; hence, it is unlikely that potential differences might be due to the personality and/or teaching style of individual tutors. Passive controls (n=24) were recruited through the University of Edinburgh Psychology Volunteer Panel, were not enrolled in any type of intensive course at the time of testing, and were following their usual daily routine.

Two volunteers (one each from the language and passive control groups) withdrew during the first session and their data were removed. In order to match the groups by age, gender, and education, two language participants and one passive control participant were excluded because of level of education (secondary school degree only) and four passive control participants were excluded because of age (80 years or above). To make sure that these exclusions did not influence the overall results, the comparison of the Elevator Task, Elevator Task with Distraction, and Elevator Task with Reversal (as reported in the results section) was conducted twice: with and without the excluded participants. The results were practically the same, with the differences smaller than 1.5%; we subsequently report the results of the matched groups.

Within the matched groups, there were no significant differences between the language group (n=33) and control group (n=34) in age: language group: 50.06±18.28, control group: 48.24±16.37; gender (percentage females): language group: 60.60%, control group: 76.47% or education (percentage with degree): language group: 93.93%, control group: 88.23%. Likewise, no significant

differences were found in the same variables between the active (n=16) and passive (n=18) control group— age: active controls: 43.69±17.68, passive controls: 52.28±14.42; gender (percentage females): active controls: 81.25%, passive controls: 72.22%; education (percentage with degree): active controls: 93.75%, passive controls: 83.33%.

In addition, all groups completed a comprehensive language background questionnaire to assess knowledge of foreign languages (see Appendix A). This self-evaluation separates an individual's command of all languages of which he/she has at least basic knowledge into four domains: expression, comprehension, reading, and writing. Each domain is then rated using a 5 point scale (from 1=basic to 5=fluent) and the composite score of all known languages (including knowledge of Gaelic before the beginning of the course) are calculated for each individual. This composite score was not different between the language and the control group (language group: 37.36±15.04, control group: 34.21±13.35) or between the active and passive controls (active controls: 34.81±13.66, passive controls: 33.67±13.44).

2.2.2. Materials/procedures

The Test of Everyday Attention (Robertson et al., 1994) is a well-established clinical test, measuring different aspects of attention. It has been designed to diagnose subtle attentional deficits and monitor effects of neuro-rehabilitation in patients with different types of brain damage. For this reason, it includes three different versions of each test to prevent practice effects. More recently, the Test of Everyday Attention subtests— the Elevator Task, Elevator Task with Distraction, and Elevator Task with Reversal— have been successfully applied to examine the influence of early and late bilingualism (Bak et al., 2014) and foreign language

learning (Vega-Mendoza et al., 2015) on attentional functions in young adults. The three subtests together take ca. 20 minutes and can be easily administered outside of laboratory settings, making them well suited for the field work involved in this study.

Each of the subtests was designed to measure distinct attentional components (sustained attention, selective attention, and attentional switching), requiring a separate assessment for each of these functions. Due to inherent task differences, performance can differ across tasks, as has been previously demonstrated (Bak et al., 2014). For this reason, we did not calculate a composite score for the separate subtests, but rather analyzed each subtest separately.

Elevator Task **(auditory sustained attention):** Participants are asked to count tones of the same pitch presented at irregular intervals (n trials=7).

Elevator Task with Distraction **(auditory selective attention/inhibition)**: Participants are asked to count low tones, while ignoring interspersed high tones (n trials=10).

Elevator Task with Reversal **(auditory attentional switching)**: Participants are presented with high, middle, and low tones. The middle tones are to be counted while the high and low tones indicate whether to add or subtract middle tones (n trials=10).

Results were measured in terms of accuracy of response. To avoid practice effects, a different version was given during each session, with the same versions and the same order (A, B, C) used in all three groups. Written informed consent was

obtained from all participants prior to commencing the study. The study was approved by the University of Edinburgh Psychology Ethics Committee.

2.2.3. Statistical analyses

Linear mixed effects regression was conducted on each attentional test by modelling the outcome variable of test score, with session (pre- and post-course) and group (language, active, passive) as fixed effects and subjects as random effects. These models also included age as an additional covariate. Deviation coding was used for session and sum coding for group as a 3 level predictor. To test for main effects and two-way interactions[1], we conducted likelihood ratio tests between mixed-effects models differing only in the presence or absence of that fixed effect; the same method was used to test for interactions. We account for multiple comparisons from our three cognitive measures with Bonferroni corrections (adjusted significance level of $p=.0166$).

Additional mixed effects models and likelihood ratio tests were carried out to examine improvement score across the three groups, the impact of Gaelic level on language learner performance, and the results of the follow-up assessment. In addition, a linear trend analysis was conducted to compare passive and active controls with the language group.

2.3. Results

2.3.1. Test of Everyday Attention subtests

2.3.1.1. Elevator Task

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[1] We took a conservative approach, modelling only two-way interactions to avoid reduced precision on the model estimates for higher order interactions.

Both the language and control group scored close to ceiling on each session (Table 2.1). Likelihood ratio tests revealed that there was no main effect of session (p=0.2286), group (p=0.5538), or age (p=0.6388). There were also no interactions (age x session: p=0.8205, age x group: p=0.1505, group x session: p=0.927).

2.3.1.2. Elevator Task with Distraction

Similar to the first subtest, likelihood ratio tests showed no main effect of session (p=0.5565), group (p=0.4863), or age (p=0.6388), nor were there any interactions (age x session: p=0.356, age x group: p=0.2632, group x session: p=0.9186).

2.3.1.3. Elevator Task with Reversal

For this subtest, likelihood ratio tests revealed that the main effect of session was statistically significant, (p<0.001), with better performance overall in the second session. There was a main effect of age (p=0.003213), which showed that as age increased, scores decreased, however age did not interact with session or group (p=0.229 and p=0.8837, respectively). There was no main effect of group (p=0.1517), but the interaction between session and group was significant (p=0.003501). Follow-up analyses checking for a main effect of session in each group (language, active, passive) revealed that language learners scored significantly better from session 1 to session 2 (β=18.788, t=6.247, p<0.001), and that active controls also experienced significant improvement (β=13.125, t=2.683, p=0.01227); however passive controls did not improve (β=-0.5556, t=-0.105, p=0.9136).

Table 2.1. Group performance on the Test of Everyday Attention subtests

	Language Group (n=33)	Controls		
		Total (n=34)	Active (n=16)	Passive (n=18)
ET 1 Mean (SD)	98.64 (4.38)	98.68 (4.32)	98.13 (5.12)	99.17 (3.54)
ET 2 Mean (SD)	99.09 (3.63)	99.56 (2.57)	99.06 (3.75)	100 (0)
Improvement	.45	.88	.93	.83
ETD 1 Mean (SD)	88.79 (22.61)	82.94 (25.17)	85.63 (21.90)	80.56 (28.17)
ETD 2 Mean (SD)	90.91 (20.06)	86.76 (22.12)	91.88 (9.81)	82.22 (28.61)
Improvement	2.12	3.82	6.25	1.66
ETR 1 Mean (SD)	59.7 (27.44)	57.06 (35.04)	60.63 (31.51)	53.89 (38.52)
ETR 2 Mean (SD)	78.48 (23.99)	62.94 (32.34)	73.75 (27.05)	53.33 (34.30)
Improvement	18.78	5.88	13.12	-.56

Mean, standard deviation, and improvement scores for all groups on the Test of Everyday Attention.
Notes:
ET: Elevator Task, ETD: Elevator Task with Distraction, ETR: Elevator Task with Reversal
Session is denoted by number (1 or 2)

2.3.1.4. Linear trend analysis of Elevator Task with Reversal Improvement

To further examine the difference in improvement between session in the language, active, and passive control groups, the ETR mean for each group in session 1 was subtracted from the ETR mean for each group in session 2. Linear mixed effects regression was conducted on the outcome variable of ETR improvement score, with group (language, active, passive) as the fixed effect and subjects as random effects. To test for a main effect of group, a likelihood ratio test was conducted between mixed effects models differing only in the presence or absence of that fixed effect of group. Results revealed an overall significant main effect of group on ETR improvement score (p=0.00451). Follow up comparisons revealed that the language group was significantly different from the passive

controls (p=.002). Although no differences were found between the language group and active controls and between the active controls and passive controls (p's>.05), a significant linear trend (β=13.678, t-value=3.424, p=0.00108) showed that proportionately the language group improved the most, followed by the active controls, and passive controls (Fig 2.1).

Figure 2.1. Linear trend performance on the Elevator Task with Reversal for the language, active, and passive control groups

Error Bars: 95% CI
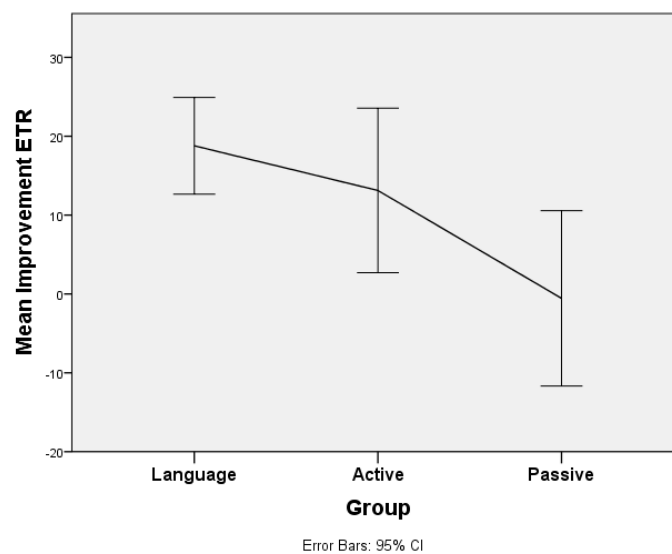
2.3.2. Difference within the language group: level of proficiency in Gaelic

To examine whether the rate of improvement was affected by previous knowledge of Gaelic, we ran mixed effects regression on the outcome variable of ETR score, with session (pre- and post-course) and Gaelic level (beginner, elementary, and intermediate) as fixed effects, and subjects as random effects (see Table 2.2 for descriptive statistics). Deviation coding was used for session, while Gaelic level was entered as a scaled continuous predictor. Likelihood ratio tests revealed that the main effect of session was statistically significant (p<.001), with

better performance in the second session, but there was no main effect of Gaelic level (p=0.4197) or interaction (p=0.0741).

Table 2.2. Elevator Task with Reversal for the three levels of Gaelic proficiency

	Gaelic Level	Total (N)	ETR 1	ETR 2	Improvement
ETR Results	Beginner	15	58.67 (28.25)	80.67 (21.2)	22
	Elementary	8	66.25 (23.86)	91.25 (13.56)	25
	Intermediate	10	56 (30.62)	65 (29.16)	9

Notes: ETR: Elevator Task with Reversal
Session is denoted by number (1 or 2), ( ) = SD

2.3.3. Longitudinal follow-up

All of the language participants were contacted via email to participate in a follow-up study; 28 out of the 33 responded. Due to logistic reasons we were only able to retest those who lived in an accessible area of the UK, bringing the total number of the longitudinal follow-up group to 17. The participants were retested ca. 9 months after the course, with a repetition of the Test of Everyday Attention subtests and a questionnaire asking on average how many hours of Gaelic per week they practiced since the summer course. The reported hours ranged from 0 to 22.5/week with a median of 4/week. An exploratory inspection of the longitudinal follow-up data suggested the existence of a possible threshold between 4 and 5 hours of practice per week: in those who practiced more the performance on Session 3 was consistently better than the baseline (Table 2.3). Of those who practiced less, some improved, some deteriorated and some stayed the same.

As a first step, we examined whether those participants who practiced more were different from those who practiced less in terms of their demographic variables or baseline performance on the Elevator Task with Reversal. To do so, the participants were divided into those who practiced 4 hours or fewer (n=9) versus 5 hours or more (n=8). A t-test for age and chi-square tests for gender and level of

education revealed no significant differences between the two groups (all $ps>.2$); both groups also did not differ in their baseline Elevator Task with Reversal performance (4 hours or fewer=55.56, 5 hours or more=55, $p=.969$).

Secondly, we examined the difference in the rate of improvement on the Elevator Task with Reversal between Session 1 and Session 3 in both groups. Those who practiced 5 hours or more performed significantly better on Session 3 than Session 1 (18.75, $t=8.275$, df=7, $p<.001$, two-tailed), whereas the improvement in those who practiced 4 hours or fewer was not significant (4.44, $t=.555$, df=8, $p=.549$, two-tailed).

Table 2.3. Individual performance on the Elevator Task with Reversal pre- and post-course and nine months later

	Post-Course Hours/Week Gaelic Study	Performance ETR 1	Performance ETR 2	Performance ETR 3	Improvement ETR 1 to ETR 3
	0	90	100	100	10
	0.5	40	60	10	-30
	1	70	90	100	30
	1	70	90	60	-10
	1	10	30	60	50
	1.5	40	90	30	-10
	3	10	40	10	0
ETR Results	4	80	90	90	10
	4	90	80	80	-10
	5	80	100	100	20
	5.5	40	90	70	30
	5.5	20	30	30	10
	5.5	40	90	60	20
	6	30	50	40	10
	10.5	70	100	90	20
	12.5	80	100	100	20
	22.5	80	100	100	20

Notes: ETR: Elevator Task with Reversal
Session is denoted by number (1, 2, 3)

As shown in the table above, there were a number of cases in which scores decreased from session 2 to session 3, even for those who practiced 5 or more

hours per week following the course. This decline in scores is not surprising: we hypothesized that the challenge of learning a language intensively would bring about changes in cognition, therefore if that intensity decreases, attentional performance might also decrease. It is also important to note that variability in attentional scores across sessions may also be influenced by individual differences for the impact of language learning on cognition (which we explore in the following chapter) as well as other post-course lifestyle factors such as taking up a new hobby or returning to a more relaxing retirement life. However, despite these differences, clear patterns emerge from the data: there is systematic evidence that improvement from baseline was maintained in all those who continued to practice for 5 or more hours per week, highlighting a potential threshold for language-related cognitive change.

2.4. Discussion

Our results demonstrate a significant improvement in an attentional switching task (the Elevator Task with Reversal) after a one-week intensive Gaelic course and that active controls also experienced significant improvement. A linear trend analysis revealed that the passive controls did not show any improvement, while the active controls took an intermediate position, and language learners proportionally improved the most. These findings expand on the results of previous research (Vega-Mendoza et al., 2015) by demonstrating for the first time a language learning-related attentional improvement longitudinally *within the same participants*. The improvement was noted across all ages. Although overall performance on the Elevator Task with Reversal decreased with age, age did not interact with session or group, demonstrating that the positive impact of intensive courses on attentional control is detectable across the lifespan. Previous research shows that ageing does

not equally affect all aspects of language (Burke & Shafto, 2004); our results suggest that indeed it does not diminish the cognitive effects of language learning. Moreover, the improvement did not depend on Gaelic knowledge – in fact, the less advanced groups displayed a larger effect than the more advanced one. It would be tempting to assume that such pronounced effects after only one week of language learning would be short-lived. However, the improvement persisted in all participants who practiced 5 hours of Gaelic or more per week.

Much recent research on bilingualism focuses on the ease with which highly proficient, balanced, early bilinguals navigate between their languages in everyday life (Bialystok, Craik, Green & Gollan, 2009). In contrast, our approach investigates adult language learners in the early stages of language mastery, stressing the role of effort and practice (Bak, 2016a) and linking it to the emerging literature on cognitive reserve (Stern, 2002) which postulates that mental exercise (including bilingualism) can compensate to a certain degree for the effects of cognitive aging (Bak et al., 2014) as well as for pathological brain processes such as dementia (Alladi et al., 2013) or stroke (Alladi et al., 2015).

Cognitive training has been shown to lead to measurable improvements beyond the practiced task, with gains independent of the age of participants or total training time (Lampit, Hallock & Valenzuela, 2014; Karbach & Verhaeghen, 2014). Specifically, "*novel, cognitively challenging activities*" seem to be more effective in improving performance on tests of cognitive functions, such as working memory, than less taxing, familiar ones (Park et al., 2014). This could also apply to language learning and use. In this respect, our study corroborates previous findings showing differences in electrophysiological responses to executive tasks after 6 months of an

introductory Spanish course (Sullivan et al., 2014) and an improvement on executive control tasks after a 20-day training program in conversational French in 4-6 year old children (Janus et al., 2016).

Interestingly, the study by Janus et al (2016) also found improvements on executive tasks in a group undergoing musical instruction of the same duration. It is important to emphasize that although our study focused primarily on language learning, significant improvement on attention switching was also observed in the active control group, which was engaged in intensive courses not related to language learning. Previous work suggests that acquiring a novel skill requires the creation of new mental representations and subsequently managing those representations online (Norman and Shallice, 1986); this process can be cognitively taxing, especially in an intensive learning environment, and can often lead to measureable improvement in cognitive performance (Park et al., 2014). Our findings support those interpretations, revealing that intensive exposure to *any type* of novel, challenging activity is likely what drives the effects found in this study. That would explain why all groups except the passive controls experienced significant attentional improvement, and why there was a systematic 5+hour/week threshold for the maintenance of language learning-related cognitive improvement.

However, this explanation alone does not account for the significant difference in improvement between language and passive controls – a difference which did not reach significance for active controls. Does acquiring a language require additional attentional effort? If so, why? Our data cannot answer this. Nevertheless, in line with our predictions from chapter 1, we speculate that a distinction can be made with regards to the complexity of the control processes

involved in the planning and execution stages of the various activities. That is, learners of art, film documentary, and English teaching may develop and rely on a routine sequence of actions (e.g. task schema) to carry out tasks over the course. For example, film students may practice a sequence of turning the camera on, checking the microphone, adjusting the lighting, recording a test clip, playing the clip back, then recording the scene. Importantly, the recruitment of task schema in well-rehearsed scenarios allows for the direct inhibition of competing schemas through contention scheduling, an automatic process that ensures proper schema is activated while preventing non-target actions from being carried out. As such, the process of learning and applying routine skills developed over these courses does not involve the continuous need to switch back and forth from previously inhibited and activated task schemas. However, the contrary is true for language learners: a dual-language classroom environment often requires unpredictable shifts between processing and producing utterances in the native and target language based on linguistic and social cues from instructors and classmates. As such, automaticity would be less sufficient and language learners would require greater recruitment of attentional mechanisms to monitor and manage interference from competing language task schema and efficiently disengage and refocus attention when switching languages. In other words, the additional level of complexity in the monitoring, organization, and planning of speech may place greater demands on attentional control beyond that required for the formation and management of new mental representations. This would explain why language learners experienced the greatest improvement in attention.

Together these results demonstrate that improvement in cognitive functions can be achieved through a wide range of mental activities (Park et al., 2014; Valenzuela & Sachdev, 2009) and future research will need to examine not only specific types of mental exercise but also their possible combinations and interactions.

Interestingly, the improvement in attention did not depend on the level of previous knowledge of Gaelic and was also detectable in the very beginners. This could point to the importance of the *"desirable difficulties"* (Bjork & Kroll, 2015) of *novelty*, *challenge* and *effort*. Many studies in basic neuroscience stress the importance of novelty for neurogenesis, synaptic tagging, and memory formation (Veyrac et al., 2008; Wang, Redondo & Morris, 2010). One of the fundamental issues in this context is the interaction between novelty, facilitating the formation of new synaptic connections, and familiarity, supporting their maintenance. Indeed, while novelty could have helped our participants to achieve an improvement in attention, it was the *continuous practice,* which determined whether such changes persisted 9 months after the language course. Interestingly, one of the largest studies of multilingualism in aging (Kavé et al., 2008) found the best cognitive performance in participants who most frequently used a language other than their native tongue. Our study postulates, therefore, the importance of both novelty and practice.

Our study has limitations. The enrolment in the courses determined the number of participants recruited, while the short time in which the testing had to be conducted, at the beginning and end of the course, imposed constraints on the number of tests used. The participants were not randomly assigned and the geographic spread of their domiciles meant that we could only follow-up on half of

them. All three groups consisted of people who either enrolled in different educational courses or signed up for the Psychology Volunteer Panel, which includes regular participation in cognitive experiments. Hence, they could be perceived as particularly keen to engage in cognitive activities and not necessarily representative of the overall population (however, the three groups were highly comparable with each other in this respect). Finally, in the analysis of the longitudinal data, we set the threshold of 4 or fewer versus 5 or more hours of practice per week based on the inspection of our results and not on previous theoretical insights, so its relevance will need to be confirmed in future studies.

However, within the limits of the achievable, our results are remarkably clear and consistent. Our groups did not differ with respect to demographic variables and baseline performance. The Elevator Task with Reversal improvement did not depend on age or knowledge of Gaelic; if anything, it was stronger in the beginners. Not a single participant who practiced Gaelic for 5 or more hours/week deteriorated in his/her performance compared to the baseline. Hence, we hope that our work will encourage further research into language learning as a form of cognitive training, drawing attention to the importance of novelty, challenge, and practice.

Chapter discussion

The study presented in this chapter revealed longitudinal attentional improvement within the same group of language learners whose ages ranged from 18 to 78 years old. Not only were cognitive changes detectable after one week of language learning, but they were also maintained nine months later in all who continued practicing the language five or more hours per week. These results contribute to our general understanding of language and cognition over the lifespan by demonstrating that brief exposure to a foreign language can modulate attentional functions, even in old age.

In the next chapter, I replicate these results in a larger group of Gaelic learners (n>100) strengthening the reliability of the findings. In an effort to better understand the cognitive effects of language learning, I investigate attributes of a learner's background (including exposure to Gaelic and other languages) that may influence individual differences for the impact of language learning on cognitive ageing.

Chapter 3: The role of novelty and familiarity in the impact of language learning on cognitive performance

This is currently under review as:

This work was also presented at:

The University of Edinburgh Psycholinguistics Coffee

Chapter overview

This chapter builds on the previous one to explore factors affecting the impact of language learning on cognitive ageing. To ensure the reliability of the findings from chapter 2, I administered the same attentional tests on a much larger sample of Gaelic learners (n>100), aged 21-85, before and after one-week courses. Further, I explored the role of previous exposure to Gaelic (i.e. novelty versus familiarity), language background, age, and gender on cognitive performance following language learning. By focusing on attributes such as an individual's language knowledge and how that interacts with cognitive outcomes, this chapter provides a more nuanced account of the interplay between language and cognition across the lifespan.

Abstract

Both novelty and familiarity affect cognitive performance: novelty increases alertness whereas familiarity helps integrate new information with pre-existing knowledge. While novelty has been implicated in the cognitive effects of language learning, the differential effects of novelty and familiarity have not been directly compared. To address this, we assessed data from 105 university-educated Gaelic learners aged 21-85. Participants were tested before and after beginner, elementary, and intermediate courses using tasks measuring sustained attention, inhibition, and switching. We examined the relationship between attentional performance and Gaelic level, previous language experience, and age. Results revealed improvement in inhibition and switching. Both novelty and familiarity influenced switching performance: those in higher Gaelic levels initially outperformed lower levels, however lower levels improved the most. Age also affected performance: as age increased switching scores decreased. Further, language experience positively influenced younger adults' sustained attention with the reverse for older adults. Age did not interact with session for any attentional measure, thus, while cognitive performance varied with age, the impact of language learning on cognition was detectable across the lifespan. Peak enrollment occurred from age 60-65, suggesting that language learning is of interest to older adults and may provide a mentally and socially stimulating outlet during retirement.

Both novelty and familiarity have been shown to influence memory performance. On the one hand, studies have shown that individuals experience increased brain activation and alertness when presented with novel information (e.g. Danckert et al., 2007) and this 'distinctiveness' factor has been argued to play an important role in the encoding of information (e.g. Kirchhoff et al., 2000). On the other hand, researchers have found that encountering familiar items as opposed to novel ones yields better subsequent episodic memory of those items (e.g. Poppenk, Köhler, & Moscovitch, 2010). The juxtaposition of these findings poses an interesting theoretical question for linguists and psychologists: what is the role of novelty versus familiarity in the impact of language learning on cognitive functions? And how does previous language learning experience interact with other language learner characteristics, such as age? The current study is one of the first to address these inquiries, providing insight into understudied factors influencing differences in cognitive outcomes following language learning.

3.1. Background

A large body of research has sought to answer the question of whether use of more than one language affects cognitive functions. Theories surrounding the role of executive functions in managing competing linguistic systems spurred investigations into the efficiency of these functions in bilinguals, the findings of which are mixed (see meta-analysis: Adesope et al., 2010; for a recent discussion see Bak, 2016b). While some postulate that the need to inhibit one language when switching to another may bring about changes in cognitive control (Kroll, Bob, & Hoshino, 2014), this idea is hotly contested, with results both in favor and against this conclusion (e.g., Woumans et al, 2015; Clare et al., 2016). Moreover, other studies find that the

effects are confined to specific language combinations (Tao et al, 2015) or associated non-linguistic factors such as education (Gollan et al., 2011).

These conflicting results may be in part due to experimental design: most studies address this question by comparing group performance (bilinguals versus monolinguals or language learners versus controls) on measures of cognitive functions. The interpretation of this type of analysis, however, is complicated by a large number of confounding variables, with many complex factors that vary across individuals and populations, potentially affecting performance (Bak, 2016a). In this study, we take a more nuanced approach: rather than comparing groups (in which differences between individual scores and their group means are undesirable sources of variance), we look *within* a group of language learners to tease apart factors affecting individual differences for the impact of language learning on cognitive functions.

Our study expands on previous research (Bak et al., 2016), which proposes that language learning may provide a sufficiently mentally stimulating activity to bring about change in cognition. Indeed, the study found that students enrolled in one-week intensive Gaelic courses experienced significant improvement in attentional switching after the course, an effect also found in active controls (who were in courses of comparable duration and intensity but not learning a language), but non-existent in passive controls (who were following their usual weekly routine). A linear trend revealed that proportionally the languages learners improved the most, followed by the active controls, then the passive controls.

To better understand the potential effects of intensive language learning on subjects with different language experience and demographic profiles,

we collected data from a much larger sample of Gaelic language learners enrolled in the same type of courses (n>100); here we apply an individual differences approach to the analysis of this extended dataset.

Our study focuses on a well-defined group of language learners: all our participants had a high level of education (university degree) and a strong motivation to learn the language (as demonstrated by their willingness to spend a week learning Gaelic in a remote college specifically dedicated to this purpose). By gathering data on a homogenously highly educated and highly motivated group of learners, we focus on understudied factors which could affect language-related changes in cognition, such as previous exposure to the target language (i.e. familiarity versus the novelty factor), as well as age, gender, and language background, and how they may interact with one another. One might argue that previous Gaelic exposure is confounded with language background, but note that the results did not change when we excluded Gaelic knowledge from language background.

Based on earlier work (e.g. Vega-Mendoza et al., 2015) we predicted that pre-existing knowledge of Gaelic would influence cognitive performance such that those enrolled in more advanced Gaelic courses would initially outperform those in lower level courses. At the same time, as a result of the novelty factor, we predicted that those in lower level courses would experience the greatest cognitive improvement (based on Bjork & Kroll, 2015; Bak et al, 2016). In contrast, we did not expect to find any influence of gender on performance (e.g. Ehrman & Oxford, 1995). We predicted that younger adults would outperform older adults, but that improvement would not be affected by age (e.g. Bak et al., 2016). Finally, existing evidence did not allow us to make an unequivocal prediction about whether knowledge of more than two

languages (in this case English and Gaelic plus additional ones) would lead to better performance on the attentional tests. Evidence regarding additional effects of knowledge of more than two languages is highly inconsistent: some studies found that cognitive performance improved with the number of languages spoken (Kavé et al., 2008) or that better cognitive performance was only observed in trilinguals as opposed to bilinguals (Chertkow et al., 2010). Others found no improvement (Alladi et al., 2013) or only very subtle improvement (Bak et al., 2014) with a third or fourth language. This debate is far from settled (Freedman et al., 2014).

3.2. Methods

3.2.1. Participant recruitment

A total of 132 language learners were recruited from Sabhal Mòr Ostaig, the National Centre for Gaelic Language and Culture located on the Isle of Skye, Scotland. Over the summer, the Centre offers intensive one-week Gaelic language courses, averaging a total of 14 hours of tuition, in addition to cultural entertainment offered in the evening such as ceilidhs, films, and conversation circles. Participants from beginner, elementary, and intermediate Gaelic levels were tested before and after their course. Given that the vast majority of participants were university educated, we removed those with varying levels of education below university (n=27) in order to focus on a more homogenous group of degree-holding individuals (n=105). Written informed consent was obtained from each participant prior to commencing the tests and the study was approved by the University of Edinburgh Psychology Ethics Committee.

3.2.2. Materials/procedures

3.2.2.1. Test of Everyday Attention

Auditory tasks from the Test of Everyday Attention (TEA) (Robertson et al., 1994) were administered. The TEA is a clinical test originally designed to measure subtle changes in attentional functions, such as the effects of neuro-rehabilitation in patients with brain damage. Accordingly, it comes with parallel versions to avoid practice effects. It has since been standardized on adults aged 18-80 (Robertson et al., 1996) and is increasingly applied to linguistic research (Bak et al., 2014; Vega-Mendoza et al., 2015; Long et al., 2018).

The three auditory tasks chosen for this study measure sustained attention, inhibition alone, and switching (jointly tapping into inhibition and release from inhibition)—functions theorized to affect language use (e.g., Tao et al., 2011).

For each task, participants envision that they have entered an elevator on the ground floor. The floor light indicator does not work, so in order to know which floor they are on they must count the tones they hear. After each trial a recorded voice asks which floor they are on.

***Elevator Task* (sustained attention, n=7 trials)**: Participants are presented with tones of the same pitch at irregular intervals and must keep track of the count.

***Elevator Task with Distraction* (selective attention/inhibition, n=10 trials)**: Participants are presented with low and high tones. They must selectively attend to low tones while ignoring interspersed high tones.

***Elevator Task with Reversal* (attentional switching, n=10 trials)**: Participants are presented with low, medium, and high tones. They must count medium tones only. Low tones indicate the elevator will begin to move down with

the subsequent medium tones, while high tones indicate the elevator will begin to move up with subsequent medium tones.

For each of these measures we calculated the percentage of trials with correct responses, 0-100.

3.2.2.2. Questionnaire

Participants completed a demographic and language background questionnaire in which they identified their gender, age, and education level. Using 5-point scales, participants rated their expression, comprehension, reading, and writing skills in every language they had at least basic knowledge of. We then compiled this into a composite language background score for each participant. All participants reported a score of at least 20 (full fluency in their native language) and any additional knowledge of other languages increased this score. Some participants reported having previous knowledge of Gaelic. In order to ensure we were not measuring the same information more than once (i.e. language background score and Gaelic level), we ran the analysis twice: first, we ran the analysis with the self-reported language background scores for all languages, then with an adjusted language background score which excluded previous knowledge of Gaelic. Following Bonferroni corrections (outlined in the following section), the results remained the same. Therefore we report statistics from the self-reported language background score below.

3.2.3 Statistical analyses

Using linear mixed effects regression for each attentional test, we modelled the outcome variable of test score, with session (pre- and post-course), age, gender, language background, and Gaelic level as fixed effects

and subjects as random effects. Deviation coding was used for session and gender (set as -.5/+.5 for pre-course/post-course and for female/male), while participant age, language background, and Gaelic level were entered as scaled continuous predictors. To test for main effects and two-way interactions[2], we conducted likelihood ratio tests between mixed-effects models differing only in the presence or absence of that fixed effect (the same method was used to test for interactions). We account for multiple comparisons from our three cognitive measures with Bonferroni corrections (adjusted significance level of $p=.0166$).

3.3. Results

3.3.1. General characteristics of the participants

A total of 105 university-educated adults were included in our sample. The majority were female (67 female, 38 male). Participants' composite language background score ranged from 20 (complete monolingual) to 94, with a median score of 37. The majority of participants were enrolled in Gaelic level 1 (n=47), Gaelic level 2 had the fewest participants (n=21), and Gaelic level 3 was in the middle (n=37). There was a wide spread of ages within the group, from 21 to 85 years old, with those in the 60-65 age group representing the largest number of participants (see Fig 3.1).

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[2]Following the conservative method from the previous chapter, we again modelled only two-way interactions to avoid reduced precision on the model estimates for higher order interactions.

Figure 3.1. Distribution of participant age within our sample

3.3.2. Performance on TEA subtests

On the sustained attention measure, performance was close to ceiling both pre- and post-course (see Table 3.1). On the inhibition measure, performance increased by 4.95 points following intensive language exposure. The greatest change was found on the switching measure, where the performance increased from session 1 to session 2 by 16.95 points.

Table 3.1. Descriptive statistics for TEA subtests

Task	*M*	SD	Min	Max	# Trials
Sustained attention (session 1)	99.05	3.582	85.71	100	7
Sustained attention (session 2)	98.37	5.358	71.43	100	7
Change over session	*-.68*				
Inhibition (session 1)	86.10	20.357	10	100	10
Inhibition (session 2)	91.05	16.048	10	100	10
Change over session	*4.95*				
Switching (session 1)	58.48	32.516	0	100	10
Switching (session 2)	75.43	27.632	0	100	10
Change over session	*16.95*				

3.3.3. Relationship between individual characteristics and performance

Table 3.2 lists the significant effects and interactions found in the respective models for sustained attention, inhibition, and switching (see Appendix B for full

model output). For sustained attention, the only effect that emerged was an interaction whereby language background had a different effect on performance for younger and older adults. Younger adults' performance increased with greater knowledge of other languages whereas the contrary was true for older adults (Fig 3.2). We conducted follow-up analyses of the subsets of younger and older adults (divided by the median age of 53). The older adults showed a main effect language background (β=-1.2023, t=-2.08, p<0.05), with more extensive language background being associated with lower performance; the younger adults showed the opposite pattern, but it was marginal (β=0.93839, t=2.00, p=0.05).

Table 3.2. Significant main effects and interactions for the three measures

Sustained attention			
Fixed effect	**Coefficient**	**T-value**	**P-value**
Age x Composite	-0.8309	-2.43	p<.05
Inhibition			
Fixed effect	**Coefficient**	**T-value**	**P-value**
Session	5.4094	4.21	p<.001
Switching			
Fixed effect	**Coefficient**	**T-value**	**P-value**
Session	16.50596	7.578	p<.001
Age (mean centered and scaled)	-9.31065	-3.276	p<.01
Session x Gaelic level	-5.93590	-2.823	p<.01

Figure 3.2. Age x composite for sustained attention (median age split)

71
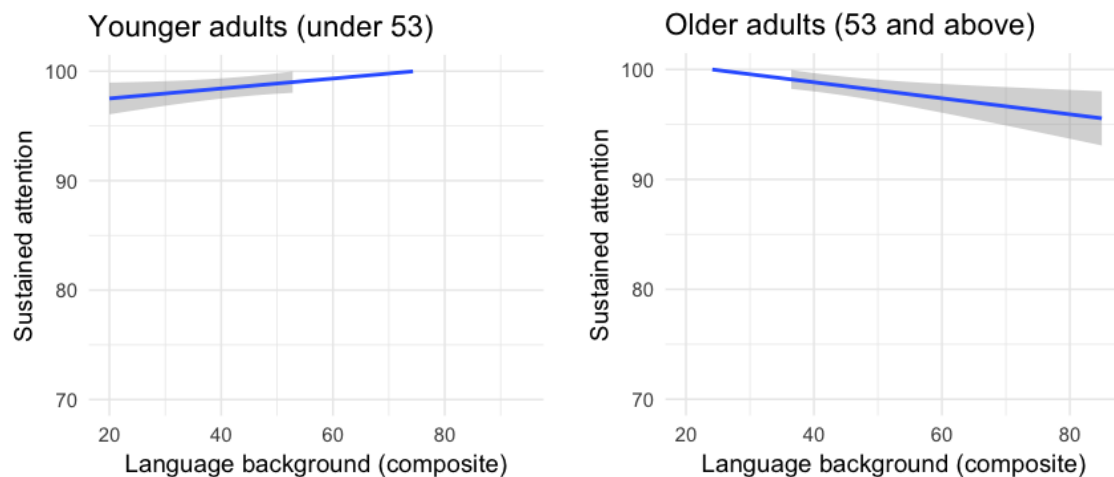
For both inhibition and switching, we found a main effect of session with improved performance post-course (Fig 3.3). For switching, there was an additional session x Gaelic level interaction: those in higher levels initially performed better but those in lower levels improved the most (Fig 3.4). Lastly, there was a main effect of age on switching: as age increased, scores decreased (Fig 3.5). There was no effect of gender on any of the measures.

Figure 3.3 Main effect of session for inhibition and switching
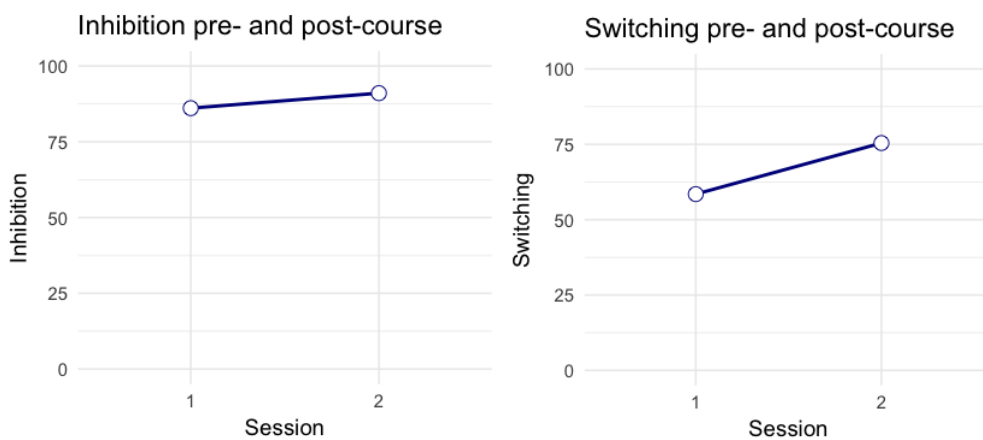
Figure 3.4. Session x Gaelic level for switching
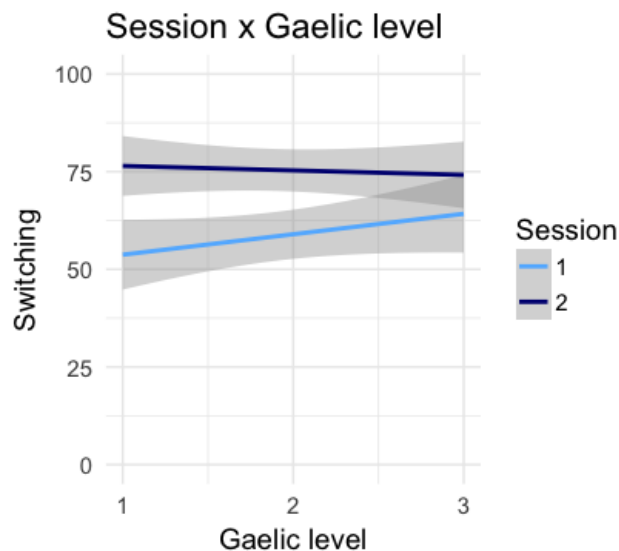
Figure 3.5. Main effect of age for switching

Switching performance by age
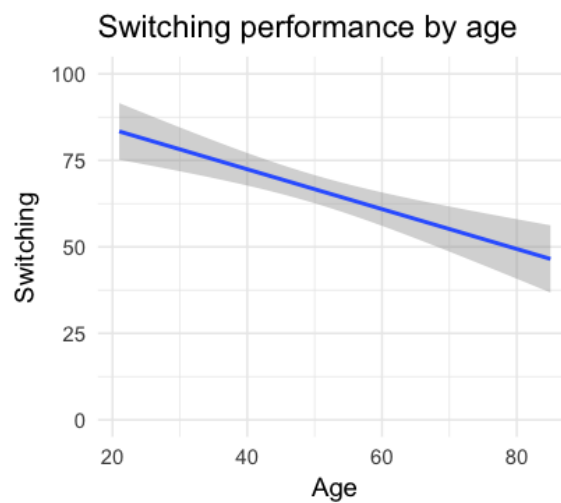
3.4. Discussion

Our study is one of the first to look *within* a group of university-educated language learners to identify factors responsible for individual differences in attention following language learning. Confirming previous studies (Bak et al. 2016), we found improved inhibition and switching post-course. These cognitive changes are likely attributable to the type of *productive engagement* involved in language learning. Specifically, in acquiring a foreign language one cannot rely solely on passive activation of prior knowledge, but must actively learn new information—from attending to sounds and mapping those sounds to word-level meaning, to processing complex syntactic structures, to forming pragmatic inferences based on contextual and cultural clues, all while actively supressing interference from one's native language or other known languages (Kroll et al., 2016; Linck et al., 2009). Indeed, previous studies have compared a variety of activities (e.g., photography, knitting, fieldtrips, entertainment) involving either passive or productive engagement and found that the most cognitively beneficial courses were those involving this productive type of learning (Park et al., 2014).

Our results also demonstrate the impact of individual differences on performance and, most interestingly, on the degree of performance improvement that an individual shows post-course. Both the level of language knowledge as well as the intensity of the one-week language learning experience positively influenced attentional switching performance. Specifically, those in higher levels of Gaelic were initially better at switching, while those in lower levels of Gaelic experienced the greatest improvement post-course. The first finding can be interpreted as reflecting a higher baseline switching ability as an effect of previous exposure and practice with Gaelic. The second finding, in which the largest cognitive gains were found in those who lacked previous Gaelic exposure, supports the notion of "desirable difficulties" (Bjork & Kroll, 2015), which posits that activities both *novel* and *mentally challenging* may provide the greatest cognitive benefits.

The fact that we did not find an effect of the composite score of other languages beyond Gaelic on attentional performance could suggest that such effects, if present, are substantially smaller and might only be detected in much larger cohorts. Another alternative is that there is no systematic additive benefit of knowledge of more than two languages. As numerous studies suggest, bilinguals are able to acquire third languages more easily than monolinguals learning a second language (for a full review see Cenoz, 2003). Perhaps the reason for this is that bilinguals have already become efficient at juggling competing linguistic systems through the development of enhanced inhibitory control and attentional switching. Therefore they may be better equipped to manage additional languages. This interpretation would suggest that a threshold of attentional efficiency may already be met through the cognitive demands imposed by a second language. Therefore

we should not expect cognitive gains to increase systematically with every additional language acquired, but rather recognize that the brain may have already optimally adapted to accommodate multiple languages.

While our data supports the interpretations above, it is important to note the limitations of our composite score measurement. This measurement was calculated by compiling participants' self-rated proficiency in each language. Though this provides a straightforward and uniform measurement across participants, it is not particularly sensitive or rigorous. Unlike a participant's level of Gaelic, confirmed by the teachers themselves, composite score was completely subjective: no follow-up tests were conducted to assess the accuracy of participants' self-rated knowledge of other languages. Further, other influences such as language typology/modality and attitudes towards the languages were not accounted for, factors which will be addressed in the following chapter in the context of language learning.

In addition to Gaelic level, participant age also played a role in predicting cognitive performance: our results show that older adults performed worse on the switching task, the most cognitively complex of the three tasks. Further, the impact of language knowledge on sustained attention affected younger and older adults differently: younger adults' performance increased with more language exposure whereas older adults showed the opposite pattern. These results demonstrate that we should not assume that effects of prior experience (here, amount of foreign language exposure) on a cognitive measure will be uniform across ages. Notably, however, age did not interact with session for any of the attentional measures. This suggests that while cognitive performance varies with age, the impact of language

learning on attention is not age-dependent, highlighting the robustness of this effect as well as the brain's adaptability over the lifespan.

This finding is particularly important in the context of the age-profile of our participants, with those aged 50-65 years old forming the largest group (Fig 3.1). The histogram shows that young adults' enrolment in language courses peaks in their 30's and that there is an even greater peak later in life at what appears to be a crucial period in one's early 60's when many adults are preparing for or settling into retirement. While most language courses are aimed at school children, students, and young adults, catering to their specific learning needs, we may be overlooking an important population of older adults who are interested in language learning and have the time to undertake such courses. As the increase in life expectancy has not been matched by a comparable change in retirement age, the percentage of life spent in retirement is continuously increasing. Moreover, the age of retirement in many countries is not voluntary and does not reflect the preferences of individuals to continue working (Steiber & Kohli, 2017); this resulting period of time spent without the routine mental and social stimulation associated with work can lead to many adults seeking opportunities to fill this void.

As our observations suggest, older adults may perceive learning new languages (or refreshing familiar ones) as an attractive retirement activity, further strengthened by recent research findings which suggest that mental activity associated with life-long education might delay the onset of dementia (Wu et al., 2017), and that language learning and practice may be part of "healthy living" in old age (Bak & Mehmedbegovic, 2017). This brings forth both opportunities and challenges in adapting teaching materials and styles to suit this growing population

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whose needs are just beginning to be recognized and addressed (Gabrys-Barker, 2017).

Overall, our findings complement current theories of cognitive change following interventions (e.g. Park et al., 2014), and offer a new angle from which to explore factors affecting individual differences in language learners' cognitive performance. In line with the predictions and results from this chapter and the previous one, we interpret this attentional improvement to be related to the challenge of learning in an intensive environment, as this requires the recruitment of attentional mechanisms for the formation and management of new task schema (Norman and Shallice, 1986; Green 1998). This explains why in the previous study both language learners and active controls experienced significant attentional improvement, and why there was a systematic 5+hour/week threshold for maintaining improvement. Further, as discussed in this chapter, the novelty of learning a completely unfamiliar activity may also result in greater cognitive gains.

Beyond the intensity and novelty factor, we argue that language learners have the additional challenge of efficiently engaging and disengaging from co-activated languages at any given moment. This likely poses further demands on the attentional network and may be what lead to their proportionally greater improvement in attentional control in the previous chapter. As such, the overall cognitive gains experienced by language learners may come from a combination of the novel, intensive environment as well as the language control needed for effective communication in a dual-language context.

Naturally, our study has limitations. With a brief window of time to administer the cognitive measures to each individual before and after the course it was

necessary to select short tests. As such, we were unable to compare reliability across multiple tasks separately tapping into switching, inhibition, and sustained attention. Only after evaluation did we note an ambiguity in the language background questionnaire, which caused some participants to exclude knowledge of Gaelic from their language background. As this was a self-selected group of learners, the results of this study are not generalizable to the greater public. Moreover, since we focus our study on language learners, we cannot determine whether other types of mental activity (and other intensive courses) produce similar effects, a question which will need to be addressed in further studies. Nevertheless, despite the challenges involved in this type of fieldwork, we were able to collect a relatively large amount of data and control for both motivation and education, allowing us to gain new perspectives on the role of novelty, age, language background in predicting language-related cognitive change. We hope these findings encourage others to look beyond categorical grouping of individuals (e.g., bilinguals versus monolinguals) to more deeply explore the complexities of the language learner profile and how these features may influence performance.

Chapter discussion

This chapter replicates the findings of the previous chapter in a larger sample, suggesting that the effects of language learning on cognitive ageing are reliable and robust. Additionally, both novelty and familiarity with the language impacted cognitive performance: familiarity was associated with higher baseline attentional abilities, whereas the novelty of learning an unfamiliar language brought about greater attentional improvement. These findings further emphasize the strength of the relationship between language and cognition by demonstrating that changes to one's linguistic environment as well as differences in one's linguistic background predict cognitive performance.

In the next chapter, I expand on this by investigating whether cognitive change is found across different language modalities by randomly assigning participants aged 23-85 to learn a spoken language (Norwegian or Turkish) or a sign language (British Sign Language). I also examine whether participants' attitudes change over the course in relation to the randomly assigned language and its impact on cognition.

Chapter 4: Cognitive psychology meets sociolinguistics: effects of brief intensive language learning on attentional functions and language attitudes

This is currently under review as:

This work was also presented at:

Chapter overview

This chapter further explores the effects of language learning on cognitive ageing by investigating whether the cognitive effects of language learning are the same across different language modalities (spoken versus sign).

To test this, 35 adults (aged 23-85) were randomly assigned to an intensive one-week course in Norwegian, Turkish, or British Sign Language. Participants were tested before and after the course using the same attentional measures from the previous chapters as well as visuospatial tasks and a questionnaire to assess whether the randomly assigned course influenced participants' attitudes towards the language and their perception of whether it was cognitively beneficial. The findings from this study contribute to our understanding of the impact of language on cognition by addressing whether the cognitive effects of language learning are modality-specific or universal across spoken and sign languages.

Abstract

A recent study revealed enhanced attentional switching after a one-week intensive Gaelic course on the Isle of Skye. To determine whether these effects were modality-specific, we conducted an intervention study in which thirty-five Edinburgh residents were randomly assigned to a course in either a spoken language (Norwegian or Turkish) or a sign language (British Sign Language). We further developed the study by adopting an interdisciplinary approach to language learning, combining cognitive measures (attentional and visuospatial tasks) with the inclusion of participants' self-reported attitudes towards the assigned languages. Our findings revealed that both spoken and sign language learners improved on attentional switching. Further, post-course attitudinal changes were found across spoken and sign languages: participants found learning spoken languages but not British Sign Language easier than expected, while motivation to learn the languages increased in both groups. Notably, a correlation was found between measurable improvement on attentional switching and the perception that the language learning experience had been cognitively beneficial.

4.1. Introduction

Recent research suggests that a brief intensive language course can lead to measurable improvement in cognitive functions. Participants in a one-week intensive Gaelic course at Sabhal Mòr Ostaig on the Isle of Skye improved significantly in their attentional performance. (Bak, Long, Vega-Mendoza & Sorace, 2016). Notably, this language learning-related attentional improvement was found across all ages, from young adults to the elderly.

Nevertheless, the reported results might have been influenced by several confounding variables which could not be controlled for in the setting in which the study was conducted. Firstly, while the Gaelic course took place on the Isle of Skye, the control participants were tested in Edinburgh, the city in which they were living. We therefore cannot exclude the possibility that at least some of the effects of the Gaelic course could be related to factors such as the particular setting of the college, intense socializing with like-minded people enhanced by a program of cultural events in the evening, immersion in an area steeped in Gaelic culture, or even the effect of spending a week away from home.

Secondly, although the groups were carefully matched in terms of their age, gender, education and previous knowledge of foreign languages, they were self-selected: people who decided to do the intensive Gaelic course could be different in some respects from their control counterparts. Although the three groups did not differ in their baseline performance on attention switching, participants attending the Gaelic course may have had a greater ability to learn a language and/or benefit from it cognitively – a subtle difference, which could not be sufficiently captured with the available screening tools.

Further, the groups might have differed in their attitudes, expectations, and beliefs connected with the course and its outcomes. For a long time attitudes, motivation, and language aptitude have been known to influence success in the acquisition of a language (see overviews by Dörnyei, 2009, 2014; Skehan, 1991); to what extent attitudes might also influence the cognitive effects of language learning is a question still to be addressed.

Against this background, we aimed to replicate the results of the Gaelic study (Bak et al., 2016) while controlling as much as possible for its confounding variables. Our study avoided the location effect as it was entirely conducted in Edinburgh, where all participants lived. Furthermore, the taught languages were not chosen by the participants but rather assigned to them by the investigators. Moreover, unlike the Gaelic study, we went beyond a purely cognitive approach and explored whether the course had any influence on participant attitudes towards language learning in general and towards the specific languages being studied.

The choice of languages in this study was influenced by practical as well as theoretical considerations. In practical terms, in order to secure successful recruitment and compliance of participants, we had to offer courses of potential interest. In order to identify preferred and non-preferred options, we conducted two consultation events which are described in detail in the Methods section. Out of the preferred choices made by participants, we selected two spoken languages: Turkish and Norwegian, and one signed language: British Sign Language (BSL). The comparison between spoken and sign languages allowed us to refine our hypothesis: previous literature suggests that bimodal bilinguals do not experience the same involvement of inhibitory control in language processing as unimodal

bilinguals, and therefore do not develop the same general attentional control enhancement (Giezen, Blumenfeld, Shook, Marian, & Emmorey, 2015; Emmorey, Luk, Pyers, & Bialystok, 2008), we therefore expected to find effects of the brief intensive language course on attentional functions in the spoken language group but not sign language group. Conversely, given the spatial challenges of sign languages, particularly the necessity of imagining oneself in the spatial position of the interlocutor and visualizing and maintaining referents in hypothetical locations during discourse (Keehner & Gathercole, 2007), we hypothesized that the sign language group would improve on complex spatial tasks such as the Reverse Corsi. Supporting our theory is a large body of work which shows that native signers outperform non-signers on dynamic spatial tasks (Rettenbach, Diller, & Sireteanu, 1999; Emmorey, Kosslyn, & Bellugi, 1993; Emmorey, Klima, & Hickok, 1998) as well as recent work showing that this effect extends to non-native hearing signers with one to five years of regular signing experience (Keehner & Gathercole, 2007).

We augmented the cognitive dimension of the study with the innovative addition of research into learners' attitudes towards the languages being taught. Many studies focus on the issue of motivation in language learning experiences (Smith, 1971; Gardner & Lambert, 1972), honing in on the psychology of the student's attitude to the learning process (Dörnyei & Ryan, 2015) or to their attitudes to themselves as learners (Öztürk, 2014), rather than on their perceptions of the language and its user community. As there is a gap in the literature with regards to this issue, we could not formulate a hypothesis based on existing research. Instead, what we hope to gain from this inquiry is an understanding of the type of attitudinal questions that are sensitive to change after language exposure, so as to inform the

development of questionnaires for future research in this area. As such, the multidisciplinary nature of this work is exploratory in a number of respects.

4.2. Methods

4.2.1. Participant recruitment and choice of languages

Participants were recruited through a bilingualism-related event at the Edinburgh International Science Festival as well as two information events in collaboration with a local language café, Yakety Yak. Participants were told that they would be offered a free one-week intensive language course, but that the choice of language would be determined through random selection. During the consultation events, participants were asked to identify languages that they would be interested in learning as well as those that they were clearly not interested in, so as to secure attendance and motivation. British Sign Language (BSL) was the top language for which no objections were made; Scandinavian languages and Turkish were also highly ranked. Languages for which group responses were polarized (roughly half in favor of and half against) included Russian, Chinese, Arabic, and Gaelic. Additionally, participants were asked to choose activities of interest not involving language learning. The most popular choice was drawing/painting – however, participants had a wide range of previous experience with it, which would have made it difficult to select a group of absolute beginners. In contrast, none of the participants had previous knowledge of BSL, Norwegian, or Turkish. We therefore selected these three languages for the current study.

A total of one hundred eighteen people were invited to participate in the study through the email list compiled at the events mentioned above. Of those, forty registered. Registered participants were asked which weeks they were available to

take part in the study (the participants did not know which languages were offered in which weeks) and were then randomly assigned to one of the three groups depending on the availability of language teachers in a given week (this explains the unequal group sizes). In addition, two BSL students, one Norwegian student, and one Turkish student dropped out before the courses began, and one Turkish student discontinued the course after the first day due to an illness. Hence, a total of thirty-five people completed the courses. This study was approved by the Ethics Committee from the University of Edinburgh Psychology Department.

4.2.2. Participant characteristics

Within the two spoken language groups, Norwegian (n=13) and Turkish (n=8), there were no significant differences in age: Norwegian: 62.23±13.33, Turkish: 61.25±12.78, gender (percentage female): Norwegian: 84.62%, Turkish: 87.50%, education (percentage with degree): Norwegian: 84.62%, Turkish: 87.50%, or composite language score: Norwegian: 49.46±17.37, Turkish: 56.63±16 (all p's>.05). Likewise, in comparing the spoken language (n=21) and sign language (n=14) groups, no differences were found in age: Spoken: 61.86±12.81, Sign: 63.57±13.66, gender (percentage female): Spoken: 85.71%, Sign: 64.29%, education (percentage with degree): Spoken: 85.71%, Sign: 100%, or composite language score: Spoken: 52.19±16.83, Sign: 51.21±20.22 (all p's>.05).

4.2.3. The choice of cognitive tests

As the current study aimed to replicate the effects from the Gaelic study (Bak et al., 2016) in a non-residential sample, we used the same auditory attentional subtests from the Test of Everyday Attention (TEA). The TEA is a well-established clinical test measuring discrete functional systems including selective attention,

inhibition, and switching (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994). It was designed and is widely used for monitoring the effects of neuro-rehabilitation in patients with brain damage (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996; Chan, 2000) and therefore includes three parallel versions with the same level of difficulty, making it particularly well suited for longitudinal studies through the minimization of potential practice effects (Clare et al, 2013).

Three auditory subtests from the TEA were used to examine different aspects of attention:

***Elevator Task (ET)* (sustained attention)**: Participants are asked to count tones of the same pitch and duration presented at irregular intervals (n trials=7).

***Elevator Task with Distraction (ETD)* (selective attention/inhibition)**: Participants continue to count the tones, however higher pitched distractor tones are introduced, which must be ignored (n trials=10).

***Elevator Task with Reversal (ETR)* (attentional switching)**: Participants are asked to count only the middle tones while changing direction with high and low tones (n trials=10).

In order to address the difference in modality for those learning BSL, two visuospatial tasks were employed:

The Corsi Block-Tapping Task (Corsi) is used to measure visuospatial short-term memory both clinically and in experimental research (Milner, 1971; Corsi, 1972). During the task, a board with nine mounted cubes is placed between the examiner and participant. From the examiner's point of view, each block is associated with a number. The examiner taps a sequence of blocks at the rate of one block per second and the participant is then asked to tap the same sequence.

For each item there are two trials, starting with sequences of two, and increasing in length up to sequences of nine. The discontinuation rule was applied when two trials of the same item were not tapped in the correct order.

The Reverse Corsi is an adapted Corsi paradigm which simulates the 180° spatial relations in sign discourse (Keehner & Gathercole, 2007). For the task, there are two identical boards with nine mounted cubes, one placed directly in front of the experimenter, the other directly in front of the participant. Each board is rotated 180° relative to the other board and visible to the examiner only are numbers indicating corresponding blocks on each set. Similar to the Corsi task, the examiner taps a sequence of blocks on the board in front of them. This time, however, the participant is asked to tap the 180° rotated equivalent on their own board. In following the Keehner and Gathercole procedure, each item has a total of six trials, and the examiner starts with a sequence length of one, increasing in length up to a maximum of five. The discontinuation rule from the original Corsi was applied.

4.2.4. The choice of language attitude questionnaire

Research on attitudes in foreign language learning typically explores students' motivation to learn the language, and whether that motivation affects language attainment and proficiency (Scholfield, 1995). In experimenting here with the design of an entirely original questionnaire to explore learners' attitudes, we did not seek to address "the characteristics of the traditional approach to SLA research, including the identification of variables, the quantification of their relative weighting, and a quest for some generalizable findings about the nature of motivation in SLA" (Sealey & Carter, 2004). Rather, our objective was to generate a set of data permitting an initial account of learners' early classroom encounters with new

languages as social objects, and of their beliefs about associated matters of social positioning.

4.2.5. Language background questionnaire

In addition to these cognitive and attitude measures, a comprehensive questionnaire about previous language experience was administered. In the self-assessment, participants were asked to rate their knowledge of languages in four domains: expression, comprehension, reading and writing; a composite score of all known languages was calculated for each individual.

4.2.6. Language teachers and course setting

In order to minimize the potential influence of the personality, charisma, and teaching style of individual tutors, each course was taught by at least two different tutors. All seven tutors chosen for this study (three for Norwegian and two each for Turkish and BSL) had extensive experience in adult language education. All classes were taught in the same location on the University of Edinburgh central campus and the classrooms that were used had similar layouts and facilities.

The intensity and duration of the courses were similar to that of the Bak et al., 2016 study: a scheduled twelve hours of language learning throughout the week included morning and afternoon classes (ten contact hours) and two hours minimum of self-study. The two Turkish courses were taught in the first and second week of June, and the two BSL courses were taught in the last two weeks of June. Participants were tested before and after the course and the test battery took approximately forty-five minutes to administer. Participants were asked to complete the language attitude questionnaire, followed by the cognitive assessment, and were given the language background questionnaire to complete by the end of the week.

4.2.7. Statistical analyses

As with the language teachers, the purpose of including two unrelated spoken languages was to minimize the influence of language typology on the overall results. Before data collection, a priori group comparisons were planned for each of the measures: the main question involved a comparison between spoken and sign languages, thus the two spoken language groups (Turkish and Norwegian) were analyzed together as one spoken language group.

The Corsi and Reverse Corsi tasks were analyzed by number of correctly identified trials before the discontinuation rule. That is, for Corsi, a perfect performance would mean a participant correctly identified sixteen trials and for Reverse Corsi a perfect performance would be thirty-six trials.

We used linear mixed effects regression for each cognitive measure, modelling the outcome variable of test score, with session (pre- and post-course) and group (sign, spoken) as fixed effects and subjects as random effects. Deviation coding was used for session and group (set as -.5/+.5 for pre-course/post-course and for sign/spoken). To test for main effects and interactions, likelihood ratio tests were conducted between mixed-effects models differing only in the presence or absence of that fixed effect; the same method was used to test for interactions. To account for multiple comparisons we applied Bonferroni corrections with an adjusted alpha of $p=.01$.

For the attitude questions, Mann-Whitney tests were used to examine whether spoken and sign language groups differed significantly in any of their responses in session one. Additionally, an attitudinal change score from session one to session two was calculated and Mann-Whitney tests were used to reveal

differences across groups in attitudinal change over the course. Here we applied Bonferroni corrections with an adjusted significance level of *p*=.02.

4.3. Results

4.3.1. TEA results

4.3.1.1. Elevator Task (ET)

There was no main effect of group or session nor was there an interaction (*p*'s>.05). See Table 4.1 for model output.

4.3.1.2. Elevator Task with Distraction (ETD)

There was no main effect of group or session nor was there an interaction (*p*'s>.05). See Table 4.2 for model output.

4.3.1.3. Elevator Task with Reversal (ETR)

There was a main effect of session (β=17.500, *t*= 3.905, *p*<.001): overall participants improved from session 1 to session 2 (Fig 4.1). There was no main effect of group nor interaction (*p*'s>.05). See Table 4.3 for model output.

Table 4.1 Model output for Elevator Task (ET)

Fixed effect	Coefficient	T-value	P-value
Session	1.0714	1.25	0.2005
Group	0.3571	0.42	0.668
Session x Group	-2.1429	-1.25	0.2005

Table 4.2 Model output for Elevator Task with Distraction (ETD)

Fixed effect	Coefficient	T-value	P-value
Session	3.810	1.531	0.1212
Group	-2.857	-0.385	0.6919
Session x Group	-3.810	-0.765	0.4326

Table 4.3 Model output for Elevator Task with Reversal (ETR)

Fixed effect	Coefficient	T-value	P-value
Session	17.500	3.905	0.0002658
Group	2.500	0.269	0.7819
Session x Group	10.714	1.196	0.2232

Figure 4.1. Main effect of session for Elevator Task with Reversal (ETR)
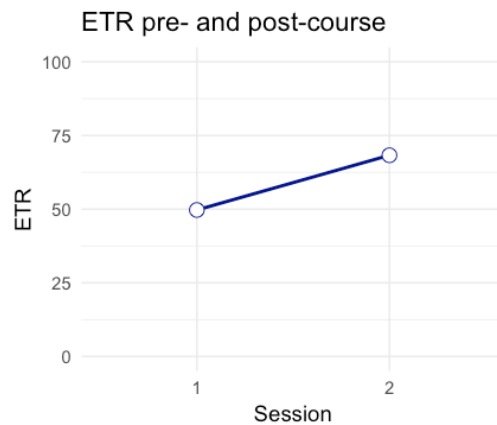
4.3.2. Corsi and Reverse Corsi results

4.3.2.1. Corsi

There was no main effect of session or group nor was there an interaction

(p's>.05). See Table 4.4 for model output[3].

4.3.2.3. Reverse Corsi

There was no main effect of session or group nor was there an interaction

(p's>.05). See Table 4.5 for model output[4].

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[3] Before adjusting the alpha for multiple comparisons, there was a trend towards a main effect of group (p=.05164) which shows that the spoken learners scored higher than the sign learners.

[4] Before adjusting the alpha for multiple comparisons, there was a trend towards a main effect of session (p=.06223), which shows improvement from session 1 to session 2. However this marginal effect provides no support for previous work (e.g. Keehner & Gathercole, 2007).

Table 4.4 Model output for Corsi

Fixed effect	Coefficient	T-value	P-value
Session	0.1667	0.457	0.6382
Group	1.0952	1.942	0.05164
Session x Group	-0.8095	-1.111	0.257

Table 4.5 Model output for Corsi Reversal

Fixed effect	Coefficient	T-value	P-value
Session	1.5952	1.857	0.06223
Group	0.6905	0.471	0.6281
Session x Group	0.9048	0.526	0.5885

4.3.3. Questionnaire results

Participants responded to seventeen questions via Likert scale (1 *strongly disagree* to 6 *strongly agree*). Three yielded significant results following Bonferroni corrections (denoted by ** in the graphs) either for group differences before or over the course, or in post-course attitude change in at least one of the groups.

As the aim is to identify questions to recommend for future studies, we also report six questions that yielded significant results before Bonferroni corrections (denoted by * in the graphs). We clustered the questions into three groups depending on the issue: (a) the value of learning the language, (b) the difficulty of learning the language, (c) the social context of the language. Below, we discuss responses to those nine questions; for the full set of questions, see Appendix C.

4.3.3.1. Questions related to the value of learning the language

Q1.) It is important for members of our community to know the language I will be learning this week.

Q8.) Schoolchildren here should have the opportunity to study this language.

Q16.) I would encourage others like me to learn this language.

Figure 4.2. Pre- and post-course group responses to questions related to the value of learning the language (Questions 1, 8, and 16)

Figure 4.2a Response to Question 1
It is important for members of our community to know the language I will be learning this week

Figure 4.2b Response to Question 8
Schoolchildren here should have the opportunity to study this language

Figure 4.2c Response to Question 16
I would encourage others like me to learn this language

Baseline group difference **

Baseline group difference **

Notes: Error bars represent ± 1 SE. *p < .05, **p < .003

Two overall tendencies can be observed here. Firstly, attitudes towards all languages improved after the course. Secondly, attitudes towards the sign language were more positive than the spoken languages, although this difference, significant for questions 1 and 8 at baseline, ceases to be significant as the importance of learning spoken languages increases.

4.3.3.2. Questions related to the difficulty of learning the language

Q3.) Older people cannot be expected to learn a language like this.

Q4.) This language is difficult to learn.

Q7.) A good language learner should have no particular trouble learning this language.

Q9.) Learning this language demands less intelligence than other languages I know.

Figure 4.3. Pre- and post-course responses to questions related to the difficulty of learning the language (Questions 3, 4, 7, and 9)

Figure 4.3a Response to Question 3

Older people cannot be expected to learn a language like this

Figure 4.3b Response to Question 4

This language is difficult to learn

Comparisons of differences between sessions *

Figure 4.3c Response to Question 7

A good language learner should have no particular trouble learning this language

Comparisons of differences between sessions *

Figure 4.3d Response to Question 9

Learning this language demands less intelligence than other languages I know

Comparisons of differences between sessions *

Notes: Error bars represent ± 1 SE. *p < .05, **p < .003

At baseline, spoken and sign languages were perceived as comparable in difficulty. The course led to a change in attitude whereby spoken languages were perceived as easier than anticipated; this was not the case with the sign language.

4.3.3.3. Questions related to the social context of the language

Q2.) There is no good reason for anyone to need to use this language in the 21st century.

Q11.) The language I'm learning belongs to a community with its own culture.

Figure 4.4. Pre- and post-course responses to questions related to the social context of the language (Questions 2 and 11)

Figure 4.4a Response to Question 2

There is no good reason for anyone to need to use this language in the 21st century

Figure 4.4b Response to Question 11

The language I'm learning belongs to a community with its own culture

Baseline group difference *

Baseline group difference **

Notes: Error bars represent ± 1 SE. *p < .05, **p < .003
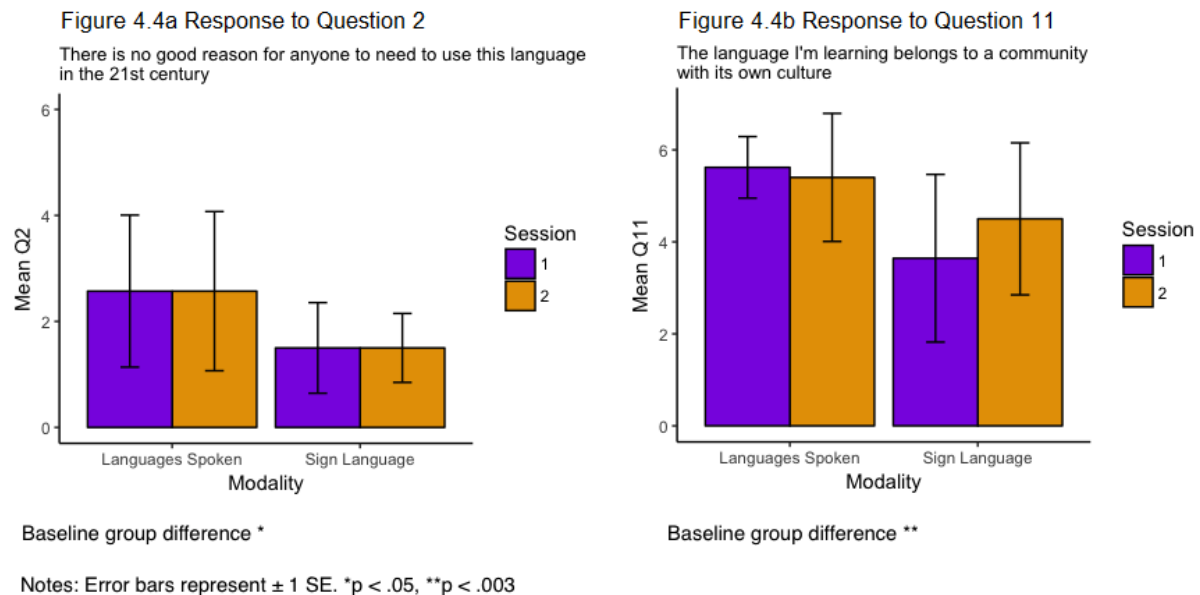
At baseline, the participants rated the sign language as less important in 21th C. and it was associated to a lesser degree with its own distinct culture than the spoken language. The course led to a higher recognition of sign languages as belonging to a community with its own culture.

4.3.4. Association between the cognitive results and attitudes

As a final step in our analysis, we explored a potential relationship between the cognitive results and attitudes towards cognitive-related questions. The only question which specifically mentioned the potential cognitive effects of language learning was question five: *It's really good for your brain to learn a language like this one*. The overall endorsement of this question was high, with no differences between the groups either before or after the course. A Spearman's rho correlation analysis revealed that those with a greater increase in agreement with this statement

were also the ones who experienced greater cognitive improvement, $r_s=.34$, $p=.043$, (Figure 4.5).

Figure 4.5. The relationship between feeling that the language learning had been cognitively beneficial and improvement on attentional switching

Figure 4.5 Relationship between improvement in ETR and change in attitude to Question 5

It's really good for your brain to learn a language like this one
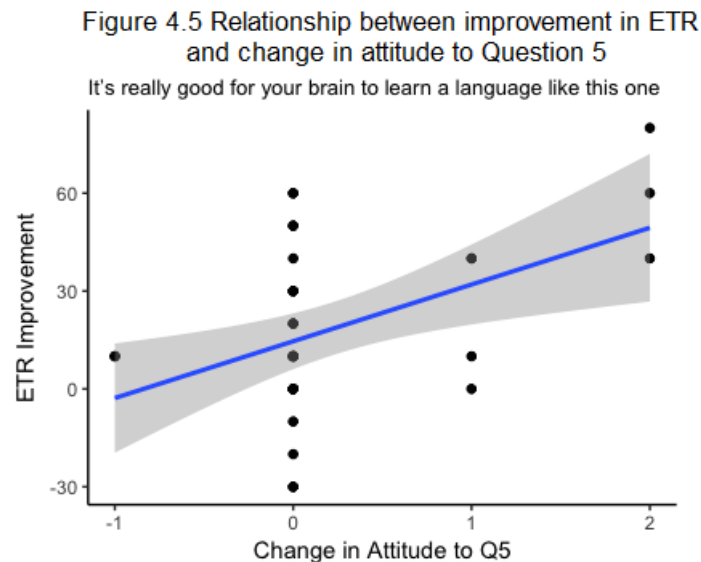
Notes: 95% CI displayed on the plot.

4.4. Discussion

Our study suggests that the improvement in attentional switching as reported in Bak et al., 2016 is not confined to a specific language (Gaelic), a circumscribed setting (a residential course in a specialized college on the Isle of Skye, or a specific modality (spoken languages). While earlier observations by Emmorey et al. (2008) suggest that bimodal bilinguals do not experience the same enhancement in general cognitive control as unimodal bilinguals, due to independent mechanisms involved in sign and spoken discourse, recent work is questioning those assumptions of domain-specific subsystems for the processing of linguistic and spatial information (Emmorey et al., 2017).

Indeed, behavioral research on bimodal bilingualism has demonstrated that

spoken and sign languages are co-activated at the lexico-semantic level in the early stages of comprehension and that in order to resolve this cross-linguistic competition, bimodal bilinguals rely on inhibitory control (an essential part of attentional switching) in much the same way as unimodal bilinguals (Giezen et al., 2015). This finding complements another recent study which found that bimodal bilinguals had difficulty in word retrieval compared to monolinguals (Giezen & Emmorey, 2017), a disadvantage commonly associated with unimodal bilingualism (Michael & Gollan, 2005; Ivanova & Costa, 2008), and believed to reflect cross-linguistic interference. Building on this work, researchers found a neuroprotective effect of bilingualism irrespective of whether participants were unimodal or bimodal bilinguals (Le et al., 2017). This suggests that in both types of bilingualism the increased load of representing and managing two separate linguistic systems may be beneficial for the brain.

The results of the current study demonstrate that the experience of learning a language, whether in the same modality or a different modality, can lead to attentional improvement. There are two possible explanations for these findings. The first is that learning a language of any type involves recruitment of the same domain general cognitive mechanisms that allow for continuous monitoring for linguistic and social cues and for efficient inhibiting/switching between languages. If this is the case, these results support the findings from above which suggest that irrespective of modality differences, languages are mutually activated and must be regulated by attentional mechanisms to allow for effective communication.

The second possibility is that the source of the sign language improvement is related to the novelty and challenge of learning a new skill, which requires the

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formation of new task schemas and imposes particular demands on attentional functions. Indeed, in chapter 1, I predicted that sign language learners would also experience attentional improvement given the intensive learning environment.

In order to tease apart these possible explanations, future work should compare spoken and sign language learners with passive controls to see if there is a significant linear trend in improvement, similar to the findings from chapter 2. This would let us know whether sign language learners' performance is more similar to active controls (in which case attentional improvement might be a general effect of intensive learning), or whether their performance is comparable to spoken language learners (which would suggest a role of monitoring and switching between languages even if the languages are in different modalities).

Importantly, variation in the type, timing, and length of the bilingual experience, can have a significant impact on cognitive effects. This may be the reason why, contrary to our predictions, we did not find a BSL-specific improvement in spatial attention, as was found by Keehner & Gathercole (2007). Several reasons might have contributed to this lack of effect: the very short time-span of one week might not have been long enough to produce such effects (previous work was based on proficient non-native signers who had self-reported daily or almost daily use of the language for at least one year). Another reason may be because our sample small size was very small; over one hundred individuals were invited to participate, however due to the intensive week-long nature of the study only a small number of individuals were recruited. To ensure reliable results, future work should attempt to address this issue.

Despite the very short duration of our language courses, they seemed to have modulated not only cognitive performance but also the attitudes of our participants to the specific languages they were learning. Given that our participants were recruited through groups such as the Yakety Yak Language Café, it was unsurprising to find that the overall attitude to language learning was very positive. However, it was interesting to find that attitudes were especially positive towards BSL, confirming the choice expressed by many participants in the consultation events and consistent with Sutton-Spence and Woll's claim in 2004 that BSL was the second most popular vocational evening class in the UK. Our findings point to a strong interest in BSL in participants within this age group who had not been exposed to it before, and will hopefully encourage the inclusion of more sign language classes for learners of all ages in adult education programs.

While the spoken languages were perceived to be easier than initially expected, the perceived level of difficulty for BSL was exactly the same before and after the course. This tendency was consistent irrespective of whether the question was posed in a positive manner ("*This language is difficult to learn*") or negative manner ("*A good language learner should have no particular trouble learning this language*").

Interestingly, we found that an increase in endorsement of the question "*It's really good for your brain to learn a language like this one*" between the first and the second session was associated with a larger improvement in attention switching performance in the same period of time. The fact that there was no association between attentional switching improvement and the initial pre-course answer to this question would negate the theory of a "self-fulfilling prophecy" phenomenon, in

which improvement was due to the expectation of a beneficial effect. It seems more likely that our participants felt in some way that they improved in their performance between the two sessions and might have attributed this to the experience of language learning. However, since we did not ask our participants whether they thought they had improved or not, we cannot be sure whether they were conscious of the fact that their results were better in the second testing. So far, we are not aware of any studies examining either the expectations or perceptions of participants in language courses regarding the possible cognitive effects of their experience, and believe that a more in-depth exploration of this question is necessary to fully understand the relationship between attitudes to language learning and cognition.

Unavoidably, our study has several limitations. The studied groups were relatively small, hence the results will need future replications in larger groups. The participants in our study were recruited from a particular age, education, and social background and comprised of people interested in science (attending the Edinburgh International Science Festival) as well as in languages (attending the Yakety Yak Language Café). Accordingly, they are not representative of the general population. However, the decision of whether a participant was allocated to a spoken language or a BSL group was made randomly, so any differences in performance between these two groups cannot be attributed to self-selection effects. In terms of the choice of tests, the selection of the TEA subtests already extensively used in bilingualism and language learning research (Bak, Vega-Mendoza & Sorace, 2014; Vega-Mendoza, West, Sorace & Bak, 2015; Bak, Long, Vega-Mendoza & Sorace, 2016) has proven fruitful, but the spatial tests selected for this study might not have

been sensitive enough. The same applies to the questionnaires used in this study: the questions would benefit from refinement in light of this initial exploration. Nevertheless, we hope that the value of this study consists not only in the results reported above but also in offering what is arguably the first attempt to bring together insights and methodologies from cognitive psychology and sociolinguistics in order to illuminate the complex interaction between attitudes and beliefs about language and language learning and subsequent cognitive effects.

Chapter discussion

The results of this chapter demonstrate that the relationship between language learning and cognition does not differ across modalities. Attentional improvement was found in adults of all ages learning typologically different spoken languages (Gaelic, Norwegian, or Turkish), as well as British Sign Language. Attitudinal changes, were also found across spoken and sign languages, suggesting that short-term exposure to a language can be both cognitively beneficial and change learners' pre-conceived notions about the language.

In the next chapter, I address the connection between language and cognition from the opposite side of the coin, by testing adults aged 17-85 to assess whether age-related changes to attention have a measureable impact on language abilities.

Chapter 5: Individual differences in switching and inhibition predict perspective-taking across the lifespan

This chapter has been published as:

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Chapter overview

In this chapter, I consider the results of the previous studies in the context of language production, branching in a new direction by asking whether the same attentional skills affected by language learning also play a role in our ability to communicate as we get older, specifically in relation to how well we consider others' perspectives in conversation. In this study, I tested 100 participants aged 17-84 using attentional and communicative perspective-taking tasks. The results of this study provide insight into the extent to which language and cognition influence each other over the lifespan, and whether changes to cognitive functions affect language in a similar way that changes to language affect cognitive functions, as demonstrated in the previous chapters.

Abstract

Studies exploring the influence of executive functions (EF) on perspective-taking have focused on inhibition and working memory in young adults or clinical populations. Less consideration has been given to more complex capacities that also involve switching attention between perspectives, or to changes in EF and concomitant effects on perspective-taking across the lifespan. To address this, we assessed whether individual differences in inhibition and attentional switching in healthy adults (ages 17-84) predict performance on a task in which speakers identified targets for a listener with size-contrasting competitors in common or privileged ground. Modification differences across conditions decreased with age. Further, perspective taking interacted with EF measures: youngest adults' sensitivity to perspective was best captured by their inhibitory performance; oldest adults' sensitivity was best captured by switching performance. Perspective-taking likely involves multiple aspects of EF, as revealed by considering a wider range of EF tasks and individual capacities across the lifespan.

During interactive discourse, we often rely on estimates about what is shared with an interlocutor (common ground) and what is not (privileged ground). Such estimates typically require *perspective-taking* to consider another's knowledge and how it may differ from one's own. The process by which people consider others' perspectives is essential to communication, yet questions remain regarding its underlying cognitive mechanisms, and about possible variation in individual perspective-taking abilities.

5.1. Background

A central question in language research is the degree to which linguistic behaviors reflect language-specific or domain-general mechanisms. For perspective-taking, executive functions (EF) are theorized to play a role in inhibiting privileged information when considering common ground. Some studies show that differences in inhibitory control and working memory predict communicative perspective-taking performance (Brown-Schmidt, 2009; Lin, Keysar & Epley, 2010; Wardlow, 2013), whereas others have failed to replicate these patterns (Brown-Schmidt & Fraundorf, 2015; Ryskin, Brown-Schmidt, Canseco-Gonzalez, Yui & Nyugen, 2014; Ryskin, Benjamin, Tullis & Brown-Schmidt, 2015).

This disparity may reflect the participant populations: the aforementioned studies focused exclusively on college-aged students. Compared to children and elderly adults, whose cognitive control exhibit substantial variability, young adults as a group likely operate at peak cognitive capacity, potentially concealing any influence of individual differences (Brown-Schmidt & Fraundorf, 2015; Comalli, Wapner & Werner, 1962; Cepeda, Kramer & Gonzalez de Sather, 2001; Zelazo, Craik & Booth, 2004). This performance advantage in early adulthood extends to

interactive dialogue: younger adults use more succinct, contextually-relevant, partner-specific language, whereas older adults are often less effective in making adjustments for particular partners (Bortfeld, Leon, Bloom, Schober & Brennan, 2001; Healey & Grossman, 2016; Horton & Spieler, 2007; Lysander & Horton, 2012).

In this context, it is reasonable to ask whether age-related communicative patterns are mediated by underlying differences in EF. In children, inhibitory control is negatively correlated with communicative egocentrism (Nilsen & Graham, 2009). At the other end of the lifespan, Wardlow, Ivanova, and Gollan (2014) observed that perspective-taking correlates more strongly with EF in Alzheimer's patients than in healthy age-matched controls. However, those EF measures were simplified for the patients, leading to ceiling-level performance in controls and possibly obscuring a relationship between perspective-taking and cognitive mechanisms in older adults. The current study addresses this by testing healthy adults of all ages.

As noted above, EF capacities targeted in prior perspective-taking work have been primarily limited to inhibition and working memory. Equally important, however, may be the ability to efficiently switch attention between perspectives, mediated by mechanisms of attentional *shifting* (Miyake et al., 2000) involving a combination of both inhibition and release from inhibition/refocusing of attention. People restrict attention to perspective-relevant information less efficiently when switching from a previous perspective, as shown in comparisons of trials that require a perspective shift from a previous context with trials that do not (Bradford, Jentszch & Gomez, 2015; Ryskin et al., 2014; Ryskin, Wang & Brown-Schmidt, 2016). This suggests a role for domain-general switching capacities in perspective-taking, alongside inhibition.

Here, we explore the simultaneous contributions of inhibition and switching to performance in a conversational perspective-taking task. Interestingly, these EF capacities are associated with two semi-independent (yet possibly concurrently engaged) modes of cognitive control. The first is a 'proactive' (Braver, 2012) or 'goal-shielding' (Goschke & Dreisbach, 2008) mode, which prioritizes the maintenance of internal goals, preventing interference from irrelevant information at the price of ignoring potentially significant contextual cues. The second is a 'reactive' or 'background monitoring' mode, which enhances the sensitivity to contextual cues at the expense of goal-maintenance. In conversation, speakers must balance the salience of their own perspectives against the need to attend to the interlocutor's. These pressures may require both the inhibition of salient-but-irrelevant information along with the readiness to refocus attention on appropriate contextual information. An individual's 'proactive' goal maintenance could be taken as the ability to consistently inhibit privileged context. In contrast, a 'reactive' mode allows for enhanced sensitivity to contextual cues, requiring modulation of inhibition when a speaker switches perspectives.

To measure these capacities, we used the Test of Everyday Attention (TEA) (Robertson, Ward, Ridgeway & Nimmo-Smith, 1994), a well-established clinical test with one subtest examining inhibition alone and another examining switching (jointly tapping into inhibition and release from inhibition) in a closely-related task. Recent work on bilingualism and language learning has used the TEA (Bak, Vega-Mendoza & Sorace, 2014; Vega-Mendoza, West, Sorace & Bak, 2015; Bak, Long, Vega-Mendoza & Sorace, 2016). However, it has not been used in linguistic perspective-

taking research. Thus, we hope to diversify approaches to analyzing EF capacities in communicative contexts.

Our perspective-taking study adapts a referential communication task from prior research (e.g., Wardlow, 2013; Wardlow et al., 2014) whereby a speaker identifies target objects presented in 4-object displays for a listener. On experimental trials, a size-contrasting competitor is also present. For common ground (CG) trials, both the target and competitor are mutually visible, while for privileged ground (PG) trials, the target is visible but the competitor is occluded from the listener's view. Successful perspective-taking is indexed by the relative frequency with which speakers include appropriate modification on CG trials but refrain from doing so on PG trials.

5.2. Method

5.2.1. Participants

Participants (N=121) were recruited from the University of Edinburgh Psychology Volunteer Panel, the University of Edinburgh Centre for Open Learning, and Sabhal Mòr Ostaig. Written informed consent was obtained. Prior to analysis, we removed data from 21 participants: 18 non-native speakers of English, 1 aphasiac, 1 with abnormally low TEA scores, and 1 due to technical malfunction. We report data from 100 native English-speaking participants aged 17-84[5].

5.2.2. Materials/procedures
5.2.2.1. Test of Everyday Attention

The TEA measures aspects of attention based on Posner and Peterson's (1990) multi-system attentional model. By separating attention into theoretically

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[5] Parental consent was obtained for the 17-year-old.

distinct factors—*sustained attention*, *selective attention*, and *attentional switching*—the TEA offers a fine-grained method of assessing an individual's cognitive resources (McAnespie, 2001). Designed to monitor the effects of neurorehabilitation in clinical populations, it is sensitive enough to detect subtle attentional impairments and has been standardized through a normative sample of healthy adults aged 18-80 (Robertson, Ward, Ridgeway & Nimmo-Smith, 1996).

Test instructions require participants to envision that they have entered an elevator on the ground floor. Because the floor indicator doesn't work, participants must count auditory tones to track the elevator's location. After each trial, a recorded voice asks which floor they ended up on. There are three subtests:

***Elevator Task* (sustained attention)**: Participants count tones of the same pitch presented at irregular intervals (7 trials). The task is not computationally difficult but participants must maintain attention. Healthy individuals are expected to perform near ceiling.

***Elevator Task with Distraction* (selective attention/inhibition)**: Participants count low tones and ignore interspersed high tones. Performing well requires that participants selectively attend to low tones only (10 trials).

***Elevator Task with Reversal* (attentional switching)**: Participants are presented with high, medium, and low tones, and must count only medium tones. High tones indicate the elevator is moving up (thus, subsequent medium tones increase the floor count) while low tones indicate the elevator is moving down (thus, subsequent medium tones decrease the floor count). Performing well requires keeping track of the count while shifting between counting up and down (10 trials).

Performance on each subtest is measured as the percentage of trials with correct responses (0-100).

5.2.2.2. Referential communication task

The referential communication task required participants to describe target objects in 4-object displays presented on an iPad that lay flat between the participant and the experimenter (see Fig 5.1). In two practice trials, participants had to demonstrate the ability to use the iPad to control the task; all successfully did so. To start each trial, the experimenter closed her eyes while the participant tapped anywhere on the screen to reveal one object in a box that flashed red, indicating it was to be occluded. The participant placed a folded index card on the surface of the iPad to occlude this object from the experimenter's view. Then, the participant tapped the screen again to reveal 3 more objects in boxes. The target location flashed green for 1.5 seconds. The participant named the target for the experimenter, who opened her eyes and pointed to the object.

Critical trials involved size contrasts between the target and a competitor. On 16 CG trials, the competitor was mutually visible, requiring modification to disambiguate the target. On 16 PG trials, the competitor was occluded, thus no modification was necessary. For 24 filler trials, the target was always unique, although two other mutually visible locations often contained size-contrasting objects. Finally, for 7 privileged target fillers, the target was occluded; the experimenter would infer that it was occluded because the description failed to match any visible objects. This procedure, adopted from Wardlow-Lane and Ferreira (2008), was intended to increase the salience of privileged objects on critical trials.

Powerpoint on the iPad was used to present the displays and cues. Experimental and filler items were randomly slotted into the presentation order, with the restriction that no more than two trials of a given type could appear in succession. Each participant completed 65 trials (two practice). Participants were told that their task on each trial was to first hide the "red" object with the occluder then name the "green" object so the experimenter could point to it.

Figure 5.1. Typical common ground trial, referential communication task
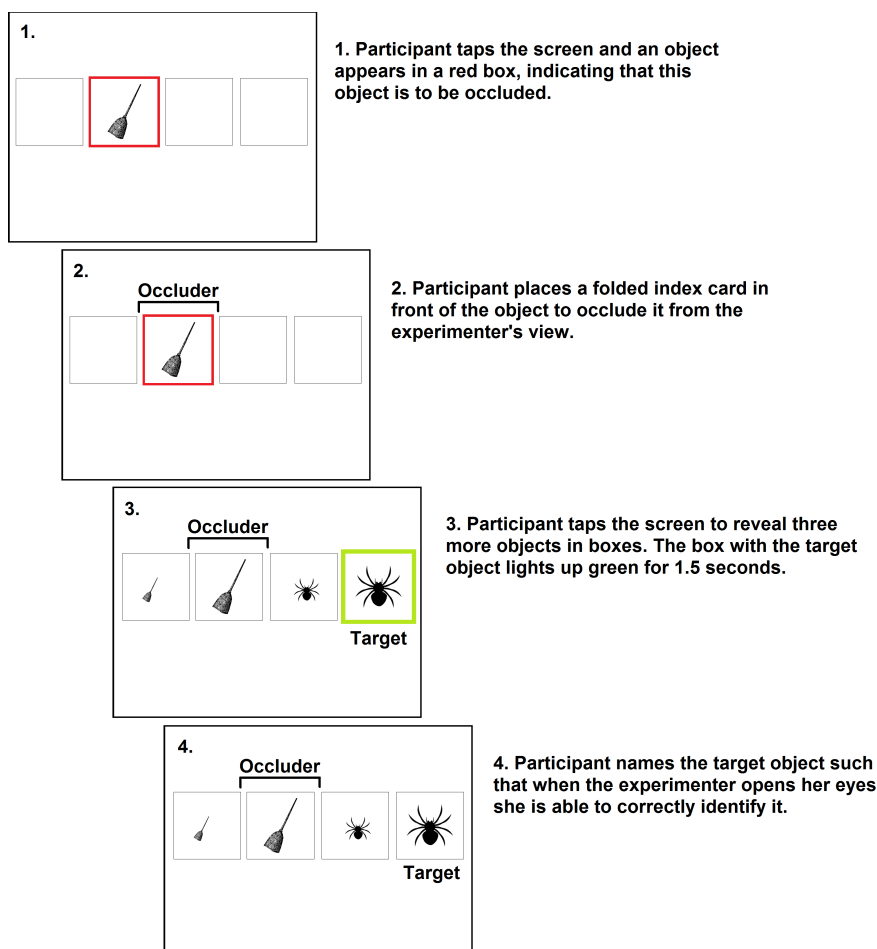
Participants' utterances were recorded and transcribed for analysis. We coded whether each target description on experimental trials reflected the presence

of the size-contrasting competitor through modification of the head noun. We implemented this coding in two ways. A liberal coding ("Any Modification") counted the presence of *any* modifying information. For example, in the CG trial in Figure 1, this includes pre-nominal modification (e.g., "big spider"), post-nominal modification (e.g., "spider that's big"), or repairs (e.g., "spider, the big spider"). A conservative coding ("Prenominal Modification") only counted pre-nominal modification as evidence that speakers distinguished the target from the competitor early in production (Brown-Schmidt & Tanenhaus, 2006).

5.3. Results

As expected, performance was at ceiling (M=99%) on the TEA Elevator Task, so this will not be considered further[6]. An effect of participant age was found for the TEA switching subtest (linear regression: β=-8.415, p<0.05) but not for the inhibition subtest (β=-1.424, p=0.44). Following Brown-Schmidt and Fraundorf (2015), we also examined reliability in the communication task by computing split-half correlations between odd and even privileged ground trials. A strong correlation (r=.95)[7] provides confidence that this task tapped into a stable aspect of perspective-taking.

Using logistic mixed effects regression we modelled the binary outcome of presence/absence of modification with Perspective, Age, and scores for the inhibition and switching tasks as fixed effects, and both subjects and items as random effects. Deviation coding was used for Perspective (CG trial=-0.5, PG

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[6] Descriptive statistics for the TEA and perspective-taking tasks (for all participants, as well as for youngest and oldest subgroups separately) are reported in Appendix D.
[7] High split-half reliability (r≥.9), was found for both any- and prenominal modification measures in PG trials alone and for modification differences on CG versus PG trials, as well as when examining older and younger adults separately.

trial=0.5), while participant age and inhibition and switching scores were entered as scaled continuous predictors. Our models also included participants' education level as an additional covariate. When possible, the model was fit with the maximal random effect structure for both subjects and items (Barr, Levy, Scheepers & Tily, 2013).

5.3.1. Results of "any modification" coding

For the liberal "any" modification measure (any modification = 1; bare NP = 0), participants showed strong evidence of perspective-taking (significant effect of Perspective: β=-4.715, SE=0.721, p<0.001), with higher rates of modification on CG trials (M=0.98, SD=0.14) than PG trials (M=0.52, SD=0.50). However, differences in modification rates decreased with increasing participant age (Age × Perspective: β=1.944, SE=.605, p<0.005). Differences in modification rates across trial types increased with inhibition scores (Perspective × Inhibition: β=-1.548, SE=0.584, p<0.01). But this interaction with EF capacity varied by age, with significant three-way interactions for both EF measures (Age × Perspective × Inhibition: β=1.624, SE=0.565, p<0.005; Age × Perspective × Switching: β=-1.357, SE=0.628, p<0.05).

To explore these interactions, we carried out a tertile age split to identify the youngest 1/3rd (Age<45) and oldest 1/3rd participants (Age>65)[8]. For each group, we fit a model that included Perspective and the two EF measures as fixed effects. Figure 5.2 presents plots for each subgroup showing the relationship between CG and PG modification rates and each of the inhibition and switching measures[9]. As these plots show, young adults' sensitivity to perspective varied with their inhibition performance (Perspective × Inhibition: β=-5.371, SE=2.620, p<0.05) but not

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[8] The same patterns hold with a median age split.
[9] For plots of the full dataset, see Appendix E.

switching (Perspective × Switching: β=2.147, SE=1.391, p=0.12). In this group, better inhibition was associated with less modification on PG trials (β=-1.121, SE=0.537, $p<0.05$) and more modification on CG trials (β=2.381, SE=1.144, $p<0.05$). Conversely, the oldest adults' sensitivity to perspective varied by their switching performance (Perspective × Switching: β=-3.503, SE=1.483, $p<0.05$) but not inhibition (Perspective × Inhibition: β=1.095, SE=1.519, p=0.47). In this group, better switching performance was associated with less modification on PG trials (β=-3.485, SE=1.246, $p<0.01$) but did not predict modification on CG trials (β=0.193, SE=0.546, p=0.72).

Figure 5.2. Perspective-taking performance of tertile split youngest adults (YA) and oldest adults (OA) using *any* modification, by inhibition and switching EF performance
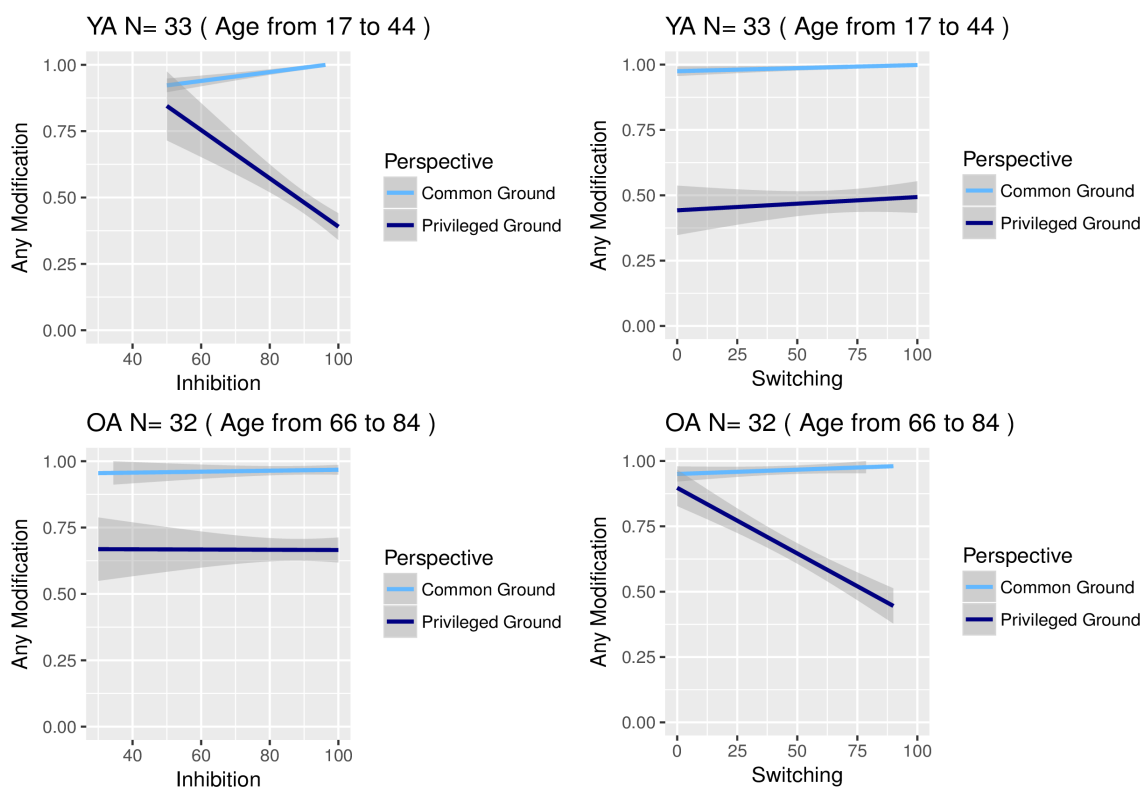
Notes: 95% confidence level intervals displayed in the plots.

5.3.1. Results of "prenominal modification" coding

We carried out the same analyses on our conservative measure (prenominal modification=1; anything else=0). Again, participants showed evidence of perspective-taking (significant effect of Perspective: β=-1.301, SE=0.547, p<0.05), with more modification on CG trials (M=0.77, SD=0.42) than on PG trials (M=0.49, SD=0.50). On this measure, modification rates on CG trials were no longer at ceiling. Even so, differences in modification rates across trial types decreased with increasing participant age (Age × Perspective: β=1.389, SE=0.398, p<0.001), although pre-modification differences across trial types varied with switching performance (Perspective × Switching: β=-0.872, SE=0.410, p<0.05; cf. Perspective × Inhibition for 'any modification' above). Importantly, the relationship between perspective-taking and EF is modulated by Age, with significant three-way interactions for both EF measures (Age × Perspective × Inhibition: β=1.047, SE=0.420, p<0.05; Age × Perspective × Switching: β=-1.066, SE=0.459, p<0.05).

Again, focusing on the data from the youngest (Age<45) and oldest participants (Age>65), we fit an additional model for each age group that included Perspective and the two EF measures as fixed effects (Fig 5.3). Young adults' sensitivity to perspective was influenced by their inhibition performance (Perspective × Inhibition: β=-1.531, SE=0.574, p<0.01) but not switching (Perspective × Switching: β=0.219, SE=0.582, p=0.71). Again for this group, better inhibition was associated with less modification on PG trials (β=-1.092, SE=0.491, p<0.05) and more modification on CG trials (β=0.642, SE=0.286, p<0.05). Conversely, the oldest adults' sensitivity to perspective was influenced by their switching performance (Perspective × Switching: β=-1.736, SE=0.755, p<0.05) but not inhibition

(Perspective × Inhibition: β=0.797, SE=0.760, p=0.29). Here, better switching performance in older adults was associated with marginally less modification on PG trials (β=-1.123, SE=0.674, p=0.10) and more modification on CG trials (β=0.613, SE=0.268, p<0.05).

Figure 5.3. Perspective-taking performance of tertile split youngest adults (YA) and oldest adults (OA) using prenominal modification only, by inhibition and switching EF performance
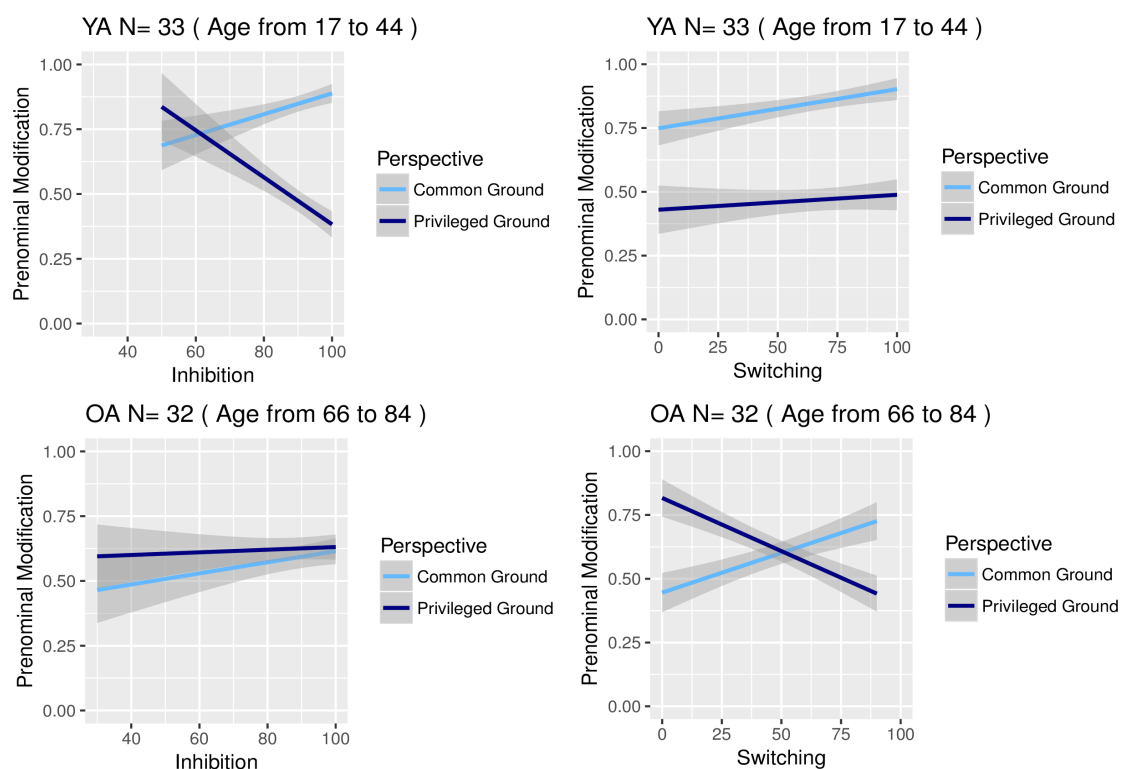
Notes: 95% confidence level intervals displayed in the plots.

5.4. Discussion

Based on the performance of a large sample of individuals varying widely in age, we provide support for the claim that individual differences—both in age and domain-general cognitive capacities—contribute to variability in communicative perspective-taking. While we cannot rule out other contributing factors, like how comfortable older participants were in responding via iPad, our results reveal

striking age-related differences in the influence of both inhibition and switching: for young adults, perspective-taking abilities were best predicted by their inhibition capacity, whereas older adults' performance varied more strongly with their switching capacity. These patterns hold for both a liberal and conservative coding of modification, the latter especially revealing of older adults' switching abilities as it requires rapid attentional shifts to produce prenominal modification for CG size contrasts.

There are admittedly multiple ways in which inhibition and switching could be relevant in this perspective-taking context, and our own data can't fully adjudicate amongst them. Initially, determining which referent to describe requires switching attention from the "red" occluded object to the "green" target object (and potentially inhibiting attention to the occluded object). Later, deciding what modification is needed requires switching perspective from one's own perspective to an addressee's (and potentially inhibiting one's own perspective on PG trials when the occluded object is irrelevant). One possibility we consider is that a participant's performance reflects strategies optimized for either initial referent determination or subsequent modification decisions. For example, some participants could use a proactive strategy of wilfully ignoring the occluded object. If so, our data are compatible with an account whereby young adults favor this inhibition-driven strategy, and their successful implementation of this shortcut therefore depends on their inhibition capacity. This would explain why young adults' performance is best predicted by inhibition rather than switching.

Nevertheless, such an approach requires continuous goal maintenance, and would likely not be optimal for older adults whose preferences may shift in the

direction of utilizing the less cognitively demanding, reactive mode of control (Paxton, Barch, Racine & Braver, 2008; Braver, 2012). Perhaps, then, the high-performing older adults in our sample relied on a *combination* of proactive and reactive modes, allowing them to partially rely on a stimulus-driven, passive mode of responding to changes while actively refocusing attention. As such, their success would depend on an ability to switch efficiently between occluded and target objects and from their own perspective to the addressee's. Older adults' switching capacity hence would better predict their performance, as we found.

Overall, our results raise intriguing questions regarding a possible shift in EF resources modulating perspective across the lifespan. Future research should therefore address how different aspects of executive function contribute to perspective-taking under different conditions.

Chapter discussion

The results of this chapter demonstrate that changes to cognitive functions can have a measureable impact on language, just as the previous chapters have shown that changes to language can have a measureable impact on cognition.

Findings from this study revealed that older adults were less sensitive to their partner's perspective than younger adults and that attentional functions predicted this ability. Interestingly, these patterns differed for younger and older adults: for younger adults inhibitory control predicted perspective-taking performance, whereas for older adults it was attentional switching. Together, these results suggest an age-related shift in the attentional mechanisms recruited to carry out this language ability, shedding light on the nature of the relationship between language and cognition over the lifespan and demonstrating the extent to which linguistic and cognitive systems influence each other.

Chapter 6. Discussion

Chapter overview

The aim of this dissertation was to explore the complex interplay between language and cognition over the adult lifespan, from language learning and its effects on cognitive ageing to cognitive ageing and its effects on language production. To this end, through a series of four studies, I addressed novel theoretical questions about the extent to which linguistic and cognitive systems interact in different contexts and over the course of a lifetime.

In this concluding chapter, I review each of these studies, summarizing the main findings (**section 1**), and providing a general discussion of the implications of these results and directions for future research (**section 2**).

6.1. Summary of main findings

In **chapter 2**, I investigated the impact of brief intensive language learning on cognitive ageing. This study expanded on previous work (Sullivan et al., 2014; Vega-Mendoza et al., 2015), by testing whether changes to attention would occur as early as one week after an intensive language course and whether the effects would extend to adults of all ages, from 18 to 78 years old.

Results showed that all ages benefitted from enhanced attentional control after one week of language exposure. Further, a nine month follow-up revealed that everyone who continued to practice the language for five or more hours per week maintained this improvement. Linking these results to work in cognitive intervention studies (Wan & Schlaug, 2010), I was able to demonstrate that language learning, like other novel, challenging activities, is a mentally stimulating activity that can promote healthy cognitive ageing by bringing about enhanced attentional control in adults of all ages.

In **chapter 3**, I extended this work by testing a larger sample of Gaelic learners, aged 21 to 85, to confirm the reliability of my findings from the previous chapter and to investigate understudied factors influencing cognitive outcomes following language learning. In particular, I was interested in directly comparing the influence of novelty and familiarity on cognitive performance, as both novelty and familiarity have been shown to influence memory (Poppenk, Köhler, & Moscovitch, 2010), and novelty has been implicated in the cognitive effects of language learning (Bak et al., 2016). In this study, I found that language learners experienced attentional improvement after just one week of an intensive Gaelic course, corroborating my original findings.

I also found that both novelty and familiarity influenced attentional switching performance: those in higher Gaelic levels initially outperformed those in lower levels, however those in lower levels improved the most. Age also impacted results: attentional performance differed by age, however the impact of language learning on attentional functions was detectable across the lifespan.

In **chapter 4**, I tested whether these effects were modality-specific by randomly assigning adults aged 23-85 to one week intensive courses in Norwegian, Turkish, or British Sign Language. Given the differential cognitive effects of spoken versus sign language in bilingualism research (Emmorey et al., 2008), I was interested in whether similar outcomes would occur in the context of language learning. I further developed the study by merging questions from sociolinguistics and cognitive psychology to measure attitudes to the randomly assigned language and its impact on cognitive functions.

Results revealed that adults of all ages in both the spoken language courses and signed language course experienced improved attention. In addition to this, there were post-course attitudinal changes: only participants in spoken languages found the course easier than initially expected, whereas participants across spoken and sign languages became more motivated to learn the language. Further, there was a correlation between measurable improvement in attentional switching and the perception that the language course was cognitively beneficial.

As these chapters have demonstrated, language learning can have a significant influence on attentional functions. In line with Green & Abutalebi's Adaptive Control Hypothesis (2013), the cognitive demands of the dual-language environment revealed improvement in the predicted areas of attentional control with

the exception of sustained attention. However, while no changes were found on the sustained attention measure, this is likely attributable to the ceiling-level performance in both sessions. Future studies should administer a more difficult measure to explore the impact of language learning on this ability.

As predicted, language learners experienced the greatest improvement in attentional switching. This hypothesis was based on predictions from Green's IC model (1998) with regards to the asymmetrical costs of switching from a weak language to a dominant language. Green posited that switching into the dominant language would incur greater costs than switching into the weak language as it involves disengaging strong inhibition of the dominant language to refocus attention on that language. Based on this account, I predicted that the demands placed on language learners' attentional switching abilities would be especially taxing and that those abilities would in turn adapt the most over the course. Findings from these chapters confirm that prediction.

Based on Norman and Shallice's model of cognitive control in routine and non-routine behaviour (1986), I predicted that learning a novel activity would lead to attentional improvement as those mechanisms are recruited to construct new task schemas and to monitor their performance in relation to task goals. As such, I hypothesized that both language learners and active controls would experience improvement in attention but that passive controls (who were following their regular routines) would not improve. Going a step further, I predicted that learning a language would impose additional demands on attentional control as it involves the continuous monitoring and management of co-activated linguistic systems, and the ability to efficiently inhibit and disengage from inhibition when switching languages.

Therefore I predicted that the results would reveal that language learners improve the most (proportionally), followed by the active controls, then passive controls. The findings confirmed these predictions.

Finally, based on previous work (Giezen, Blumenfeld, Shook, Marian, & Emmorey, 2015; Emmorey, Luk, Pyers, & Bialystok, 2008; Keehner & Gathercole, 2007) I predicted that spoken language learners (as opposed to sign language learners) would experience the greatest improvement in attention due to the competition for articulation between languages in the same perceptual system. However, I also predicted that due to the intensive learning environment, both spoken language learners and sign language learners would improve in attentional skills over the course. Further, I predicted that sign language learners would experience improvement in visuospatial working memory due to the significance of sign space and mental rotations in sign discourse. My predictions were partially correct. Both spoken language learners and sign language learners experienced improved attention over the course, however sign language learners did not experience improvement in the visuospatial tasks. The latter finding may reflect the fact that language-related changes to visuospatial working memory may not occur within the short timespan of a week. Indeed, in the Keehner and Gathercole 2007 study, non-native signers who demonstrated enhanced visuospatial skills had at least 1-5 years of regular training in sign language. Another possibility is that these results are not entirely reliable due to the small group sizes. Unlike the results of the Gaelic learners, which were later confirmed in a much larger sample, these results should be corroborated through future studies before any definitive conclusions can be made.

Overall, these results provide new insights that could help to address some of the bigger questions in the field of bilingualism, especially with regards to the linguistic circumstances that give rise to cognitive change and to individual differences in cognitive performance. As detailed above, all of the predictions I made based on the Adaptive Control Hypothesis and the IC model were confirmed. This provides strong evidence that these models represent an accurate picture of the processes involved in managing two languages not only at the late stages of bilingualism (e.g. when two languages are fully formed and represented in the mind), but also during the early stages (i.e. the start of second language acquisition). Accordingly, this work contributes to a comprehensive account of bilingual language control in a dual-language environment.

In addition to this, the work from these chapters highlight factors that affect the impact of language learning on cognitive control, which can be applied to studies in bilingualism. As much of the literature is mixed with regards to the existence of a bilingual advantage, it is important to explore what may be causing these divergent results. For example, in this thesis, I found that language learners experienced significant attentional improvement after an intensive course (14 hours/week) and that nine months later, everyone who continued to practice Gaelic for 5 or more hours per week maintained improvement from their baseline. This has not be tested or documented before with respect to language learning, and has implications for the way in which frequency of language use is factored into bilingualism studies. Moreover, age and familiarity/novelty with the language also affected the results in these chapters, which suggests that each of these factors could influence bilingualism and cognitive control in a similar way. In the future,

these factors should serve as predictor variables in regression analyses, allowing us to more deeply explore the specific linguistic circumstances and personal profiles that affect individual differences for the cognitive effects of bilingualism.

Overall, the results of these chapters demonstrate that brief intensive language learning can bring about measureable improvements in attention. In **chapter 5**, I investigated the other side of this relationship: whether attentional functions influence language, namely communicative perspective-taking abilities. Previous work on this topic produced mixed results (Keysar, & Epley, 2010; Wardlow, 2013; Ryskin, Brown-Schmidt, Canseco-Gonzalez, Yiu & Nguyen, 2014), however this study addressed several gaps in the literature which may have influenced previous findings. Namely, this study was the first to examine the relationship between perspective-taking and attentional functions – *sustained attention, inhibition, and attentional switching* – across the entire adult lifespan (from 17-84 years old).

Results revealed that older adults were less sensitive to their partner's perspective than younger adults, replicating prior work (Horton & Spieler, 2007). Notably, attentional control predicted this communicative ability and the patterns differed for younger and older adults. For younger adults, perspective-taking was influenced by their inhibitory control whereas for older adults perspective-taking was influenced by attentional switching abilities. These results are in line with the predictions made in chapter 1 based on Braver's 2012 dual-mechanisms framework. In the context of perspective-taking, the proactive mode could be viewed as the ability to consistently inhibit privileged context from the early stages of production whereas the reactive mode could be viewed as the modulation of inhibition when switching perspectives. As such, our results suggest that younger

adults may adopt an inhibition-driven strategy whereas older adults may rely on reactive control, engaging in background monitoring and attentional switching to shift between perspectives. Overall, these results demonstrate that not only do attentional mechanisms have a measureable influence on language production, but that there may be an age-related shift in the mechanisms recruited to carry out this communicative ability.

6.2. General discussion and future directions

The results from each chapter of this thesis demonstrate the strength of the relationship between linguistic and cognitive systems. In **chapters 2-4** I found that changes to one's linguistic environment had an effect on cognitive functions and in **chapter 5** I found that age-related changes to cognitive functions also affected linguistic abilities.

The first three studies (**chapters 2-4**) demonstrated that short intensive language exposure has the potential to bring about improvement in attention for adults of all ages. To further explore this, I teased apart differences in the impact of language learning on cognitive performance and found that novelty and familiarity influenced performance. Specifically, those in higher levels (i.e. those more familiar with the target language) initially outperformed those in lower levels in attentional switching. This higher baseline cognitive performance likely reflects previous exposure and practice with the language. On the other hand, those in lower levels (i.e. the novices) experienced the greatest improvement post-course. This supports the notion of "desirable difficulties" (Bjork & Kroll, 2015), which posits that activities both *novel* and *mentally challenging* bring about the greatest cognitive improvement.

Further, the effects of brief intensive language learning were the same across all spoken languages (Gaelic, Norwegian, Turkish), as well as British Sign Language.

Collectively, these findings suggest that taking up a language later in life can positively impact cognitive health, while continuous practice can help maintain these benefits. Given the high older adult enrollment rate in the language courses, the positive attitudinal changes towards the languages, and the robust cognitive effects, it could be a wise investment to offer retired adults more opportunities to learn a new language. Indeed, if older adults had more chances to engage in this type of activity, they could in turn maintain cognitive health and independence for longer.

In addition to the immediate practical implications of these findings, this work also paves the way for future research. For example, we could conduct similar studies over longer periods of time, following older language learners and controls for ten to twenty years to examine how language learners fare compared to their counterparts and to what extent language learning mitigates cognitive decline with ageing. Further, it would be interesting to investigate whether language learning plays a role in staving off the onset of brain diseases or in aiding cognitive recovery, as has been found in various bilingualism studies (Alladi et al, 2013; Woumans et al, 2015; Alladi et al, 2015).

Other directions for future research would be to explore whether the attentional changes found in adults learning typologically different languages (in this case Norwegian, Gaelic, and Turkish) extend to learners of languages with different alphabets and/or very different phonological systems (e.g. tone or vowel harmony), which would provide additional challenges for a native English speaker. In that respect we could assess whether learning a more cognitively taxing language would

have an even greater impact on attention or whether other cognitive effects would emerge.

It would also be interesting to assess the linguistic progress made over the course. While the results of the previous chapters suggest that intensively learning an unfamiliar language is challenging enough to confer cognitive benefits, it may be that learners in the Norwegian class made the most progress in the acquisition of vocabulary and syntactic structures due to the similarity between Norwegian and English. Perhaps in a non-intensive environment differences between learning a language that is typologically similar to one's native language versus one that is typologically distant would be more apparent. A possible prediction for this line of research would be that a typologically similar language would allow an individual to rely on already well-established syntactic structures and cognates to facilitate the learning process, therein imposing less demands on cognitive control. In relation to the Norman and Shallice model (1986), it may be that similar task schema from the native language could be retrieved and adjustments made to suit the linguistic goal. On the other hand, learning a typologically distinct language would involve learning completely foreign vocabulary and linguistic structures and creating subsequent mental associations; the need to construct completely new task schema while managing interference from the native language could therefore result in more demands imposed on attentional mechanisms.

Interestingly, in the case of lifelong bilingualism, the opposite prediction could be made: two fully formed and closely related languages might be more difficult to manage due to the constant activation of similar sounds and structures, while two very distinct languages may allow for more global control of competing linguistic

systems as little interference would be caused by similar linguistic features. As such, less cognitive resources may be needed for lifelong bilinguals with typologically distinct languages whereas the opposite may be true for language learners.

In the context of sign language, it would be interesting to test whether the same enhanced visuospatial skills documented in bimodal bilinguals would extend to those learning a sign language for longer than a week (as Keehner and Gathercole found with non-native sign language learners with intensive exposure over the course of 1 to 5 years). While the results of my study did not reveal improvement in visuospatial skills, these changes may become detectable with more exposure to the language.

Moving on to the final study (**chapter 5**), in which I examined the influence of cognitive functions on language production, results revealed that age-related changes to attention impacted communicative perspective-taking over the lifespan. As this investigation is the first to take a lifespan approach to the study of perspective-taking and its cognitive underpinnings, it is important that future studies attempt to replicate these findings. If the patterns remain the same, and older adults consistently rely on attentional switching to guide perspective-taking while younger adults rely on inhibition, we can begin to build credible cognitive models of these and other types of pragmatic abilities, to better understand how age-related cognitive changes influence these communicative skills.

As briefly touched upon in chapter 1, what is unique about the measure used to assess inhibitory control in this study and the previous language learning studies is that it could also be considered a measure of selective attention depending on the strategy used by the participant. Based on predictions from Braver's dual

mechanisms framework, an individual who favors a more proactive mode of cognitive control might be more likely to selectively attend to the specified tone of interest whereas someone who favors a more reactive mode of control might respond to distractor tones by inhibiting them after activation. Similar to the results presented in the perspective-taking study, the way in which participants solve this task may reflect individual differences for proactive versus reactive control strategies. Further, based on the results of the perspective-taking study and previous work (e.g. Braver, 2012), another prediction would be that older adults might be more likely to adopt a reactive control strategy to complete the task whereas younger adults might adopt a more proactive strategy. It would be interesting to attempt to design a measure that would allow us to identify which strategy was used and explore these potential individual differences in depth.

Overall, each study presented in this thesis contributes to providing a comprehensive picture of the interplay between linguistic and cognitive systems over the lifespan. From language learning to perspective-taking, this thesis offers new insights into the ageing brain, paving the way for future intervention studies designed to help us maintain linguistic and cognitive health well into old age.

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Appendix A: Language background questionnaire

	Participant ID

PART I: GENERAL DEMOGRAPHIC INFORMATION

Age...Gender...............................Handedness...........

Profession/Subject studied..

Current level of study or highest level achieved..

At what age did you start school? At .... yrs old

Have you lived in other places in which other languages are spoken?...............................

If so, where and for how long?...…

....

Place of birth:...

PART II: LANGUAGES SPOKEN

1.
2.
3.
4.
5.

PART III: PARENTS' MOTHER TONGUES:

What is your father's mother tongue?
Does your father speak any other languages? Please specify
What is your mother's mother tongue?
Does your mother speak any other languages? Please specify
If you have a child, which is their first language?
Does your child speak any other languages? Please specify

<div align="center">LANGUAGE 1:</div>

LANGUAGE HISTORY – ACQUISITION OF LANGUAGE

1. First contact with the language: since birth/at ___ yrs of age
2. Choose the most appropriate option: - I hear the language spoken but I don't speak it ☐   - I both hear and speak the language ☐
3. If you were schooled in this language, at what age did you learn to write it? ____ yrs old
4. Environment in which you used the language in childhood: Frequency of use (choose one):

	Always	Often	Sometimes	Rarely	Never	Not applicable
Family						
Mother						
Father						
Grandparents						
Siblings						
Other relatives						
Official						
Schooling						
Teachers						
Classmates						
Immediate Environment						
Friends						
Neighbours						

LANGUAGE USE						
1. Do you continue to use the language? Yes☐ No☐ (If no, when did you stop using it? ___ yrs old)						
If yes, how often do you use it in each one of the following contexts (choose one)						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Partner						
Siblings/Nephews/Nieces						
Children						
Other relatives						
Official						
Colleagues						
Shopping						
Radio/TV						
Books/magazines						
Immediate environment						
Friends						
Neighbours						
Church/society						
Do you use different languages with the same person?						

COMMAND OF THE LANGUAGE					
Evaluate your command of the language in each of the following categories:					
	Basic	**Weak**	**Moderate**	**Advanced**	**Fluent**
Expression					
Comprehension					
Reading					
Writing					

LANGUAGE 2:

LANGUAGE HISTORY – ACQUISITION OF LANGUAGE						
1. First contact with the language: since birth/at ___ yrs of age						
2. Choose the most appropriate option: - I hear the language spoken but I don't speak it ☐ - I both hear and speak the language ☐						
3. If you were schooled in this language, at what age did you learn to write it? ____ yrs old						
4. Environment in which you used the language in childhood: Frequency of use (choose one):						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Mother						
Father						
Grandparents						
Siblings						
Other relatives						
Official						
Schooling						
Teachers						
Classmates						
Immediate Environment						
Friends						
Neighbours						

LANGUAGE USE						
1. Do you continue to use the language? Yes☐ No☐ (If no, when did you stop using it? ___ yrs old)						
If yes, how often do you use it in each one of the following contexts (choose one)						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Partner						
Siblings/Nephews/Nieces						
Children						
Other relatives						
Official						
Colleagues						
Shopping						
Radio/TV						
Books/magazines						
Immediate environment						
Friends						
Neighbours						
Church/society						
Do you use different languages with the same person?						

COMMAND OF THE LANGUAGE					
Evaluate your command of the language in each of the following categories:					
	Basic	**Weak**	**Moderate**	**Advanced**	**Fluent**
Expression					
Comprehension					
Reading					
Writing					

LANGUAGE 3:

LANGUAGE HISTORY – ACQUISITION OF LANGUAGE						
1. First contact with the language: since birth/at ___ yrs of age						
2. Choose the most appropriate option: - I hear the language spoken but I don't speak it ☐ - I both hear and speak the language ☐						
3. If you were schooled in this language, at what age did you learn to write it? ____ yrs old						
4. Environment in which you used the language in childhood: Frequency of use (choose one):						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Mother						
Father						
Grandparents						
Siblings						
Other relatives						
Official						
Schooling						
Teachers						
Classmates						
Immediate Environment						
Friends						
Neighbours						

LANGUAGE USE						
1. Do you continue to use the language? Yes☐ No☐ (If no, when did you stop using it? ___ yrs old)						
If yes, how often do you use it in each one of the following contexts (choose one)						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Partner						
Siblings/Nephews/Nieces						
Children						
Other relatives						
Official						
Colleagues						
Shopping						
Radio/TV						
Books/magazines						
Immediate environment						
Friends						
Neighbours						
Church/society						
Do you use different languages with the same person?						

COMMAND OF THE LANGUAGE					
Evaluate your command of the language in each of the following categories:					
	Basic	**Weak**	**Moderate**	**Advanced**	**Fluent**
Expression					
Comprehension					
Reading					
Writing					

LANGUAGE 4:

LANGUAGE HISTORY – ACQUISITION OF LANGUAGE						
1. First contact with the language: since birth/at ___ yrs of age						
2. Choose the most appropriate option: - I hear the language spoken but I don't speak it ☐ - I both hear and speak the language ☐						
3. If you were schooled in this language, at what age did you learn to write it? ____ yrs old						
4. Environment in which you used the language in childhood: Frequency of use (choose one):						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Mother						
Father						
Grandparents						
Siblings						
Other relatives						
Official						
Schooling						
Teachers						
Classmates						
Immediate Environment						
Friends						
Neighbours						

LANGUAGE USE						
1. Do you continue to use the language? Yes☐ No☐ (If no, when did you stop using it? ___ yrs old)						
If yes, how often do you use it in each one of the following contexts (choose one)						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Partner						
Siblings/Nephews/Nieces						
Children						
Other relatives						
Official						
Colleagues						
Shopping						
Radio/TV						
Books/magazines						
Immediate environment						
Friends						
Neighbours						
Church/society						
Do you use different languages with the same person?						

COMMAND OF THE LANGUAGE					
Evaluate your command of the language in each of the following categories:					
	Basic	**Weak**	**Moderate**	**Advanced**	**Fluent**
Expression					
Comprehension					
Reading					
Writing					

<div align="center">

LANGUAGE 5:

</div>

LANGUAGE HISTORY – ACQUISITION OF LANGUAGE						
1. First contact with the language: since birth/at ___ yrs of age						
2. Choose the most appropriate option: - I hear the language spoken but I don't speak it ☐ - I both hear and speak the language ☐						
3. If you were schooled in this language, at what age did you learn to write it? ____ yrs old						
4. Environment in which you used the language in childhood: Frequency of use (choose one):						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Mother						
Father						
Grandparents						
Siblings						
Other relatives						
Official						
Schooling						
Teachers						
Classmates						
Immediate Environment						
Friends						
Neighbours						

LANGUAGE USE						
1. Do you continue to use the language? Yes☐ No☐ (If no, when did you stop using it? ___ yrs old)						
If yes, how often do you use it in each one of the following contexts (choose one)						
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Not applicable**
Family						
Partner						
Siblings/Nephews/Nieces						
Children						
Other relatives						
Official						
Colleagues						
Shopping						
Radio/TV						
Books/magazines						
Immediate environment						
Friends						
Neighbours						
Church/society						
Do you use different languages with the same person?						
COMMAND OF THE LANGUAGE						
Evaluate your command of the language in each of the following categories:						
	Basic	**Weak**	**Moderate**	**Advanced**	**Fluent**	
Expression						
Comprehension						
Reading						
Writing						

Would you be happy to be contacted again to participate in other experiments? Yes / No

If yes, please provide your contact information:
_____

Appendix B: Full output from model comparisons

Table 1. Model output for sustained attention

Fixed effect	Coefficient	T-value	P-value
Session	-0.8149	-1.33	0.1841
Age (mean centered and scaled)	0.4929	1.44	0.1517
Gender	-0.5296	-0.79	0.4277
Composite	0.1902	0.54	0.5870
Gaelic level	-0.3659	-1.07	0.2847
Session x Gaelic level	-0.2473	-0.42	0.6752
Session x Gender	-0.9751	-0.77	0.4400
Session x Age	0.5060	0.84	0.4002
Session x Composite	-0.2217	-0.37	0.7116
Gender x Age	0.7354	1.09	0.2762
Gender x Composite	0.5943	0.91	0.3653
Age x Composite	-0.8309	-2.43	0.0165
Gender x Gaelic level	-1.5392	-2.20	0.02941
Age x Gaelic level	0.6561	1.82	0.07026
Composite x Gaelic level	0.2985	0.91	0.3627

Notes: Effects whose p-values survive Bonferroni corrections are shaded.

Table 2. Model output for inhibition

Fixed effect	Coefficient	T-value	P-value
Session	5.4094	4.21	5.217e-05
Age (mean centered and scaled)	-2.5618	-1.47	0.1448
Gender	-4.8034	-1.41	0.1604
Composite	2.4283	1.36	0.1763
Gaelic level	-1.0131	-0.58	0.5613
Session x Gaelic level	0.8417	0.68	0.4981
Session x Gender	3.3094	1.25	0.2139
Session x Age	0.6055	0.48	0.6319
Session x Composite	-0.4409	-0.35	0.7266
Gender x Age	-1.0193	-0.30	0.7670
Gender x Composite	5.0885	1.52	0.1305
Age x Composite	2.6971	1.54	0.1245
Gender x Gaelic level	2.9541	0.83	0.4086
Age x Gaelic level	0.0327	0.02	0.9858
Composite x Gaelic level	0.8819	0.53	0.5981

Notes: Effects whose p-values survive Bonferroni corrections are shaded.

Table 3. Model output for switching

Fixed effect	Coefficient	T-value	P-value
Session	16.50596	7.578	1.307e-11
Age (mean centered and scaled)	-9.31065	-3.276	0.00139
Gender	3.65576	0.660	0.5096
Composite	4.13888	1.424	0.1565
Gaelic level	1.83584	0.648	0.5174
Session x Gaelic level	-5.93590	-2.823	0.005586
Session x Gender	-3.23272	-0.719	0.4726
Session x Age	-1.89928	-0.887	0.3758
Session x Composite	-3.89066	-1.821	0.07083
Gender x Age	1.41155	0.252	0.8008
Gender x Composite	2.85119	0.524	0.6005
Age x Composite	-1.95353	-0.688	0.4919
Gender x Gaelic level	0.13044	0.022	0.9821
Age x Gaelic level	-0.09366	-0.031	0.9750
Composite x Gaelic level	-0.27246	-0.100	0.9202

Notes: Effects whose p-values survive Bonferroni corrections are shaded.

Appendix C: Language learning attitude questionnaire

Following are a number of statements with which some people agree and others disagree. Please circle one alternative below each statement according to the amount of your agreement or disagreement with that item. Which one you choose would indicate your own feeling based on everything you know and have seen and heard. Note: there is no right or wrong answer.

    i.   It is important for members of our community to know the language I will be learning this week.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    ii.   There's no good reason for anyone to need to use this language in 21st century Scotland.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    iii.   Older people cannot be expected to learn a language like this.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    iv.   This language is difficult to learn.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    v.   It's really good for your brain to learn a language like this one

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    vi.   In the modern world, there will soon be no need for this language to survive.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

    vii.   A good language learner should have no particular trouble learning this language.

Disagree Strongly   Disagree Moderately   Disagree Slightly   Agree Slightly   Agree Moderately   Agree Strongly

viii.   Schoolchildren here should have the opportunity to study this language.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

ix.   Learning this language demands less intelligence than other languages I know.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

x.   It takes a particular kind of brain to learn this language.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xi.   The language I'm learning belongs to a community with its own culture.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xii.   It is not appropriate to ask normal people to learn this language.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xiii.   I can't imagine myself using this language except in the classroom.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xiv.   It does not matter whether the language is written.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xv.   I am here because I like a mental challenge.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xvi.   I would encourage others like me to learn this language.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

xvii.   This language is worth preserving.

Disagree Strongly Disagree Moderately Disagree Slightly Agree Slightly Agree Moderately Agree Strongly

Appendix D: Descriptive statistics for TEA and perspective-taking tasks

Table 1. Performance on the Test of Everyday Attention

	Mean	SD	Range
Elevator Task			
All Participants	99.169	3.881	71.43-100
Youngest Tertile	99.182	4.766	71.43-100
Oldest Tertile	99.160	3.362	85.71-100
Elevator Task with Distraction			
All Participants	89.714	17.982	30-100
Youngest Tertile	90.620	13.706	50-100
Oldest Tertile	88.157	21.277	30-100
Elevator Task with Reversal			
All Participants	55.444	35.390	0-100
Youngest Tertile	66.374	33.835	0-100
Oldest Tertile	46.195	31.041	0-90

Table 2. Rate of modification on common ground (CG) trials and privileged ground (PG) trials

	Mean	SD	Range
CG (Any Modification)			
All Participants	0.977	0.148	0-1
Youngest Tertile	0.990	0.097	0-1
Oldest Tertile	0.965	0.182	0-1
PG (Any Modification)			
All Participants	0.567	0.495	0-1
Youngest Tertile	0.476	0.499	0-1
Oldest Tertile	0.666	0.472	0-1
CG (Prenominal Modification)			
All Participants	0.728	0.444	0-1
Youngest Tertile	0.850	0.356	0-1
Oldest Tertile	0.589	0.492	0-1
PG (Prenominal Modification)			
All Participants	0.540	0.498	0-1
Youngest Tertile	0.468	0.499	0-1
Oldest Tertile	0.624	0.484	0-1

Appendix E: Plot of the full dataset

Figure 1. All participants' perspective-taking performance using any modification (1a, 1b) and prenominal modification only (1c, 1d), by inhibition and switching