UNIVERSITEIT GENT

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

Effects of Bilingualism on Cognition

Evy Woumans

Promotor: Prof. Dr. Wouter Duyck
Co-Promotor: Dr. Evy Ceuleers

Proefschrift ingediend tot het behalen van de academische graad
van Doctor in de Psychologie

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ACKNOWLEDGEMENTS

« The most elementary and
valuable statement in science,
the beginning of wisdom is
'I do not know'. »

Lt. Commander Data

Firstly, I would like to express my gratitude towards my supervisor Wouter Duyck and towards Ghent University for giving me the opportunity to obtain this PhD. Wouter, ik had niet aan de Universiteit Gent gestudeerd, was geen psychologe, maar toch mocht ik van jou deze doctoraatspositie invullen. You took a chance on me, waarvoor mijn oprechte dank. I will probably be switching languages as I go along, dat is wel toepasselijk voor een proefschrift rond meertaligheid.

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Evy

11th March 2015

CHAPTER 1
LINGUISTIC AND COGNITIVE PROCESSES IN BILINGUALS

Bilingualism may influence the social, professional, and cultural status of those people who have mastered two or more languages, but does it also affect their cognition? This is not a particularly novel research question, as it has been investigated for over one hundred years. In the early years, there was a consensus that bilingualism had a detrimental effect on cognitive development. First, bilinguals were thought to have smaller vocabularies (Grabo, 1931) and poorer writing and grammatical skills (Saer, 1923). Second, bilingual children were also found to be cognitively inferior to monolingual children, as demonstrated by their scores on both verbal and non-verbal intelligence tests (e.g. Arsenian, 1937; Darcy, 1946). There was no question that bilingualism only led to disadvantages, until Peal and Lambert (1962) published a study in which they claimed the opposite. They found that bilingual children actually obtained better scores on all sorts of verbal and non-verbal intelligence measures, results that were later confirmed by Ben-Zeev (1977). Peal and Lambert believed that the bilingual children's constant switching between languages had optimised their mental flexibility, prompting them to perform better on cognitive tests.

The discrepancy between these later and earlier studies could be due to the fact that the early studies struggled with flaws that could easily have influenced their results. For instance, they never controlled for socioeconomic status (SES), which was (then) often lower in the bilingual group (McCarthy, 1930). It is now known that lower SES is also associated with lower intelligence scores (Fischbein, 1980), so that bilingual effects could also have been confounded with intelligence effects. In addition, the term BILINGUALISM was scarcely defined and children were sometimes classified as bilingual when their surname sounded foreign or if their parents' origin was different from the others' (Darcy, 1953). That way, even children that did not actually speak two languages (yet) were deemed bilingual. Bilingual children also had the disadvantage that intelligence tests were carried out in their second language (L2) and not in their native or first language (L1), while L2 proficiency was still very low for most participants (Hakuta, 1986). In contrast, other studies employed such strict measures in matching monolinguals and bilinguals that they actually controlled for output variables. To illustrate, a study by Hill (1935) equated monolinguals and bilinguals not only on age, gender, language proficiency, and education, but also on mental age and intelligence. Not surprisingly, Hill found no effects of group on other verbal and non-verbal tasks tapping into the same cognitive processes, related to intelligence.

Eventually, research on the topic of bilingualism and intelligence faded without a general consensus. Admittedly, bilingualism was no longer perceived as harmful, but it was also not considered to be beneficial. Until about two decades ago, when the topic suddenly revived in the more specialised psycholinguistic literature on bilingualism, where the broad concept of intelligence was abandoned for the more specific concept of cognitive control (also called executive control or executive functioning). This cognitive control encompasses all executive functions that allow moment-to-moment information processing and behaviour adaptation with regard to current goals. The shift of emphasis from intelligence to cognitive control evolved gradually. Initially, focus shifted to the impact of bilingualism on metalinguistic awareness. Seemingly, bilingual children were more aware of the conventional nature of language and its symbols, words, and structures (Ben-Zeev, 1977; Bialystok, 1988; Cummins, 1978; Ianco-Worrall, 1972). It was Bialystok (1992) who eventually drew a connection between metalinguistic awareness (in the form of grammaticality judgement and form-meaning selection) and cognitive control (more specifically, field independence), suggesting that both types of processing might be driven by a domain-general mechanism, which implicates solutions to linguistic as well as non-linguistic problems. Eventually, the studies that followed claimed that bilingualism not only led to enhanced metalinguistic awareness, but also to improved cognitive control (e.g. Bialystok & Majumder, 1998; Bialystok, Martin, & Viswanathan, 2005; Costa, Hernández, & Sebastián-Gallés, 2008). These findings could be explained in view of a specific model of bilingual language processing, set forth by Green (1998). His Inhibitory Control (IC) model assumes that language selection in bilinguals takes place through activating representations from the currently relevant language, while inhibiting those of the irrelevant language. Crucially, these processes of activation and inhibition are not thought to be language-specific, but domain-general, driven by an executive control system that also manages other types of (non-linguistic) cognitive control. Thus, if both are governed by the same mechanism, it is possible that extensive practice in language control (as is the case in bilinguals) leads to enhanced cognitive control. Below, we discuss the evolution of bilingual research that inspired the question of language control.

BILINGUAL LEXICAL ACCESS AND LANGUAGE CONTROL

For many years, it was assumed that the languages of a bilingual were stored in two separate lexicons, either in different areas (Krashen, 1973) or the same area (Paradis, 1997) of the brain. In their Revised Hierarchical Model, Kroll and Stewart (1994) theorised separate lexicons for L1 and L2, which were connected to each other and to a shared semantic system (Figure 1). In unbalanced bilinguals (i.e. bilinguals who are more proficient in L1 than L2), the model assumed stronger connections between L1 words and their meaning than between L2 words and their meaning. It also proposed that the link between L2 word forms and their L1 translation equivalents were stronger than the other way around, because L2 words are learnt by associating them with the L1 translation. Furthermore, increasing L2 proficiency was suggested to strengthen the connections between L2 lexical word forms and the semantic system.

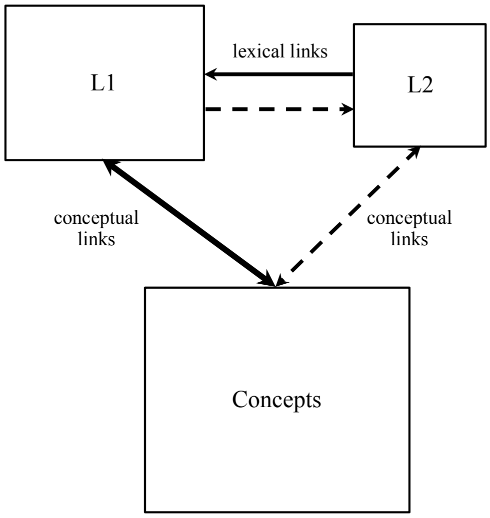

Figure 1. Revised Hierarchical Model (Kroll & Stewart, 1994). Lexical and conceptual representations in bilingual memory.

NON-SELECTIVE ACCESS IN VISUAL AND AUDITORY WORD RECOGNITION

Nowadays, bilingual models with two separate or independent lexicons have been superseded. Indeed, more recent studies began supporting the hypothesis of language non-selective access, as it became increasingly evident that a bilingual's languages are constantly and simultaneously activated (Brysbaert, 1998; Duyck, 2005; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009; Van Hell & Dijkstra, 2002).

Studies into both visual and auditory word recognition have provided evidence for an integrated lexicon. With regard to visual word recognition, Dijkstra, Grainger, and van Heuven (1999) demonstrated faster responses in an L2 lexical decision task for cognates, i.e. words that are orthographically and semantically similar in both languages, compared with control words. They also reported slower responses to interlingual homographs, which are words that are spelt identically in the two languages, but have different meanings. Moreover, Van Assche et al. (2009) found that bilinguals read cognates faster in a sentence context and even when reading in L1. These studies all suggest that even when reading in a single language, representations from a non-target language also and automatically get activated.

Similar findings have been reported in auditory word recognition studies. In a visual world paradigm, Marian and Spivey (2003) instructed proficient Russian-English bilinguals to, for instance, « Pick up the marker ». They found that the participants fixated more on competitor items with L1 names that were phonologically similar to the L2 target (e.g. a stamp, which is called MARKA in Russian) than on distractor items with L1 names phonologically unrelated to the L2 target. They replicated these findings for L1 instructions with L2 competitor items (Marian, Spivey, & Hirsch, 2003), indicating that between-language competition is present both for L1 and L2 auditory word recognition. Furthermore, Lagrou, Hartsuiker, and Duyck (2011) found that when bilinguals are required to perform a monolingual auditory lexical decision task, they are slower in recognising L1/L2 interlingual homophones (i.e. words that sound the same, but have different meanings in the two languages). This again suggests that both languages of a bilingual become activated during word recognition.

NON-SELECTIVE ACCESS IN SPEECH PRODUCTION

The literature referenced above indicated that both languages in a bilingual are activated in parallel during word recognition. This is perhaps not entirely surprising given that word recognition does not necessarily require language selection; recognition of the word and semantic access may in theory occur without language identification. This is different in word production, which by definition requires a language selection for the word used to convey meaning. Research on word production, however, produced comparable results with regard to selectivity of lexical access. For instance, Costa, Caramazza, and Sebastián-Gallés (2000) reported that Catalan-Spanish bilinguals displayed shorter naming latencies for cognate targets than for non-cognate targets in a picture naming task, both in L1 and L2. Moreover, Hermans, Bongaerts, de Bot, and Schreuder (1998) employed a picture-word interference paradigm to demonstrate that bilinguals are unable to restrict language activation to the target language. Their Dutch-English participants had to name the pictures in English, appearing along with spoken English words that were to be ignored. When the English word distractors were phonologically similar to the Dutch picture names, naming was slowed down significantly. A more recent study by Colomé and Miozzo (2010) also presented Spanish-Catalan bilinguals with pairs of partially overlapping coloured pictures. Participants were instructed to name the green picture in Spanish and ignore the red picture, which was either a cognate or non-cognate in Catalan. The authors determined that distractor pictures with cognate names interfered more with picture naming than those with non-cognate names. Again, this suggests parallel activation of both languages.

MODELS OF BILINGUALISM

The findings of the studies referenced above elicited the need for a model of bilingual lexical access. With respect to visual word recognition, the Bilingual Interactive Activation model (BIA, Dijkstra & van Heuven, 1998; and by extension the BIA+ model, Dijkstra & van Heuven, 2002) was proposed, which postulates that a presented word activates its sublexical and lexical representations. These, in turn, activate the semantic representation and language nodes that indicate membership to a particular language and can inhibit activation of word candidates from other languages. The BIA+ model extends its predecessor with phonological and semantic lexical representations, next to the orthographic ones. Also important to note is that the BIA+ model does not assume the top-down inhibition mechanism from language nodes to word nodes.

For bilingual speech production, there are models that adopt the theories of Levelt (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999) and suppose lexical selection through competition between lemmas. For instance, Poulisse and Bongaerts (1994) stated that lemmas are tagged with a language label and language selection is driven by language cues in the conceptual input. Their model assumes that the presence of a language cue in the preverbal message suffices to produce words in the intended language. It proposes that conceptual information, together with the language cue, selects the correct phonological parts (or nodes) of the appropriate meaning and language, but without completely inactivating the nodes of the other language. In other words, the speaker's intention to use a specific language would simply activate the words of that language more than the word equivalents in the other language. Take, for example, a French-Dutch bilingual who wants to talk about a bike in Dutch. His language selection mechanism will consider the level of activation of all lexical nodes irrespective of the language to which they belong, but eventually only the phonological nodes of FIETS and not VÉLO will be produced (Figure 2).

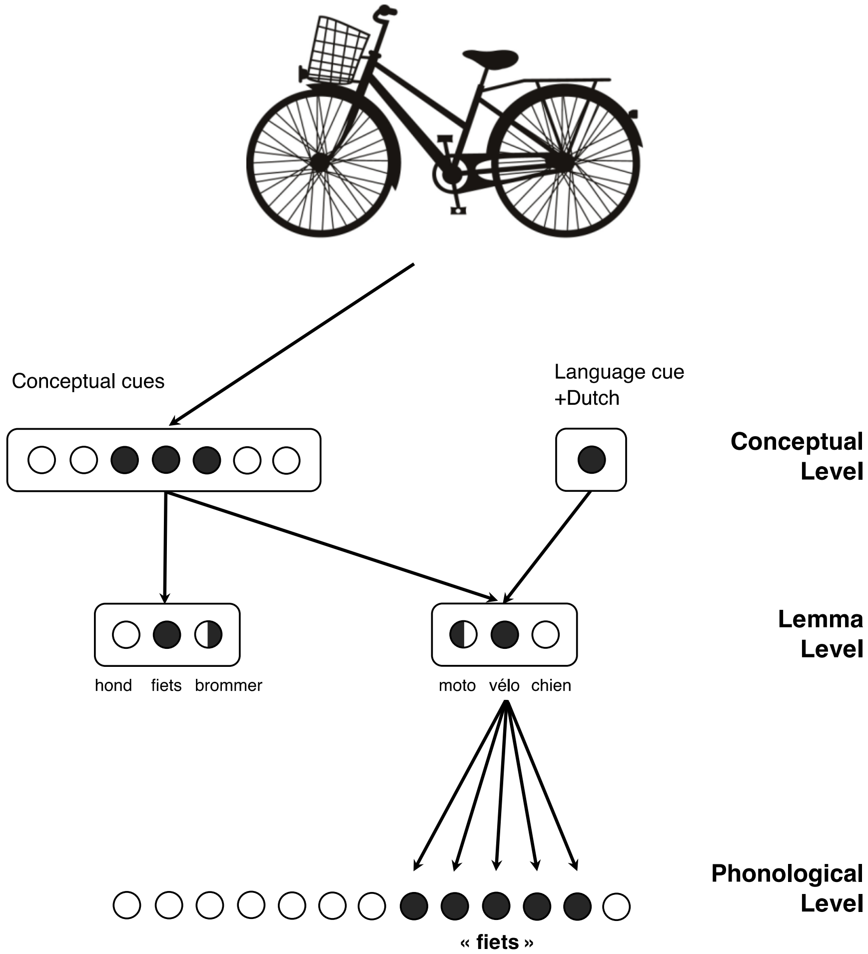

Figure 2. Schematic representation of the bilingual language non-specific selection mechanism.

In contrast, there are other models that departed from active inhibitory processes. For instance, Paradis (1997) asserted that the intention to speak one language rather than the other reduces the activation threshold of the intended languages and raises that of the non-intended language. The activation and deactivation of language systems would allow bilinguals to achieve different language modes (see also Grosjean, 1998). On the one hand, they could keep to a single language (unilingual mode), highly activating it, while deactivating the other language. On the other hand, they could mix and switch between languages (bilingual mode), in which case both languages would be activated.

Also the previously mentioned IC model set forth by Green (1998) departs from active inhibition at the stage of output selection (i.e. not before lexical access, but after activation of words in both languages). Like the BIA model (but unlike the BIA+ model), the IC model postulates that competition between word candidates in the two languages can be differentially inhibited top-down on the basis of language. Figure 3 depicts how, according to the IC model, a conceptual representation is generated at the onset of planning. That conceptual activity activates both the lexico-semantic system and the supervisory attentional system (SAS), which controls the activation of task schemas for particular language processing goals. Furthermore, the IC model assumes that lemmas are tagged for language membership. The task schemas' role is activating lemmas in the intended language and inhibiting those in the unintended language.

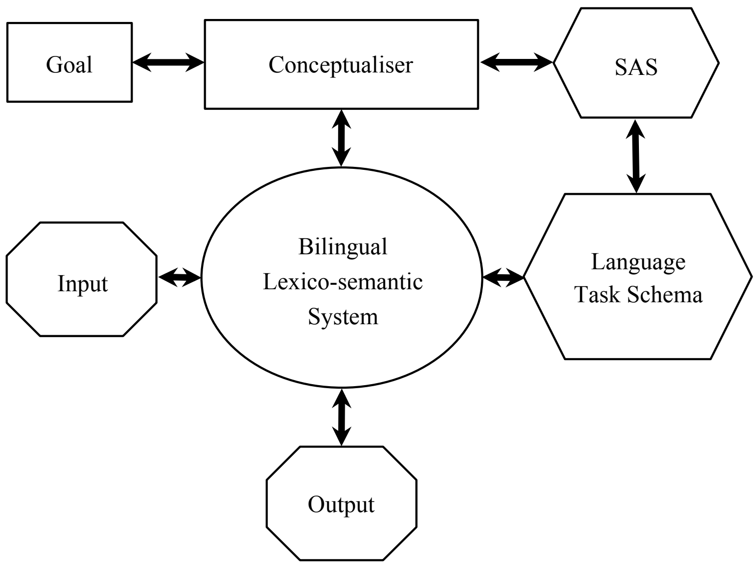

Figure 3. Green's model of Inhibitory Control (1998). The activation and inhibition of languages in a bilingual are regulated by domain-general mechanisms.

Clearly, there are different accounts of bilingual language selection, but they all agree that some sort of selection must take place. Uncertain is what triggers this selection. The work by Dijkstra et al. (1999), Marian et al. (2003), and Van Assche et al. (2009) demonstrated that linguistic context, such as the language of a written sentence or the instruction language, are insufficient to restrict activation to a single language.

COGNITIVE CONTROL THROUGHOUT THE BILINGUAL LIFESPAN

When bilinguals are reading, it is not essential for them to restrict language activation to only one language. For that reason, the bilingual models of word recognition (e.g. BIA+, Dijkstra & Van Heuven, 2002) do not assume any specific mechanisms for language control. This is different for bilingual speech production, as speaking requires restricting utterances to one language. This is why Green's model (1998), discussed above, proposes an active inhibitory control mechanism that activates the relevant and suppresses the irrelevant language. This constant cognitive regulation of utterances is thought to be at the basis of the bilingual cognitive advantage. The mechanism for language control is believed to be domain-general. This implies that training the mechanism through continually activating one language and inhibiting the other might also improve other types of non-verbal cognitive control.

During the last twenty years, bilingual research has shown an important emphasis on the question whether bilingual experience in language control may lead to improved cognitive control outside the verbal domain. Indeed, it seems that bilinguals often outperform their monolingual peers on executive tasks measuring different aspects of cognitive control (e.g. Bialystok, Craik, Klein, & Viswanathan, 2004; Costa et al., 2008; Luk, De Sa, & Bialystok, 2011). Practice in inhibiting one of two conflicting languages would help with inhibiting one of two types of conflicting non-verbal stimuli features. In other words, a bilingual's need to constantly control two languages by focusing on the relevant one and avoiding interference from the irrelevant one might be at the origin of the so-called BILINGUAL ADVANTAGE in cognitive control.

Indeed, the bilingual advantage has often been demonstrated on tasks, such the Simon (Simon & Rudell, 1967). In this task, coloured dots (e.g. red and green) appear either on the left or the right side of a computer screen and participants are asked to ignore their position and only respond to their colour by pressing, as fast and accurately as possible, the left button for a green dot and the right button for a red dot (Figure 4). When position and colour elicit the same response, the trials are called CONGRUENT. When they elicit different responses, they are called INCONGRUENT. This particular task is based on stimulus-response compatibility, meaning that the difficulty lies in inhibiting a prepotent response, which is similar to inhibiting naming an object in your native language, when speaking in L2. Another type of inhibition, namely interference inhibition, is measured by tasks such as the flanker task (Eriksen & Eriksen, 1974). Here, five arrows are shown and participants have to indicate the direction of the central arrow by pressing the left or right button (Figure 4). The four flanker arrows can either point into the same direction (congruent trials) or in the opposite (incongruent trials). Performance on both tasks is mainly conveyed in terms of reaction times (RTs), but sometimes also in accuracy scores. Consequently, conflict resolution skills are measured by subtracting congruent RTs from incongruent RTs. What remains, is the so-called CONGRUENCY EFFECT.

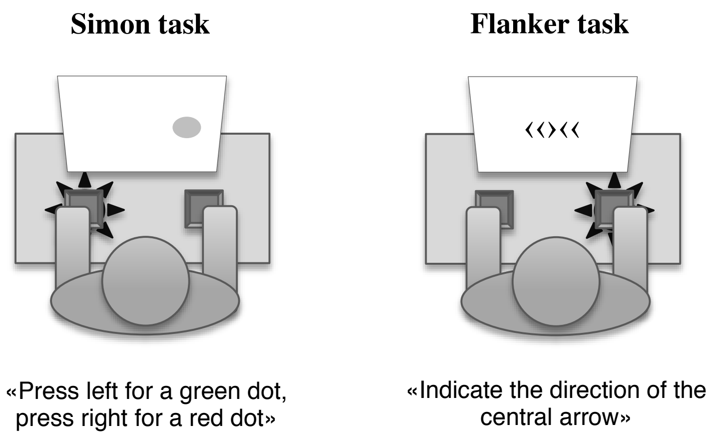

Figure 4. Procedure for the Simon (left) and the flanker (right) task. Both images depict an example of an incongruent trial. In the Simon task, a green dot is shown.

Compelling evidence that bilingual language control practice leads to cognitive advantages was put forward by Emmorey, Luk, Pyers, and Bialystok (2009). This study compared unimodal bilinguals (having mastered two spoken languages) as well as bimodal bilinguals (having mastered one spoken and one signed language) to a group of monolinguals. The difference between unimodal and bimodal bilinguals is that only unimodal bilinguals require inhibition and monitoring to communicate. Bimodal bilinguals can speak and sign at the same time without convoluting the message and have therefore no need for improved language control. That is why bimodal bilinguals were not expected to show enhanced cognitive control either. Indeed, the results matched the predictions; only unimodal bilinguals exhibited the cognitive control advantage over monolinguals and bimodal bilinguals, and this on both congruent and incongruent conditions in the flanker task.

Yet, bilinguals have not only been found to react faster on conflict (i.e. incongruent) trials, but also on non-conflict (i.e. congruent) trials (Bialystok, 2006; Bialystok et al., 2005; Costa et al., 2008; Martin-Rhee & Bialystok, 2008). This may reflect an effect of bilingualism on the efficiency of other cognitive processes apart from conflict resolution. Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) postulated that bilinguals are also better at monitoring situations and determining whether or not conflict is present. Faster assessment of the situation would then lead to faster responses on both types of trials. But, why would bilinguals be better at monitoring these situations? Seemingly, at any moment during any type of conversation, bilinguals also need to survey which language is being employed, hereby enhancing their general monitoring system, according to Costa et al. (2009).

Furthermore, bilinguals do not only seem to display superior performance on tasks of inhibition, but also on tasks of cognitive flexibility, such as the Dimensional Change Card Sort (DCCS, Zelazo, 2006). In this task, bivalent cards must be sorted according to either shape or colour. First, participants are trained to sort the according to one dimension (e.g. shape). Then the rules change, and they have to sort them according to the other dimension (e.g. colour). Bilinguals seem to adapt more swiftly to these changing rules (e.g. Bialystok, 1999; Bialystok & Martin, 2004). Similarly, they also seem to perform better on perceptual switch tasks (e.g. Prior & Gollan, 2011; Prior & MacWhinney, 2010). In this type of task, participants determine a figure's dimensions, such as its shape (e.g. triangle, square) or its colour (e.g. blue, yellow), by pressing the corresponding buttons. Each trial is preceded by the word SHAPE or COLOUR, so that participants know to which dimension they need to respond. Often, the first two lists of trials are blocked (either shape or colour), while the third switches constantly between the two dimensions. Differences in RTs and accuracy scores between the first two lists and the third are then reflected in the so-called SWITCH COST.

The referenced studies here were carried out among children, adults, and older adults, disclosing that bilingualism reinforces cognitive development as well as counteract cognitive decline. Below, a more detailed description is given of the cognitive advantages of bilingualism during different stages of the bilingual lifespan, because the present dissertation will also focus on different stages of cognitive development in different chapters.

BILINGUALISM AND COGNITIVE DEVELOPMENT

Children are an interesting group of subjects for bilingual research. As opposed to monolingual children, bilinguals receive roughly twice as much linguistic input, but still manage to reach the different linguistic milestones at the same age (De Houwer, Bornstein, & Putnick, 2013). Evidently, bilingualism does not seem to have any immediate negative impact on a child's linguistic development. But what is more, it seems that these bilingual children already enjoy the cognitive advantages that have been described above.

Even in preverbal infants, differences between children growing up with one and two languages have been reported. Kovács and Mehler (2009a) did an eye-tracking study among 7-month-olds and showed them speech cues (trisyllabic meaningless words) on one side of a computer screen. This speech cue was then followed by a visual reward (a looming puppet) on the same side. Infants learnt that the words predicted the location of the puppet, and that it was therefore rewarding to direct their gaze toward that side. Afterwards, new trisyllabic words were presented and the puppet appeared on the opposite side of the screen. Only infants growing up with two languages were able to reprogramme their anticipatory looks when the cue predicted that the reward would appear on the other side. Hence, bilinguals demonstrated more cognitive flexibility. In a second study (Kovács &

Mehler, 2009b), similar results were obtained in 12-month-olds. These children heard trisyllabic speech structures (e.g. ABA or AAB) while watching a prominent stimulus centred on the computer screen. Once more, a visual reward appeared either on the left or right side on the screen. The location of this reward was determined by the speech structure (e.g. after structure AAB, the reward was shown on the left). The infants growing up in a bilingual environment learnt to associate two structures with the visual reward, while the ones growing up in a monolingual environment only learnt one. The authors therefore concluded that these bilingual infants are more flexible learners.

Not only infants, but also older children seem to benefit from being bilingual. A task that is often used to compare cognitive flexibility between monolingual and bilingual children is the DCCS (Zelazo, 2006). Several studies found that bilinguals are better at applying the new rule in this task than monolinguals (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008), verifying that, even in children, bilingualism is associated with more effortless resolution of problems based on attention and conflict. Given that the DCCS is a non-verbal task, these studies confirmed that the bilingual advantage is general and not specific to language processing.

Interestingly, the bilingual advantage seems to interact with parameters of language use. One such moderating factor is L2 proficiency. When Carlson and Meltzoff (2008) compared monolinguals, monolinguals that had been enrolled in L2 immersion for six months, and early bilinguals (from birth) on nine different measures of cognitive functioning, they found that the early bilinguals consistently outperformed the two other groups. Furthermore, they found no differences between monolingual and L2 immersion children. These results were afterwards confirmed by Poarch and van Hell (2012), who included monolinguals, children with 1.5 years of L2 immersion, children with 3 years of L2 immersion, and trilinguals (i.e. early bilinguals with 2-3 years of L3 immersion). A cognitive advantage was only found for children with 3 years of L2 immersion and for trilinguals. Hence, it seems that a certain amount of L2 proficiency or L2 use is necessary to develop enhanced cognitive control. Nevertheless, trilinguals did not enjoy additional benefits from knowing a third language, indicating some kind of ceiling effect. Another aspect that needs to be taken into account is age of L2 acquisition (L2 AoA). This was demonstrated by Kapa and Colombo (2013), who reported that early bilinguals (who acquired their L2 before age 3) exhibited better cognitive functioning over monolinguals, while late bilinguals (who acquired their L2 after age 3) did not. There were no significant differences in L2 proficiency between the two bilingual groups and so the authors concluded that the distinction must lie in either L2 AoA or in the duration of the bilingual experience.

ADULT EXPERTS IN LANGUAGE CONTROL

From the developmental studies, we can deduce that certain linguistic variables (e.g. L2 proficiency and L2 use) are key to determining a cognitive control advantage. In studies among adult participants, these variables are being taken into account more and more often. After all, it is conceivable that a person with high proficiency in several languages will also require higher levels of inhibition and activation, every time one of the languages needs to be suppressed. Consequently, this person will also require, and develop, improved mechanisms of control. If this is the case, then people who have a need to constantly switch between languages (e.g. at work or among family and friends) may depend even more upon these mechanisms of control than those who reserve one specific language for one specific context.

Prior and Gollan (2011) suggested that it is actually the constant practice of language switching that prompts the bilingual advantage, at least in task switching. They compared a group of English monolinguals with a group of Spanish-English bilinguals who reported frequent language switching and one of Mandarin-English bilinguals who reported infrequent language switching. All participants were students and the task was a perceptual switch task. Results showed that the group of frequent switching bilinguals obtained better switch scores (i.e. lower switch costs) than the group of monolinguals, while the group of infrequent switching bilinguals performed similar to the monolinguals. Furthermore, a language-switching task, in which numbers had to be named in either L1 or L2, revealed that reported switching went hand in hand with actual language switching abilities, as the frequent switchers also exhibited smaller switch costs in the verbal task.

Clearly, the way in which bilinguals employ their languages modulates cognitive control. In this regard, Green and Abutalebi (2013) formulated their ADAPTIVE CONTROL HYPOTHESIS, which states that a bilingual's control processes (both linguistic and non-linguistic) adapt to the recurrent demands placed on them by the interactional context. So, if the interactional demands attune cognitive control, what can be expected from bilinguals who often find themselves in very challenging linguistic circumstances? One example of such bilinguals is simultaneous interpreters. Those are the people who perform the complex task of converting a message from one language (source language – SL) into the other (target language – TL) in real time (i.e. with no delay). A multitude of cognitive processes are at play here, such as listening to and comprehending the SL, translating from SL to TL, producing the message in the TL, and monitoring the produced output for possible mistakes. It is plausible that constantly managing these different processes may lead to some sort of cognitive boost. In fact, apart from the finding that interpreters display better working memory over monolinguals and other bilinguals (Christoffels, de Groot, & Kroll, 2006; Köpke & Nespoulous, 2006; Padilla, Bajo, & Macizo, 2005), some initial exploratory studies have suggested that they also exhibit other enhanced cognitive abilities. For instance, a study by Yudes, Macizo, and Bajo (2011) determined that a group of interpreters displayed more cognitive flexibility, as measured by the Wisconsin Card Sorting Test (WCST – Grant & Berg, 1948), than groups of monolinguals and bilinguals. This finding was especially notable, as the interpreters were overall 10 to 15 years older and thus, past their cognitive peak. Furthermore, Timarová et al. (2014) measured both interpreting skills and several types of non-verbal cognitive functioning, and showed that more refined interpreting abilities correlate with better cognitive control. Another recent study by Dong and Xie (2014) also proposed a similar correlation between cognitive control and the amount of interpreters training.

BILINGUALISM AND COGNITIVE RESERVE

It is apparent that bilingualism affects cognitive functioning, both in children and in different adult populations. But what happens when these bilinguals get older? In the first decennia of our lives, our cognitive capacities seem to constantly flourish and develop, but at a certain point – a peak, around the age of 20 to 30 – they again start to diminish (Salthouse, 2009). This is less the case for crystallised intelligence (e.g. vocabulary, general knowledge), but especially so for cognitive control. Yet, some factors, such as sports and social network, have been found to serve as a protection against this cognitive ageing (e.g. Scarmeas, Levy, Tang, Manly, & Stern, 2001). Strikingly, bilingualism has been determined as one of those factors and hence, it seems to contribute to COGNITIVE RESERVE; which is functional compensation of brain degeneration (Stern, 2002).

When Bak, Nissan, Allerhand, and Deary (2014) presented bilinguals with the same verbal and non-verbal intelligence measures than they had taken at the age of 11, about sixty years earlier, the researchers found that bilinguals performed remarkably better than predicted from their baseline scores, with strongest effects on general intelligence and reading. These effects were obtained in both early and late bilinguals. These findings suggest a protective effect of bilingualism against age-related cognitive decline, independently of childhood intelligence. Several cross-sectional studies have produced similar outcomes. For instance, Bialystok et al. (2004) compared monolingual and bilingual middle-aged and older adults on performance in the Simon task. Overall, bilingualism was associated with better conflict resolution (i.e. smaller Simon effects) and the difference between groups was greatest for older participants. Additionally, Pelham and Abrams (2014) found that both early and late bilinguals experience cognitive benefits, hereby indicating that proficient and habitual use of two languages during the course of a lifetime and not age of L2 acquisition modulate the bilingual advantage. Furthermore, contrary to what was found in the research on bilingualism and cognitive development (cf. Poarch & van Hell, 2012), some studies found that mastery of more than two languages leads to a cognitive advantage in the form of more cognitive reserve (Kavé, Eyal, Shorek, & Cohen-Mansfield, 2008; Perquin et al., 2013).

Gold, Kim, Johnson, Kryscio, and Smith (2013) provided substantial evidence for a neural basis of cognitive reserve procured through bilingualism. The study included both young and older adult monolinguals and bilinguals. All participants completed a perceptual switch task, while their brain activation was being measured through functional Magnetic Resonance Imaging (fMRI). As predicted, all younger participants performed better on the switch task than the older participants. The older participants also exhibited more brain activation, which indicates they had to make stronger efforts to complete the task. Critically, the bilingual advantage was reflected in both task performance and brain activation. The latter was only demonstrated in older adults, as bilinguals required less activation to complete the task, demonstrating greater neural efficiency in these older bilingual participants.

A study by Schweizer, Ware, Fischer, Craik, and Bialystok (2011) also proved that when it comes to neural efficiency, bilinguals are able to do more with less. They matched a group of monolingual to a group of bilingual patients suffering from probable Alzheimer's disease (AD) on different sorts of cognitive functions, before measuring brain atrophy through computed tomography (CT). The scans revealed that bilingual AD patients exhibited substantially greater amounts of brain degeneration. Hence, the authors concluded that bilingualism contributes to cognitive reserve, delaying the onset of AD by requiring greater amounts of biological neuropathology before the disease manifests itself functionally. Other patient studies comparing monolinguals and bilinguals diagnosed with AD have estimated this delay at about four to five years (Bialystok, Craik, & Freedman, 2007; Craik, Bialystok, & Freedman, 2010). A recent study by Bialystok, Craik, Binns, Ossher, and Freedman (2014) once again confirmed this number and also excluded that this finding is not due to bilinguals consulting a neurologist during more advanced stages of the diseases. Importantly, the progression rate seems to be the same in monolinguals and bilinguals; i.e. later AD manifestation in bilinguals is not associated with faster cognitive deterioration afterwards.

It must be noted that all the abovementioned studies reporting a bilingual AD delay exclusively included groups of bilinguals consisting mostly of immigrants and groups of monolinguals composed almost entirely of non-immigrants. Of course, there is a distinct variance between populations with a different immigration status. It seems plausible that people who move to another country and have the determination to learn the language of their new community are more socially or cognitively active. Therefore, Chertkow and colleagues (2010) aimed to replicate the previous findings in a large-scale study among immigrant and native bilinguals, compared with native monolinguals. They reproduced the advantage in their immigrant bilingual population, but failed to do so in the native bilingual population. Nevertheless, when Alladi et al. (2013) attempted the same in the first non-Canadian study on the topic, an AD delay for native bilinguals was also found. This equally large-scaled study was performed in India and also included other types of dementia next to AD. The bilingual advantage was found for several types of dementia (AD, frontotemporal dementia, and vascular dementia) and could even be recorded in illiterate patients.

HITCHES IN THE BILINGUAL ADVANTAGE

The previous section clearly demonstrates that bilingualism can be a cognitive asset throughout the entire lifespan, from development to old age and during pathology related cognitive decline. Yet, lately there have also been an increasing number of studies contradicting these bilingual effects. One of the first to dispute earlier findings was a study by Morton and Harper (2007). When they compared a group of bilingual six-year-olds with a group of monolingual peers on a Simon task, they did not find any differences between language groups. There was, however, a difference between children with different SES, with those higher on the ladder obtaining superior performances. Consequently, the authors concluded that the differences previously established between monolinguals and bilinguals could be ascribed to confounding variables, such as SES. More recent studies have substantiated this claim. Antón et al. (2014) compared well-matched monolingual and bilingual children on a child version of the Attention Network Test (child's ANT, Rueda et al., 2004), a type of flanker task with additional cues. Duñabeitia et al. (2014) did the same, but employed a verbal and a numerical version of the Stroop task (Stroop, 1935), in which form and meaning of the stimuli elicit contradicting responses. Neither of the studies obtained any evidence for a bilingual advantage.

With regard to adults, similar null results have been reported. When Kousaie and Phillips (2012a) compared young and older bilingual and monolingual adults on verbal Stroop performance, they found that bilingual young adults displayed a general speed advantage relative to their monolingual peers. Nevertheless, they did not display a smaller Stroop effect and there were no differences at all between the older groups. With reference to non-verbal executive tasks, the bilingual advantage has been elusive among young bilinguals for both inhibitory control and task switching (Kousaie & Phillips, 2012b; Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014; Paap & Greenberg, 2013; Paap & Sawi, 2014).

These findings are in stark contrast with those maintaining a bilingual advantage. The discrepancies may be accounted for by several variables. Morton and Harper (2007) already demonstrated the importance of controlling for SES. In addition, Calvo and Bialystok (2014) established that both SES and bilingualism contribute independently to children's cognitive functioning. They found that bilinguals performed better on executive tasks than monolinguals, and that the same was true for middle class children as opposed to working class children. Additionally, immigration status may influence the bilingual advantage as well. The study by Chertkow et al. (2010) among monolingual and bilingual patients diagnoses with probable

Alzheimer evidenced that bilingual immigrant populations do not always correspond to bilingual non-immigrant populations. In their study, the delay in AD symptom manifestation was only present in bilingual immigrants.

Furthermore, Paap and Greenberg (2013) questioned the cross-validity of the different tasks that have been employed in the myriad of bilingual studies and proposed that they may elicit different results. Miyake and Friedman (2012) similarly noted that different types of control tasks might tap into different kinds of inhibitory control. This makes comparisons between studies implementing tasks that are different in nature (e.g. flanker vs. Simon) or even tasks of the same kind, but with different parameters (e.g. the percentage of congruent trials or various stimulus-onset asynchrony – SOA) very difficult.

As became clear over the course of this exposé, socioeconomic, cultural, and task variables are not the only ones to be considered. Linguistic variables may also play a consequential part. Kroll and Bialystok (2013) already noted that bilingualism is a rather broad concept consisting of different linguistic parameters, and these parameters may all modify the efficiency of the control network. First, and perhaps foremost, there is L2 proficiency and L2 exposure. Bialystok and Barac (2012) showed that in a sample of bilingual children executive control performance improved with increased experience in a bilingual education environment. The same was found by Poarch and van Hell (2012), when their factor analysis showed a cognitive advantage for children with three years of L2 immersion, but not for those with only 1.5 years. Kapa and Colombo (2013) demonstrated that, even when L2 proficiency is matched, L2 AoA could still play a role. They reported that early bilinguals exhibited better cognitive skills over monolinguals, while late bilinguals did not. Another factor to be considered is language control practice. For instance, Prior and Gollan (2011) asserted that language switching experience influences the magnitude of the bilingual cognitive advantage. Nevertheless, we must bear in mind that this study confounded switching frequency with language pair dissimilarity; i.e. the frequent switchers were all Spanish-English bilinguals, while the non-frequent switchers were Mandarin-English bilinguals. Therefore, it is unclear whether the authors found a pure effect of language switching. Especially since, only recently, Coderre and van Heuven (2014) showed that bilinguals whose two languages have a larger degree of orthographic overlap require more effective domain-general control, as high orthographic overlap creates more cross-linguistic activation and increases the daily demands on cognitive control.

Verily, all these variables could influence the outcome of bilingual studies, providing an explanation for all the recent inconsistencies. So far, the studies referenced in the previous paragraph have provided evidence that different linguistic variables could indeed modulate cognition. Hence, these studies point into the direction that those variables are key to unravelling the ambivalence surrounding the bilingual control advantage. Yet, more research needs to be done to determine which variables contribute most to the advantage and how the interplay of some or all variables lead to those inconsistent findings.

THE PRESENT DISSERTATION

The aim of the current dissertation is to assess the bilingual cognitive advantage throughout the lifespan, including better-controlled longitudinal follow-ups of the development of the advantage, special language experience populations, and resistance to cognitive pathology. The first section deals with how the bilingual advantage manifests itself, when individual confounding variables (i.e. socioeconomic, cultural, initial cognitive skills) are controlled for, using a longitudinal design. The second section explores how specific bilingual experiences, more specifically language switching frequency and skill, contribute to the advantage. In the third section, the possible effects of bilingualism on Alzheimer’s disease are recorded in a non-immigrant patient sample. The fourth and final section does not address cognitive control, but instead considers how language selection in bilinguals can be cued.

COGNITIVE DEVELOPMENT IN BILINGUALS: A LONGITUDINAL APPROACH

A large body of evidence seems to point toward the existence of a bilingual advantage, yet, several studies that failed to find confirmation propose that the results of their counterparts are confounded by other variables. Because cross-sectional group comparisons may never completely exclude the possibility that an unidentified third variable other than bilingualism affects the dependent variable of interest, we reasoned that the foremost way of dealing with this problem was to set up a longitudinal design. The study that resulted from this reasoning is advanced in CHAPTER 2. In this study, we started by testing two groups of monolingual five-year-olds, matched for L1 proficiency and SES as well as intelligence and cognitive control. This baseline test moment took place right before one of the two groups commenced an L2 immersion school programme, in which 50% of all classroom communication occurred in the new language. The other group remained in the traditional monolingual school programme and also remained monolingual. One school year later, both groups of children were tested again. In this time, bilingualism (to a certain degree) became an additional factor for the L2 immersion group. We employed the same test battery as at baseline, which included a non-verbal intelligence test (Raven's Coloured Progressive Matrices), a cognitive control task (Simon paradigm), and a verbal fluency task (L1 semantic fluency), to see whether attending becoming bilingual had nurtured cognitive development.

By employing a longitudinal design in this field study with participants that were matched on the dependent variables at the beginning of the study (before bilingualism); we were able to exclude individual differences correlated with the dependent variables. The results of these efforts are presented in CHAPTER 2.

VARIATION IN THE BILINGUAL EXPERIENCE

Bilingualism is often regarded as a single concept and little emphasis is placed on the different aspects that may define a bilingual. Particularly in research on the bilingual control advantage, an individual is often considered either bilingual or not, with no regard for additional subdivisions. Nonetheless, it could be those unrecognised aspects that potentially drive the bilingual advantage and determine its presence.

In CHAPTER 3 and CHAPTER 4, we explore a number of characteristics tied to the bilingual experience. CHAPTER 3 mainly focuses on how language switching frequency in daily life and cognitive control relate. For this reason, balanced bilinguals reporting frequent switching and those reporting non-frequent switching were compared on two inhibitory control tasks (Simon and flanker). Unbalanced bilinguals were included as a control group. We discuss how these groups differed from and resembled each other. In CHAPTER 4, language switching is again examined, but more prominent here is language switching proficiency and not frequency. Switching proficiency was measured through an adapted dual-language version of the semantic verbal fluency task. Furthermore, the effects of L2 proficiency and interpreting experience are also reviewed. The entire study was run among four different language groups; interpreters, balanced bilinguals, unbalanced bilinguals, and monolinguals. The tasks at hand for measuring cognitive control were the ANT and a version of the Simon task.

COGNITIVE RESERVE AND IMMIGRATION STATUS

An interesting line of research that has developed within the bilingual advantage scope, is the one that deals with how bilingualism influences cognitive reserve and what its effects are on (accelerated) cognitive decline. Our intention was to investigate whether there were any differences between European monolingual and bilingual patients with probable Alzheimer's disease. We therefore compared the recorded ages of clinical manifestation of Alzheimer symptoms and the ages of diagnosis for patients in both language groups. These patients were recruited at the University Hospital of Ghent (mainly monolinguals) and the University Hospital of Brussels (mainly bilinguals). Medical assessments were made by two neurologists at the respective hospitals, while patient and caregiver interviews were carried out by us in order to paint a detailed picture of the patients' linguistic background. We paid specific attention to L2 proficiency, L2 AoA, and L2 use. Other variables that could interact with the effect of interest (i.e. that of language group) were also incorporated in the analyses. The results of these analyses are presented in CHAPTER 5.

A VISUAL CUE FOR LANGUAGE SELECTION

This dissertation is predominantly concerned with the effects of bilingualism on cognition. However, the entire theoretical support for the bilingual advantage phenomenon is predicated on the hypothesis that a bilingual's two languages are constantly activated at the same time. The bilingual's efforts to speak one language while repressing the other are thought to be strenuous, although he or she may not notice this, leading to cognitive benefits also in non-verbal areas. Surprisingly, little is yet knows about how this lexical selection actually takes place, and what factors may trigger it. Several theories have been formed, all assuming an integrated lexical network and language regulation by activation. A question that arises is how correct activation is achieved. Linguistic cues, such as context, have been suggested, but are found to be insufficient (cf. Dijkstra et al., 1999; Marian et al., 2003). Van Assche et al. (2009) for instance, showed that even the (unilingual) language of a sentence in which a to-be-recognised word occurs does not suffice to restrict lexical search to lexical representations of the language of the sentence. Therefore, in the present dissertation, we will divert form such ineffective linguistics cues, and instead focus on visual cues.

Up until now, a few rare studies provided limited evidence that extralinguistic (i.e. visual) cues might actually be able to direct activation to a specific language. Jared, Pei Jun Poh, and Pavio (2013), for example, revealed that Mandarin-English bilinguals named culturally biased images faster in the culturally congruent language (e.g. the Mandarin equivalent for VASE when they saw a Chinese vase) than in the incongruent language (e.g. the English word MASK when they saw a Chinese mask). The sociocultural identity of an interlocutor's face was also shown to influence bilingual language production by facilitating responses in picture naming when face identity was consistent with the target language (Li, Yang, Scherf, & Li, 2013) and reducing linguistic fluency when face identity was inconsistent with the target language (Zhang, Morris, Cheng, & Yap, 2013).

In CHAPTER 6, we investigate whether the face of the interlocutor can serve as a visual cue for language selection in bilinguals whose languages are not linked to different sociocultural identities. We present two distinct experiments. The first one was conducted among Spanish-Catalan bilinguals, who were asked to execute simulated Skype conversations in both languages. During these simulations, they were familiarised with certain faces and their according speech language. Afterwards, participants carried out a language production task, in which they had to generate verbs associated with the nouns produced by familiar and unfamiliar faces on screen. The second experiment was similar, but included Dutch-French bilinguals. They were also presented with the familiarisation phase in the form of Skype conversations in French and Dutch. Only, the association task was slightly adapted, with noun-noun associations and altered arrangement of the different types of trials.

To conclude this dissertation, CHAPTER 7 will give an overview of the results that arose from the different studies presented and will discuss them in light of previous findings and theories. Subsequently, the theoretical implications will be presented and general conclusions will be draws before suggesting some advancements and novel ideas for future research.

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CHAPTER 2
CHILDREN ATTENDING BILINGUAL KINDERGARTEN SCHOOL BECOME SMARTER[1][2]

Throughout the past century, the effects of bilingualism on general cognition have been extensively explored. Studies evolved from a negative to a more positive perspective, but longitudinal assessments of effects of bilingualism are scarce. This study investigated the long-term effect of becoming bilingual on the development of cognitive control and general intelligence. We followed 27 five-year-old children initiating bilingual kindergarten school and 27 age-matched controls enrolled in monolingual kindergarten school. The two groups were similar with regard to socioeconomic status. At baseline, both groups spoke only French and performed equally on measures of intelligence, cognitive control, and verbal fluency. One year later, all children were tested again. Results revealed that, after one year, both groups improved similarly on verbal fluency and cognitive control. However, only children attending bilingual kindergarten improved significantly on intelligence, indicating that cognitive practice gained from acquiring a second language may improve general cognitive abilities assessed by intelligence tests, also outside the verbal domain.

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[2]This study was co-authored by Jill Surmont, Esli Struys, and Wouter Duyck.

INTRODUCTION

Does becoming bilingual impair cognitive development or does it make children smarter? This question dates back to the first half of the 20th century, when there was a consensus that bilingualism was detrimental and that bilinguals performed worse on measures of intelligence (Darcy, 1946). This view remained dominant until the sixties, when Peal and Lambert (1962) reported for the first time that bilinguals actually outperformed their monolingual peers on tests of intellectual reasoning. They argued that the constant switching between languages enhanced mental flexibility, yielding benefits for non-linguistic mental abilities. This outcome was later confirmed by Ben-Zeev (1977). The difference between the earliest and later studies was that the former failed to control for confounding between-group variables. As pointed out by McCarthy (1930), bilingual children often had a lower socioeconomic status (SES). They also did not take into account children's degree of bilingualism (Brunner, 1929). Conversely, other studies employed such strict measures of control that they were matching the groups for the same abilities as those underlying the tasks for which they were trying to find differences (Hill, 1935).

Contemporary psycholinguistic research has now abandoned the broad concept of intelligence when measuring the effects of bilingualism on cognition. Instead, it focuses on the more specific concept of cognitive control (or executive functioning). This shift of interest evolved from the recent consensus that a bilingual's languages are always simultaneously active and interacting (Dijkstra, Grainger, Van Heuven, 1999; Martin, Dering, Thomas, & Thierry, 2009) both during production (Costa, Caramazza, & Sebastián-Gallés, 2000) and comprehension (Van Assche, Duyck, Hartsuiker, & Diependaele, 2009). So, when bilinguals are reading or speaking in a given language (even their native language), the other irrelevant language is always also active to a certain degree. Hence, bilingualism implies constant cognitive conflict and requires monitoring each situation, activating the appropriate language, while resisting interference from the irrelevant language (Green, 1998).

Interestingly, it has recently been hypothesised that this practice of language control is assumed to transfer into, and improve, domain-general processes of cognitive control. For instance, Bialystok and colleagues showed that bilinguals show smaller Simon effects than monolinguals (Bialystok, Martin, & Viswanathan, 2005). Ample studies have now reported superior performance of bilinguals, relative to monolinguals, for several types of cognitive control tasks, throughout the entire lifespan. These studies included accelerated development of cognitive control in bilingual children (Bialystok & Barac, 2012; Carlson & Meltzoff, 2008; Kovács & Mehler, 2009a&b), advanced cognitive control for bilingual young (Costa, Hernández, & Sebastián-Gallés, 2008) and middle adults (Bialystok, Klein, Craik, & Viswanathan, 2004), improved cognitive reserve in ageing bilingual adults (Bialystok, Craik, & Luk, 2008), and delayed clinical manifestation of neurodegenerative diseases like Alzheimer's disease (Bialystok, Craik, & Freedman, 2007). Recently, however, these bilingual effects on cognitive control have failed to replicate consistently. Several authors have now reported null effects in all age groups (Antón et al., 2014; Duñabeitia et al., 2014; Kousaie & Phillips, 2012; Morton & Harper, 2007; Paap & Greenberg, 2013), and confounding variables other than bilingualism have been suggested as alternative explanations for between-group differences in studies claiming a bilingual advantage. So, following the research tradition started by Peal and Lambert, history has repeated itself, and the much more recent bilingual cognitive control studies also resulted in disagreement, without reference to the much earlier bilingual intelligence debate.

As both research lines evolved into a debate about confounding variables, we propose that the only way to answer the question about the cognitive effects of bilingualism properly is to conduct a longitudinal field study. The only previous study to do this reported higher intelligence scores in bilinguals (Hakuta & Diaz, 1985), but the bilinguals here were Hispanics with Spanish as their first language (L1), living in a second language (L2) dominant (English) environment (New Haven, U.S.). We wanted to start from two monolingual groups, speaking the same L1, matched for intelligence as well as cognitive control at baseline, and for which bilingualism became an additional factor over time. Therefore, we followed a group of 54 monolingual French-speaking five-year-olds in two types of kindergarten schools; for the last kindergarten year, half of children were about to enrol in a traditional monolingual and half in a bilingual programme. Because it was impossible, and maybe even ethically unacceptable, to assign children randomly to educational programmes independently from the parents' preference, we opted to match children's cognitive profile and background at baseline between the two groups that resulted from the parent's choice. In this last kindergarten year there was no formal education; the bilingual option just implied that 50% of everyday classroom communication occurred in a new second language, Dutch. Our main focus was the development of intelligence, as this remains the most frequently investigated and valid concept of cognitive ability. Given the evolution in the literature towards the more specific concept of cognitive control, we also included such a measure, even though these paradigms are primarily developed to study functional processes, and are not designed as equally reliable and normed measures of individual cognitive ability differences (Miyake & Friedman, 2012).

We employed Raven's Coloured Matrices (Raven, Court, & Raven, 1998), a test of analytic reasoning, generally accepted as a good measure of fluid intelligence (Daley, Whaley, Sigman, Espinosa, & Neumann, 2003; Mani, Mullainathan, Shafir, & Zhao, 2013). Importantly, because this is a non-verbal test, it allows the assessment of general cognitive effects of bilingualism, independent of linguistic development, which may be influenced (either for the better or the worse) by becoming a bilingual. As a measure of cognitive control, we implemented the Simon task (Simon & Rudell, 1967), commonly used in the psycholinguistic literature discussed above. This is a spatial incompatibility task requiring rapid responses, sometimes contrary to initial impulses. At baseline, before the start of the last kindergarten year, both groups were matched for these measures. They were tested again one school year later to see whether attending bilingual kindergarten, and hence becoming a bilingual, had influenced development.

MATERIALS AND METHODS

PARTICIPANTS

At the beginning of the school year (September 2012 - T0), we started monitoring 54 preschool children who had only attended French-speaking kindergarten, and who spoke no other language at home. Initially, 64 participants were considered for participation from schools offering either monolingual ($N = 29$) and bilingual ($N = 35$) school programmes. However, controlling for intelligence, socioeconomic status (SES), verbal fluency, and cognitive control left us to exclude 10 children with deviant (low or high) scores on any of these pre-matching variables (which could confound the effect of interest), so that the largest-possible ($N = 54$) subset of 2 equally-large groups remained, for which independent samples t-tests between groups yielded $p > .30$ for all matching variables. Hence, we selected two groups of maximally comparable pupils at T0; 27 children that would enrol in a bilingual final kindergarten year, with Dutch as a second language (L2), and 27 in a traditional monolingual (L1) French programme. Only these children were then followed for a year.

Participants were recruited from six different schools in the same region of the Walloon Community, Belgium. Kindergarten schools do not yet have final attainment levels or formal education, but they do have ‘developmental goals with regard to skills and social competences, which every school should pursue’ (Portal Belgian Government, 2012). We contacted the schools before the children started their final (third) kindergarten year. For the bilingual schools, this is the year when pupils first come in contact with the second language (Dutch). The two prior years are the same as in monolingual schools. We obtained consent from parents through an information letter distributed by the schools. From the three monolingual schools, we recruited, 5, 6, and 11 participants; from the two bilingual schools, 8 and 10 participants. One school offered both traditional and bilingual education. Here, there were 5 monolingual and 9 bilingual participants. Both the school and parents were blind to the actual purpose of the study. Instead, the aim was kept very vague in all communication, stating our intention was to record children's development. This way, we were able to inform parents and schools about our test battery without revealing that afterwards, a comparison between monolingual and bilingual school programmes was about to take place.

Consenting parents completed a questionnaire assessing the child's and parents' linguistic background and SES. They confirmed their child did not have learning disorders or language development, comprehension or sight problems. SES was a composite score of the parents' educational (elementary, lower secondary, higher secondary, or higher education) and occupational levels, based on the PISA classification (OECD, 2014), which is Europe's most developed and comprehensive educational monitor. All parents were monolinguals and none of the children had any exposure to other languages prior to the study. Our two groups were matched for intelligence, SES, verbal fluency, and cognitive control, and also did not differ on age (months) or male/female ratio.

DESIGN AND PROCEDURE

All tasks were administered two times for all 54 participants, once at the beginning (T0) and once at the end of the school year (T1). An entire session usually lasted no longer than 30 minutes per child and entailed a verbal fluency task, Raven's Coloured Matrices, and a Simon task. Initially the test battery also consisted of an Attention Network Test (ANT, Rueda et al., 2004), but this task appeared to be too difficult and was discarded for analyses below. At baseline, 25% of the children performed around chance level (<55% accuracy) and 45% performed below levels that are generally considered to be acceptable accuracy in this task (75%)[3]. Testing took place in one of the empty classrooms of the children's respective schools. All participants received a present for participation.

Semantic Verbal Fluency. This was applied as a measure of L1 proficiency. Participants were given 60 seconds twice to verbally produce as many word exemplars as possible, within the categories ANIMALS and THINGS YOU CAN EAT OR DRINK. The order in which the categories were administered was counterbalanced across participants.

Raven's Coloured Progressive Matrices. Raven's Matrices is a non-verbal test of analytic reasoning, generally accepted as a good measure of fluid intelligence. The coloured version is designed for children aged five to eleven (Raven, Court, & Raven, 1998). The test consists of 36 items over 3 sets (A, Ab, B). Within each set, coloured items are ordered in terms of increasing difficulty. All items have a missing segment with six possible options for completion. Participants were asked to indicate which of the six pieces would fit the drawing best. Percentile scores were used for analyses and calculated from the raw scores, following the Raven's instruction manual (Raven, Raven, & Court, 1998). The manual offers a chart with normative scores for children from the ages of 48 to 120 months, for every six months. Extrapolations for ages in between were done according to the equations provided by the manual (Table 1). A percentile score of 50 is equivalent to an IQ of 100, the population average.

Simon task. This task was adapted from Simon and Rudell (1967). Coloured dots appeared either on the left or right side of the screen. The children were asked to press the left (right) key on the keyboard when a green dot

[3]We still analysed the evolution of ANT performance between T0 and T1. Similar to the Simon task, no Group effect or Time*Group interaction was obtained (RT: $F_{1,52} = 2.595$, $p = .114$, ACC: $F_{1,52} = .761$, $p = .387$). ICC analysis determined RT reliability (ICC(C,k) = 0.280, $F_{1,52} = 1.39$, $p = .243$, 95% CI = [-2.82, 0.99]).

appeared, and the right (left) key when the red dot appeared as quickly and as accurately as possible. The response keys were marked with red and green stickers. Response mapping was counterbalanced across participants according to parity of participant number. Each trial began with a fixation of 800 ms, then the coloured dot appeared until the participant's response or up until 5000 ms. There was a 500 ms blank interval before the next fixation period. The task consisted of 10 randomised practice trials and four blocks of 25 randomised Expal trials. Half of all trials presented the coloured dot on the same side of the associated response key (congruent trials) and half on the opposite side (incongruent trials). Participants could take a break between Expal blocks. They viewed the screen from a distance of approximately 60 cm. Stimuli were presented via Tscope software (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006) on an IBM-compatible laptop with 15-inch screen, running XP.

RESULTS

Analyses revealed that at baseline, the two groups did not differ for age, gender, SES, or verbal fluency (tests and results reported in Table 1), which confirmed their similar background. Crucially, they performed equally on Raven's intelligence test (t_{52} = -.032, p = .975) (age-controlled percentiles). Cognitive control tasks were analysed by mean RTs and accuracy scores. Outlier RTs were trimmed for individual participants by calculating the mean across all trials and excluding any response deviating by more than 2.5 SD of the mean. This procedure eliminated 3.58% of all Simon data. At baseline, groups did not differ for overall performance on the Simon task (RT: t_{52} = .591, p = .407, ACC: t_{52} = -.118, p = .907).

Table 1. Demographic data and verbal fluency scores by group (SD).

	Monolinguals	Bilinguals	Test	*p*
N	27	27		
Male/female ratio	15/12	13/14	$Chi^2(2) = 0.30$	.586
Age (months)	63.6 (4.2)	62.5 (3.8)	$t_{52} = 1.20$	.235
SES	3.1 (0.5)	3.3 (0.6)	$t_{52} = -0.90$	.375
Verbal Fluency at T0 (words)	16.9 (4.2)	15.6 (4.8)	$t_{52} = 1.00$	.320
Verbal Fluency at T1 (words)	20.6 (5.7)	20.3 (4.6)	$t_{52} = 0.49$	.627

Verbal fluency. To compare performance of the two groups over time, repeated measures analyses of variance were performed with 'Time' as within-subject factor and 'Group' as between-subject factor. Results revealed that both groups produced significantly more words at T1 than at baseline ($F_{1,52} = 33.55$, $p < .001$, $\eta p^2 = .392$), after a year of kindergarten (and ageing), but there was no effect of Group ($F_{1,52} = .699$, $p = .407$, $\eta p^2 = .013$) and no Time*Group interaction ($F_{1,52} = .149$, $p = .701$, $\eta p^2 = .003$). This shows that both groups improved similarly on verbal fluency.

Raven's Coloured Progressive Matrices. Analyses did not yield an overall effect of Group ($F_{1,52} = 1.93$, $p = .171$, $\eta p^2 = .036$), but did reveal a significant effect of Time ($F_{1,52} = 29.07$, $p < .001$, $\eta p^2 = .359$) on age-controlled Raven intelligence scores, qualified by the crucial significant Time*Group interaction ($F_{1,52} = 7.69$, $p = .008$, $\eta p^2 = .129$). Intelligence of bilingual school children (T0 = 50.61; T1 = 76.04) improved significantly more than that of monolinguals (T0 = 50.39; T1 = 58.54). Planned comparisons showed that the monolingual children did not improve significantly ($F_{1,52} = 3.43$, $p = .070$), whereas the bilingual children did ($F_{1,52} = 33.34$, $p < .001$) (Figure 1).

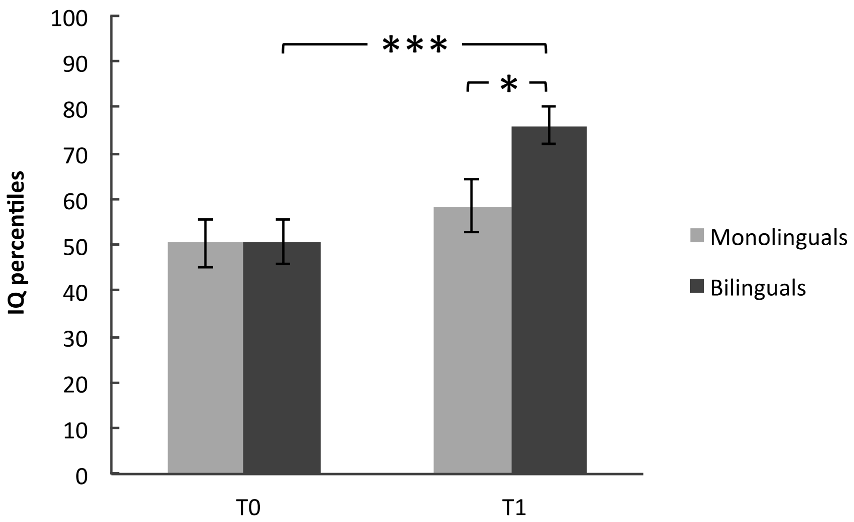

Figure 1. IQ percentiles for monolinguals and bilinguals at T0 and T1, derived from Raven's coloured matrices. Error bars reflect ± 1 SEM. All group and planned comparisons were performed, but only significant comparisons are indicated by horizontal bars. $*p < .05$, $**p < .01$, $***p < .001$

Simon task. For the Simon task, Congruency was added as a within-subject (task) factor. RT analyses showed main effects of Time ($F_{1,52}$ = 35.67, p < .001, ηp^2 = .407) and Congruency ($F_{1,52}$ = 101.99, p < .001, ηp^2 = .662), showing that both groups improved over time and reacted faster to congruent trials, which validates the paradigm. There was, however, no effect of Group ($F_{1,52}$ = 1.17, p = .284, ηp^2 = .022) and no significant Time*Congruency interaction ($F_{1,52}$ = 2.53, p = .139, ηp^2 = .042). Neither were there any interaction effects with Group (for all interaction effects p > .591). Accuracy analyses yielded a main effect of Time ($F_{1,52}$ = 9.56, p = .003, ηp^2 = .155) and Congruency ($F_{1,52}$ = 35.18, p < .001,ηp^2 = .404), showing that both groups actually became a little less accurate over time, probably due to the fact they reacted much faster. There was no main effect Group ($F_{1,52}$ = .095, p = .760, ηp^2 = .002) and no Time*Congruency interaction ($F_{1,52}$ = 1.36, p = .249, ηp^2 = .025). Interaction effects with Group were also not found (for all interaction effects p > .387) (Figure 2). Intraclass correlation analyses determined the reliability of RTs (ICC(C,k) = 0.651, $F_{1,52}$ = 2.86, p = .096, 95% CI = [-0.85, 0.99]).

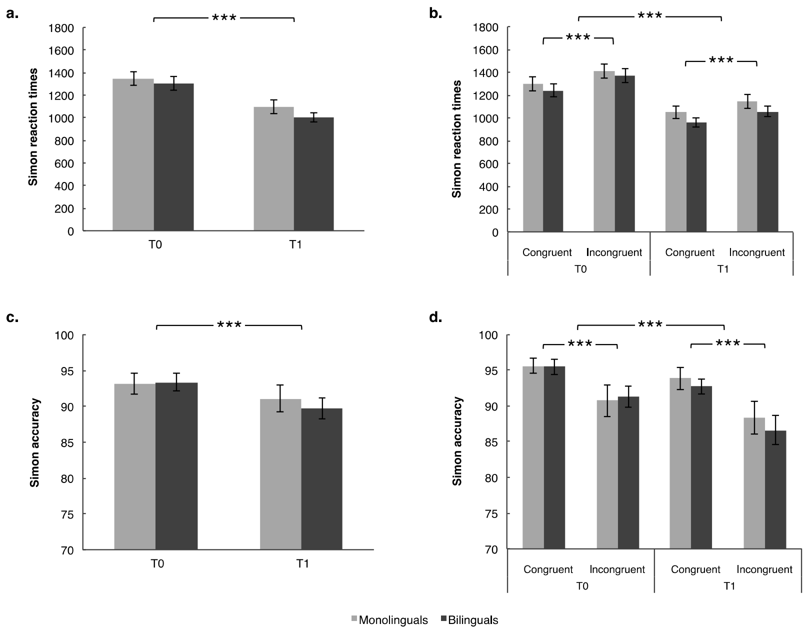

Figure 2. Reaction time and accuracy performance on the Simon task for monolinguals and bilinguals at T0 and T1. Overall reaction time performance. (a.) Reaction time performance broken for congruency. (b.) Overall accuracy performance. (c.) Accuracy performance broken for congruency. (d.) Error bars reflect ± 1 SEM. All planned comparisons and interaction analyses were performed, but only significant ones are indicated by horizontal bars. Top horizontal bars represent interactions. *$p < .05$, **$p < .01$, ***$p < .001$

DISCUSSION

For almost a century, research has tried to determine the effects of bilingualism on general cognitive development. The earlier studies focused on the broad concept of intelligence, and ended in disagreement following an evolution from a negative to a positive view on bilingualism. Recent literature on the more specific concept of cognitive control has also yielded inconsistent results, and showed the opposite evolution from positive effects to null results. For all of these studies however, bilingual effects were assessed by cross-group comparisons, which leaves room for confounding variables.

This is the first longitudinal study assessing the domain-general cognitive effect of becoming a bilingual WITHIN participants, starting from two groups of young monolingual children who did not have any previous exposure to another language. Firstly, we established that L2 learning does not reduce L1 fluency, although subtler effects on production may exist (e.g. Gollan, Montoya, & Werner, 2002) for which the task that was currently administered as a matching variable is not well-suited. Secondly, this study demonstrated a bilingual advantage for non-verbal intelligence, a measure on which our groups were initially matched. After one year of schooling, we observed gains in age-controlled intelligence scores of 17 percentile points for children attending bilingual kindergarten, whereas monolingual children only improved numerically. Although the cognitive control advantage was absent in this study, we believe the observed intellectual advantage has the same origins, as the two are concepts strongly correlated (e.g. Dempster, 1991). The absence of a bilingual effect on cognitive control here may be due to the low reliability of RTs and accuracy in control tasks as measures of individual cognitive ability differences (see also Miyake & Friedman, 2012; Paap & Greenberg, 2013). The intelligence test did not have this problem, as it has been standardised.

Another possible explanation is that the advantage specific to cognitive control only emerges after particular bilingual experience. For instance, several studies have recently reported that enhanced control may depend on language switching practice (Prior & Gollan, 2011; Soveri, Rodriguez-Fornell, & Laine, 2011; Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2015). To illustrate, Verreyt et al. found an inhibitory control advantage among young adults for balanced bilinguals who frequently switched between languages, but not for those who switched infrequently. Then, it is not surprising that the children in the current study did not display a cognitive control advantage, as they only had very little language switching practice (they only spoke their L2 at school, not intermixed with L1).

This study assessed bilingual cognitive advantages longitudinally, monitoring cognitive development within participants. As such, this is perhaps the most convincing demonstration of a bilingual advantage, and a considerable extension of the literature that compares cognitive control measures across groups, often not even taking intelligence measurements into account (e.g. Poarch & van Hell, 2012). We must however acknowledge that children were not randomly assigned by the authors to one of the kindergarten conditions. Such a study might never occur, as random educational assignment is unlikely to be acceptable for parents after full disclosure of the study's aim, and perhaps not even ethically acceptable. Parents made the choice for the third kindergarten year two years prior to our study, when their child initiated kindergarten. Nevertheless, our groups were perfectly matched at T0 (all *p*s > .30) on all relevant variables (verbal fluency, cognitive control, intelligence) after already having completed two years in their respective schools. It therefore seems very unlikely that any difference between parents would specifically benefit cognitive development in the third kindergarten year. Furthermore, the children were matched for parents' SES, using the method of the *Programme for International Student Assessment* (PISA) to avoid a bias in children's backgrounds. SES matching is common (also accepted in sociological work focusing specifically on nurture effects) and often the only practical way to control children's background. In this respect, it is important to note that we also did *not* observe a bilingual (dis)advantage for verbal fluency or cognitive control, which suggest otherwise similar cognitive development.

To conclude, we have obtained evidence that the mental exercise and processes that are associated with becoming bilingual may have positive, long-term effects on general cognitive abilities, even outside the linguistic domain. These findings are extremely relevant for policy makers in education.

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CHAPTER 3
THE INFLUENCE OF LANGUAGE SWITCHING EXPERIENCE ON THE BILINGUAL EXECUTIVE CONTROL ADVANTAGE[1,2]

In an ongoing debate, bilingual research currently discusses whether bilingualism enhances non-linguistic executive control. The goal of this study was to investigate the influence of language switching experience, rather than language proficiency, on this bilingual executive control advantage. We compared the performance of unbalanced bilinguals, balanced non-switching, and balanced switching bilinguals on two executive control tasks, i.e. a flanker and a Simon task. We found that the balanced switching bilinguals outperformed both other groups in terms of executive control performance, whereas the unbalanced and balanced non-switching bilinguals did not differ. These findings indicate that language switching experience, rather than high second-language proficiency, is the key determinant of the bilingual advantage in cognitive control processes related to interference resolution.

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[1]Verreyt, N., Woumans, E., Vandelanotte, D., Szmalec, A., & Duyck, W. (in press2015) The influence of language switching experience on the bilingual executive control advantage. *Bilingualism: Language and Cognition*. doi: 10.1017/S1366728914000352

[2]This article is based on Chapter 2 from the doctoral dissertation 'The underlying mechanism of selective and differential recovery in bilingual aphasia' by Nele Verreyt.

INTRODUCTION

About 50% of the world population is considered to be bilingual (Grosjean, 1989). Besides the obvious communicative advantage, several associated and even non-linguistic cognitive benefits of bilingualism have recently been explored. One well-replicated advantage is the finding that bilinguals show improved performance on a broad range of executive control tasks. Here, EXECUTIVE CONTROL refers to a range of high-level control functions that support goal-directed behaviour. Three main control functions can be identified: inhibition, updating and shifting (Miyake et al., 2000). In what follows, we will summarise earlier evidence pointing towards bilingual advantages for tasks assessing inhibition and shifting functions.

There are several reports that bilinguals outperform monolinguals on a range of tasks tapping into inhibition. Bialystok, Craik, and Luk (2008), for example, observed that bilinguals outperform monolinguals on a Stroop task, an interference inhibition task in which participants have to name the ink colour of colour words (e.g. the word GREEN printed in red), while suppressing the natural tendency to read the colour word. Another measure of interference inhibition is the Eriksen flanker task (Eriksen & Eriksen, 1974). This task requires participants to react to the direction of the central of five arrows (<<><<), while trying to ignore the direction of the four flanking arrows. Bilinguals outperform monolinguals on this task as well (Costa, Hernandez, & Sebastian-Gallès, 2008). The positive effect of bilingualism on inhibitory control tasks also seems apparent throughout a person's entire life. It has been found that bilingual children already show enhanced performance compared to their monolingual peers on tasks tapping into inhibition (Carlson & Meltzoff, 2008). In addition, the advantage remains consistent in bilingual elderly (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok et al., 2008; Weissberger, Wierenga, Bondi, & Gollan, 2012).

These findings are compatible with a highly influential cognitive account of bilingualism and bilingual language control, the Inhibitory Control Model (Green, 1998). This model assumes that bilinguals experience a continuous competition (conflict/interference) between lexical representations of both languages, which are indeed always active to a certain degree in speaking (Hermans, Bongaerts, De Bot, & Schreuder, 1999), reading (Van Assche, Duyck, Hartsuiker, & Diependaele, 2009) and listening (Lagrou, Hartsuiker, & Duyck, 2011). To resolve this competition, control resources are recruited to inhibit the conflicting activation of the non-target language. Importantly, these inhibitory mechanisms seem to be domain-general[3], so that experience in managing competition between linguistic representations also transfers to non-linguistic tasks (Bialystok et al., 2005; Bialystok, Craik, & Ryan, 2006; Colzato et al., 2008; Costa et al., 2008; Martin-Rhee & Bialystok, 2008). The central role for inhibition also becomes clear from a study by Emmorey, Luk, Pyers, and Bialystok (2009), who reported the performance of bilinguals who know two spoken languages (unimodal bilinguals) and of bilinguals who know both a spoken and a sign language (bimodal bilinguals) in such a flanker paradigm. The clever manipulation here implies that only the unimodal bilinguals have to inhibit representations in the non-target language to be able to achieve lexical selection for production in the target language. Inhibition is not necessarily required in bimodal bilinguals, because they can both execute the sign and produce the word, even simultaneously if needed. And, indeed, only unimodal bilinguals showed an advantage in the flanker task, suggesting that resolving interlingual

[3]Whether the EC processes put at play by bilingual language control are fully subsidiary of domain-general EC processes is still a matter of debate. Some studies did not find any correlation between linguistic and non-linguistic tasks (Bialystok, Craik, & Luk, 2008; Calabria, Hernandez, Branzi, & Costa, 2012). However, this issue goes beyond the objective of the present article.

competition through inhibition is important for the executive control advantage.

Interestingly, the bilingual advantage on tasks tapping into inhibition is not only measurable on trials that involve competition between relevant and irrelevant information (like incongruent trials or switch trials) but also on trials that require a simple choice reaction without any cognitive conflict (like congruent trials or non-switch trials) (Costa et al., 2008). This finding suggests that the cognitive benefits of bilingualism are not restricted to one specific executive control function, but may be extended to the entire, domain-general executive control system. Indeed, besides inhibitory control, bilinguals also show an advantage on tasks tapping into shifting, i.e. showing smaller shift costs compared to monolinguals (Bialystok & Viswanathan, 2009; Garbin et al., 2010; Prior & Gollan, 2011; Prior & MacWhinney, 2010). Prior and MacWhinney (2010) also found reduced shift costs in the bilingual compared to the monolingual group.

Based on the findings that (a) the bilingual advantage does not only appear in conflict trials, but also in non-conflict trials, and that (b) bilinguals also show enhanced performance on other executive functioning tasks, which do not necessarily tap into inhibition, it was suggested that mastering two languages not only enhanced inhibitory control, but leads to improved executive control functions in general.

Importantly, the mere fact of knowing two languages does not always suffice for enhancing executive control functioning. Luk, De Sa, and Bialystok (2011) administered a flanker task in a group of monolinguals, late bilinguals and early bilinguals. Only the early bilinguals showed better performance on the control task; no difference was found between the late bilinguals and the monolinguals. So it seems that being bilingual per se does not suffice to enhance performance on executive control tasks.

Interestingly, the bilingual executive control advantage was also recently challenged by a large study of Paap and Greenberg (2013). They compared fairly large groups of monolinguals and bilinguals on a wide range of 15 executive control tasks. Although all of the tasks yielded the expected congruency or inhibition effects, none of these tasks yielded a bilingual advantage, except one task, which actually showed a bilingual disadvantage. In another recent study (Hernández, Martin, Barceló, & Costa, 2013), the bilingual advantage also failed to show on several measures of task switching, These null effects, combined with the observation that most of the reported bilingual advantage reports indeed come from very specific and a limited number of bilingual populations, suggests that the bilingual advantage does not emerge from bilingualism in itself, but instead that certain characteristics of language use may be crucial for development of the control advantage. Currently however, it is unclear what these language use/learning factors are.

In the current paper, we aim to further clarify one bilingual parameter that may be crucial for development of the bilingual control advantage. More specifically, we further investigated the role of language switching in daily life. Indirectly, it was already suggested in the paper of Emmorey and colleagues (2009) that the amount of (language) switching might underlie the bilingual executive control advantage. They hypothesised that the difference in control performance between unimodal and bimodal bilinguals could be due to the fact that unimodal bilinguals have to switch languages in their communication, whereas bimodal bilinguals prefer to produce both the sign and the word (i.e. blend), therefore rarely switching between languages.

In addition, Prior and Gollan (2011) compared the performance of a group of bilinguals who regularly switch between languages with the performance of a group of bilinguals who switch between languages less often. They only found an advantage on non-linguistic task shifting in the bilinguals who often switch languages. Discussing Prior and Gollan (2011), Paap and Greenberg (2013) cite switching as a factor but dismiss it as a crucial determinant, because "… *our bilinguals overwhelmingly report that they use both languages every day and switch every day… our bilinguals switch as often, if not more often, than Prior and Gollan…*". It is true that the bilinguals of Paap and Greenberg probably use their two languages every day (they did not actually assess language switching explicitly), and therefore once in a while must experience a language switch. This is very different however, from the amount of language switching that the Spanish-English bilinguals in San Diego do. In southern California, Hispanics use Spanish and English interchangeably, often multiple times within a sentence. The same occurs in Catalan-Spanish speech in the bilingual population tested by Costa and colleagues (2009; 2008). It is unclear whether this also applies to the San Francisco population of Paap and Greenberg (2013). Although their sample will certainly contain Hispanics similar to those of Prior and Gollan (numbers are not provided for each language pair), it is definitely more diverse, with 30 language pairs for 122 bilinguals, and for most of these languages, repeated language switching may not occur in everyday conversations. As such, we believe that the Paap and Greenberg (2013) study did not directly assess language switching and therefore it does not provide a definite answer of its importance as a determinant for the bilingual cognitive control advantage.

Finally, also Yim and Bialystok (2012) investigated the role of language switching on non-verbal and verbal task shifting performance in a group of Cantonese-English bilinguals. They only found a positive effect of language switching performance in an Expal language switching task, but no relationship between the degree of language switching and non-verbal task shifting was found, in contrast with Prior and Gollan (2011).

Above, we have summarised evidence suggesting that bilinguals develop more effective general control abilities because they must control the continuous interference between lexical representations associated with both languages, and we discussed what factor may contribute to this advantage. The primary aim of our study is to gain novel insight into the mechanisms that underlie the bilingual executive control advantage, by investigating the role of language switching experience. From a memory perspective, the interference between languages comprises competition between active lexical representations of those languages in long-term memory. As described in the memory literature (Oberauer, 2009), memory contents have the potential to cause interference when they are in an active state, but once the activation starts to decay, interference effects also rapidly disappear (Szmalec, Verbruggen, Vandierendonck, & Kemps, 2011). Therefore, we predict that the bilingual advantage originating from the competition between languages should primarily occur in bilinguals who show similarly strong activation in lexical representations of both languages at the same time, i.e. bilinguals who use both languages interchangeably within the same context (and even within the same sentence), and often switch languages. In contrast, equally proficient bilinguals who use different languages in different contexts and therefore do not switch that often, should suffer less from interference effects, so that the executive control system is less likely to develop a bilingual advantage.

It is the aim of this study to investigate whether high L2 proficiency suffices for developing the bilingual control advantage, or whether a high amount of language switching experience, implying frequent simultaneous high activation in representations from both languages, is necessary. In the present study, we will therefore investigate whether a group of (Brussels) balanced bilinguals that typically switch languages WITHIN DISCOURSES OR SENTENCES show different control than regular bilinguals that do not switch that often, within the same language pair. We will compare their performance with a group of qualitatively different, but also, balanced bilinguals, and with a group of unbalanced bilinguals. Prior and Gollan (2011) already showed that bilinguals who often switch languages are better task shifters. This finding is important in the current context, but it remains unclear whether experience with language switching also interacts with bilingual advantages in tasks that share less task demands, as was the case for Prior and Gollan, i.e. cognitive control tasks that imply inhibition instead of switching. Obviously, language switching experience is much more likely to transfer to non-verbal task shifting than to inhibition, and bilingual advantages across tasks that tap into different executive functions would suggest a more fundamental and general change to the cognitive system. Therefore, we will use two tasks that primarily measure inhibitory control, namely the flanker task and the Simon arrow task. The distinction between training tasks and training abilities is currently a major debate in the executive control literature. Some findings suggest that cognitive abilities can be trained. Jaeggi, Buschkuehl, Jonides, and Perrig (2008), for example, reported higher fluid intelligence in participants that were trained with an executive control demanding *n*-back task. Other researchers recognise several methodological concerns with such artificial training studies and claim that to this day, not one study has convincingly demonstrated that cognitive abilities can be trained, over and above (strategic) improvements in specific task demands (Shipstead, Redick, & Engle, 2010). In this view, showing that the amount of language switching by bilinguals produces an advantage for tasks with little overlap in task demands while measuring common cognitive (control) abilities, would make a strong case for this discussion in the control literature as well.

The second aim of this study concerns the dissociation of language switching experience from language pair characteristics. Prior and Gollan (2011) included Spanish-English bilinguals who regularly switch between languages and Mandarin-English bilinguals who switch less often. Only the Spanish-English bilinguals showed an advantage on task switching. It was assumed that only bilinguals who often language switch train their executive control capacities, causing better performance on executive control tasks. However, these two Expal groups do not only differ in their amount of switching between languages, but also in the amount of overlap between these languages. Because languages that share orthography (in this case: English and Spanish, both alphabetic languages) and language pairs with a distinct script (English and Mandarin) require different representational structures (Gollan, Forster, & Frost, 1997) and hence also control demands, it is plausible that the bilingual advantages arising from competition between these two language pairs also differ. Indeed, task shifting research has shown that shifting between overlapping cognitive tasks (e.g. by using bivalent stimuli) causes a much greater shift cost than shifting between tasks that share fewer task features (Rogers & Monsell, 1995). Therefore, the higher shift cost for the Mandarin-English group in the Prior and Gollan study does not necessarily reflect the fact that they switch less often between languages, but may be alternatively explained by the smaller lexical overlap, between Mandarin and English. Yim and Bialystok (2012), who investigated effects of language switching performance in an Expal language switching task within a single population of Cantonese-English bilinguals, observed no such effect on non-verbal task shifting.

In summary, our aim is twofold. We intend to further disentangle the role of language switching experience for an executive function like interference resolution, while also controlling for language pair dissimilarities, including only a single language pair (unlike Prior and Gollan, 2011).

We hypothesise that the general control advantage in bilingualism originates from very frequent switching between both languages, within similar contexts and within conversations. To test this hypothesis, we tested three qualitatively different groups of bilinguals: a group of unbalanced bilinguals, a group of balanced non-switching bilinguals, and a group of balanced bilinguals that do often switch languages. Importantly, the bilinguals in the three groups all master the same languages, Dutch (L1) and French (L2). We predict that the switching group will show a better performance on inhibitory control tasks compared to the unbalanced group and the non-switching group that also has high L2 proficiency. We aimed to test only one executive function (i.e. interference control), and therefore only included a flanker task and a Simon arrow task, two tasks that tap into that specific function.

METHOD

PARTICIPANTS

To be able to include these three different groups of bilinguals, we recruited participants in two different ways: (a) Psychology students of Ghent University, participating for credits, and (b) bilinguals that were recruited through an advertisement on the university website, and who were paid for their participation. All participants had Dutch as their L1, French as L2, and had a good knowledge of English (L3). They were all born in Belgium, highly educated, and differed in their L2 proficiency and the extent of switching. We included participants from three bilingual populations; unbalanced (UB), balanced switching (BSB), and balanced non-switching bilinguals (BnSB). The three groups all consisted of both paid and voluntary participants.

Demographic participant information is shown in Table 1. All groups were matched for age, sex, and general intelligence, based on the Raven Advanced Progressive Matrices. We employed a language questionnaire (see Appendix 1) to obtain self-reported language proficiency in Dutch and French, and to assess switching behaviour. Participants rated their proficiency for listening, speaking, reading, and writing on a seven point Likert scale for every language that they had acquired (1 = very badly, 7 = very well). These measures were then averaged to create a general proficiency level. They also stated how many days per week they spoke each language The UB lived in a Dutch-dominant environment and acquired French before the age of 11 at school. After the age of 18, they hardly came in contact with the French language again. All balanced bilinguals acquired the two languages before the age of six and were highly proficient in both. As mentioned, the balanced bilinguals were divided into switchers and non-switchers. This classification was based on the information retrieved from the language questionnaire. There, the bilinguals had to indicate how often they switched between languages on a scale ranging from 0 (= never) to 7 (= very often). Balanced bilinguals with a rating of 2 or lower were referred to the non-switch group (BnSB). Balanced bilinguals with a rating of 4 or higher were assigned to the switch (BSB) group (no participant rated him/herself 3). As expected, there were no unbalanced bilinguals that switched often. Consequently, the non-switch group (BnSB) were almost never confronted (*Mean* = 0.9, *SD* = 0.7) with contexts in which language switching took place, while the switch group (BSB) regularly switched between languages within sentences and conversations (*Mean* = 5.8, *SD* = 0.9).

Table 1. Self-reported data and scores on Raven's Matrices by group.

	Unbalanced bilinguals (UB)	Balanced non-switching bilinguals (BnSB)	Balanced switching bilinguals (BSB)
N	28	17	20
Male/female ratio	9/19	3/14	4/17
Age (years)	20.7 (1.7)	20.9 (3.4)	21.7 (6.1)
Raven's Matrices (score on 12)	11.0 (1.0)	10.8 (1.4)	10.8 (1.3)
Computer games (days/week)	2.3 (1.8)	1.9 (0.8)	2.0 (1.7)
Dutch (L1) (self-reported)[1]	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)
Age of acquisition	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Frequency of use (days/week)[2]	7 (0.0)	7 (0.0)	6.8 (0.5)
French (L2) (self-reported)[1]	2.7 (0.9)	5.2 (0.8)	6.3 (0.8)
Age of acquisition	10.2 (0.7)	1.2 (1.7)	0.9 (1.9)
Frequency of use (days/week)[2]	0.6 (0.6)	3.0 (2.0)	6.2 (1.7)
Frequency of switching[3]	0.5 (0.6)	0.9 (0.7)	5.8 (0.9)

[1]L1 and L2 proficiency were indicated on a 7-point Likert scale, ranging from 1 (= very bad) to 7 (= very good).
[2]Participants responded how many days per week they spoke Dutch and French.
[3]Frequency of switching was indicated on an 8-point-Likert scale, ranging from 0 (= never) to 7 (= very often).

MATERIALS

Flanker task. The stimuli were white arrows on a black background. One stimulus consisted of five arrows, participants indicated the direction of the central arrow by pressing the left or the right button. The arrows could all be pointing in the same direction (congruent trials, e.g. >>>>>) or the central arrow could be pointing in the other direction than the flankers (incongruent trials, e.g. >><>>). The proportion congruent/incongruent trials was 75%/25% (Costa et al., 2009).

Simon arrow task. The stimuli were single white arrows on a black background. The arrows could be pointing to the right or the left, and appeared on either the left or the right side of the screen. Trials in which the direction of the arrow corresponded with the side of appearance on the screen are labelled congruent trials; trials in which the direction and the side of appearance did not correspond are incongruent trials. The proportion congruent/incongruent trials was also 75%/25% (Costa et al., 2009).

PROCEDURE AND DESIGN

The informed consent form and language questionnaire were completed before starting the Exp. The procedure in both Exps was the following: (1) a fixation cross for 400 ms; (2) the Expal stimuli appeared until a response was given, or for maximum 1700 ms; (3) a blank screen for 1000 ms. There were 24 practice trials, followed by 3 blocks of 96 trials each. Afterwards, participants completed the Raven Advanced Progressive Matrices. We used a 2 (Congruency) x 3 (Block) x 3 (Group) design with Congruency and Block as within subjects variables and Group as a between subjects variable. The Exps were run on a standard colour monitor and were programmed and conducted using E-Prime. Reaction times were measured with a Cedrus serial USB response box.

RESULTS

DEMOGRAPHIC DATA

No significant differences were found across groups in male/female ratio, age, or intelligence (Raven) scores. Participants were asked to rate their proficiency, age of acquisition (AoA) and frequency of use of Dutch and French. There were no significant differences in general proficiency or AoA for Dutch. The UB and the BnSB used Dutch more frequently than the BSB. Significant differences between groups were found for French proficiency: the UB had significant lower L2 proficiency scores than the BnSB (t (43) = -8.97, p < .001) and the BSB (t (46) = -15.50, p < .001). Differences in general French proficiency were also found between the two balanced groups (t (35) = -4.52, p < .001), although L2 proficiency was also very high in the BnSB group. The French AoA of the UB differed significantly from the BnSB (t (19.548) = 20.68, p < .001) and from the BSB (t (22.827) = 20.36, p < .001). No differences in AoA were found between the two balanced groups (t (35) < 1). The three groups differed significantly in frequency of use of French, with UB showing a lower frequency of use than the BnSB (t (17,904) = -4.71, p < .001) and the BSB (t (46) = -18.77, p < .001). In addition, a difference in frequency of use was found between the two balanced groups as well (t (35) = -5.90, p < .001). The BSB differed significantly from the BnSB (t (34.77) = -18.78, p < .001) and the UB (t (46) = -25.15, p < .001) in switching frequency.

EXPERIMENTS

RTs that deviated more than 2.5 SD from the participant's mean in that task were removed (0.02% of the total amount of trials). The error rate was 0.05%. Incorrect trials were excluded from the analyses. For both experiments we conducted an analysis of variance (ANCOVA) on RTs with Group as a categorical, between-subjects factor, and Congruency as within-subjects factor. Because of the difference between the groups concerning

French proficiency and Frequency of use of French (L2), we included these variables as covariates[4]. The dependent variable was the mean RT on correct trials and accuracy. In case of a significant difference across groups, we ran planned comparisons to investigate which group differed from the others. Furthermore, we calculated partial correlations, controlling for L2 proficiency, between the measure of switch frequency and reaction time performance on flanker and Simon tasks, across all bilingual groups.

Flanker task. A significant main effect of Group (F (2,61) = 5.23, p = .008, MSE = 16746) and a marginally significant effect of Congruency (F (1,61) = 3.42, p = .069, MSE = 4318) on mean RTs was found (see Figure 1). The effect of the covariate French Proficiency was not significant (F (1,60) < 1), nor was the interaction (F (1,60) < 1). The effect of French Frequency of use did also not reach significance (F (1,60) < 1.20, p = .277). Planned comparisons show no significant differences in mean RTs between UB and BnSB (t (43) = 0.65, p = .517). The BSB were faster than the BnSB (t (35) = 4.22, p < .001) and than the UB (t (46) = 3.24, p = .002). Analysing the data with the flanker effect as dependent variable, we found no significant interaction between Group and Congruency (F (2,61) = 2.42, p = .097, MSE = 4318) (see Figure 2). However, to further elaborate this interaction, we ran planned comparisons showing a significant difference between the UB and BSB (t (32,266) = 2.38, p = .023) and between the BnSB and BSB (t (35) = 4.39, p < .001). The UB and the BnSB did not differ significantly (t (43) < 1).

[4]Since frequency of language switching cannot be considered as a continuous variable, we could not include it as a covariate in the analysis.

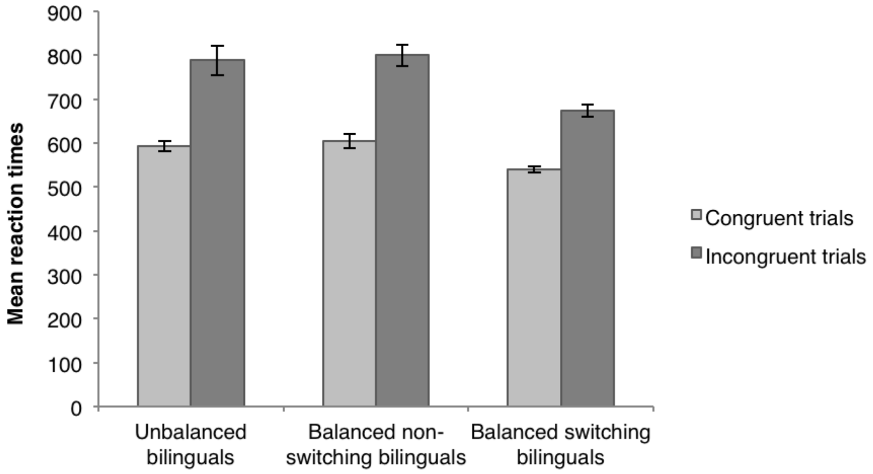

Figure 1. Reaction times by congruency (congruent vs. incongruent) in the flanker task. Bars represent standard errors.

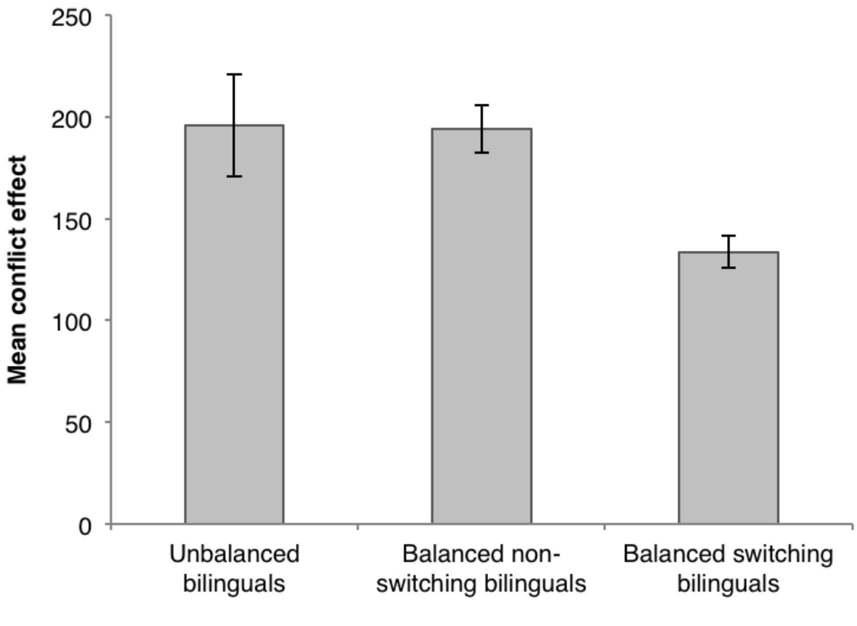

Figure 2. Size of the congruency effect in the flanker task by groups. Bars represent standard errors.

Concerning the error rates, we only found a main effect of Congruency (F (1,62) = 65.55, p < .001, MSE = 0.83), validating the task. No other effects reached significance (F < 1).

Simon arrow task. The ANCOVA on RTs revealed a significant main effect of Group (F (2,61) = 4.29, p = .018, MSE = 6751), and Congruency (F (1,61) = 4.10, p = .047, MSE = 721) (see Figure 3). The effect of the covariate French Proficiency was again not significant (F (1,60) < 1), nor was the effect of French Frequency of use (F (1,60) < 1). Planned comparisons show no significant differences in RTs between the UB and BnSB (t (43) < 1 for congruent trials and t (43) = -1.60, p = .117 for incongruent trials), nor between the UB and BSB for congruent trials (t (46) = 1.46, p =.150). For incongruent trials, we found a marginally significant difference (t (46) = 2.00, p = .051). The BnSB differed significantly from BSB (t (35) = 2.05, p = .047 for congruent trials and t (35) = 3.33, p = .002 for incongruent trials). Analysing the data with the Simon effect as dependent variable showed a significant interaction between Group and Congruency (F (2,61) = 6.68, p = .002, MSE = 721) (Figure 4). Planned comparisons show a significant difference between the BSB and BnSB (t (35) = 3.21, p = .003). The UB did not differ significantly from the BnSB (t (43) = -1.84, p = .073), nor from the BSB (t (46) = 1.54, p = .131)[5]. French Proficiency did only marginally significantly interact with congruency (p = .077), implying that the slightly higher L2 proficiency of BSB cannot account for the bilingual advantage.

[5]The fact that the difference between BnSB and BSB was significant, whereas the difference between the UB and the BSB was not, confirms that switching experience matters more than plain L2 proficiency. This confirms the correlations analyses in Table 2, controlling for L2 proficiency.

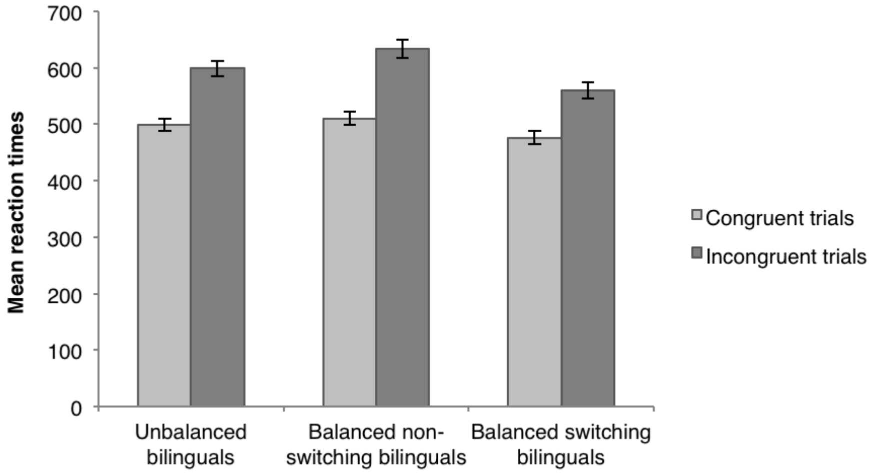

Figure 3. Reaction times by congruency (congruent vs. incongruent) in the Simon Arrow task. Bars represent standard errors.

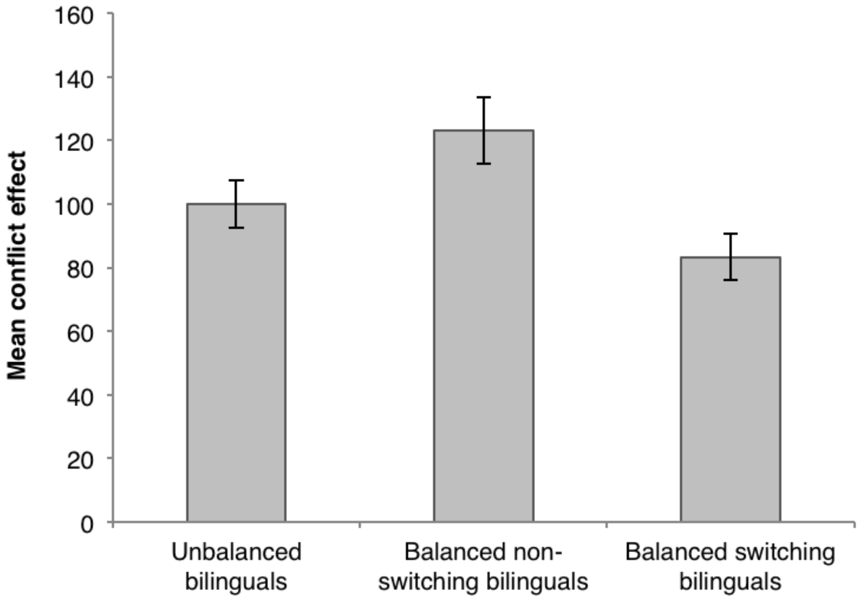

Figure 4. Size of the congruency effect in the Simon Arrow task by group. Bars represent standard errors.

Partial correlations. Partial correlation analyses (see Table 2), across groups and controlling for L2 proficiency, showed that frequency of language switching was significantly correlated with the size of the congruency effects and overall RTs on incongruent trials, for both Simon and flanker tasks. For the flanker task, the correlation for congruent trials was also significant.

Table 2. Partial correlations, controlling for L2 proficiency, between switch frequency and measures of executive control (flanker and Simon tasks) across the three groups. ** = $p < .01$, * = $p < .05$.[1]

	Flanker			**Simon**		
	Congruent	Incongruent	Effect	Congruent	Incongruent	Effect
Switch frequency	- .388**	- .344**	- .258*	- .187	- .354**	- .388**

[1]Non-parametric Spearman correlations between switching frequency and executive control yield the same pattern of significant correlations.

DISCUSSION

The aim of this study was twofold. Firstly, we wanted to investigate the influence of language switching experience in bilinguals on a manifestation of executive control other than task switching. We therefore employed tasks tapping into interference control. Secondly, for the first time, this issue was studied by investigating language switching experience effects within a single language pair, hereby controlling for possible confounds due to language pair dissimilarities (cf. Prior & Gollan, 2011). We conducted a flanker task and a Simon arrow task, and compared the performance of unbalanced Dutch-French bilinguals, balanced bilinguals who often switch between languages in their daily lives, and bilinguals who do not often switch between languages.

The results of both tasks point largely in the same direction; balanced bilingual participants that often switch (BSB) between languages show smaller congruency effects than balanced bilinguals who do not often switch between languages (BnSB)[4] , even though these bilinguals also had very high L2 proficiency. Moreover, our measure of switch frequency was strongly correlated with performance on both flanker and Simon tasks, across groups and even after controlling for L2 proficiency. This suggests that an executive control advantage is only present when the lexical representations of both languages are often simultaneously active and used or inhibited during frequent language switching, e.g. in bilinguals who switch languages within conversations. The frequent simultaneous activation between strong lexical representations of different languages causes competition and necessitates the bilinguals to engage their executive control

[4]In the flanker task, the BSB also showed smaller congruency effects compared to the UB, which was not the case for the Simon arrow task.

mechanism to select representations in the target language, and inhibit the non-target language. This practice then transfers not only to task switching (cf. Prior & Gollan, 2011), but also to interference resolution. It is our belief that demonstrating an effect of bilingual language switching on such measure is a stronger demonstration of the fact that the bilingual advantage is a domain-general phenomenon. Demonstrating that more frequent language switchers are also better task switchers is interesting, but less surprising, and more vulnerable to circularity considerations.

Additionally, we found that language switching was correlated with performance on both congruent and incongruent trials in the two tasks. Our results therefore seem to support the suggestion of Costa et al. (2009) that bilingual advantages may not only relate to conflict resolution (Bialystok et al., 2006), but generalise to overall performance (Bialystok et al., 2004; Costa et al. 2008). Costa and colleagues reasoned that the bilingual's more efficient monitoring system was at the basis of this, as bilinguals need to continuously monitor the appropriate language for each communicative interaction, depending on the interlocutor(s). Bilinguals who often find themselves in situations in which switching takes place frequently might have an even greater need to monitor the situation. This may explain why the frequent switchers in our study performed better on the two conflict tasks, not just regarding the congruency effect, but also for overall measures.

Our findings supplement the work of Prior and Gollan (2011), who showed that language and (non-verbal) task shifting was only better in bilinguals who regularly switch between languages. However, because Prior and Gollan compared switching English-Spanish bilinguals with non-switching English-Mandarin bilinguals, it was yet unclear whether the difference between these groups reflected switching experience or rather different language pair similarity. The present study clearly shows that the bilingual advantage emerges from language switching experience as groups with the same single language pair were compared. Nevertheless, given that Dutch and French are typographically similar, we do not know whether this switching effect would also generalise to a pair of typographically dissimilar languages. Yim and Biaystok (2012), for example, did not find a relation between language switching and non-verbal task shifting in Cantonese-English bilinguals. However, they did not investigate a specific group of language switching bilinguals, but instead analysed effects of a continuous measure of language switching performance in an experimental language switching task.

The present findings may contribute to an explanation why findings about the bilingual executive control advantage are rather inconsistent. Whereas relatively consistent bilingual advantages have been found by Bialystok and colleagues in Canada (e.g. Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, 2006; Bialystok & Feng, 2009) and Costa and colleagues in bilingual Barcelona (e.g. Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009; Costa, Hernandez, & Sebastian-Gallès, 2008), a recent study by Paap and Greenberg (2013) failed to find such evidence in any of 15 executive control tasks, testing 122 bilinguals from 30 different language pairs in San Francisco. The present study suggests that active and frequent language switching may the crucial determinant for the development of the bilingual executive control advantage. Although Paap and Greenberg claim that their bilinguals switch languages daily, it is unclear whether this implies just switching languages between contexts (e.g. speaking English at university and Russian at home), or instead active and very frequent language switching within conversations, as is the case for Catalan-Spanish bilinguals[5] , or for the BSB bilinguals in Brussels from this study. Given that the large (30) number of language combinations are unlikely to be used simultaneously in San Francisco, we suspect that their bilingual population is most comparable to the BnSB from this study, which also did not show a

[5]We may speculate that the Catalan-Spanish bilinguals tested by Costa and colleagues also often switch languages, similar to the bilinguals in the present study. However, there is no quantitative data directly comparing these different bilinguals across studies.

bilingual advantage. Furthermore, it should be noted that it may also be type of switching and not simply switching frequency that plays a role in bilingual cognitive control. It seems that different types of language switching require different types of cognitive control processes (Green & Wei, 2014). This has also been suggested by Green and Abutalebi (2013) in their adaptive control hypothesis, which states that the interactional context (e.g. switching languages with different speakers vs. switching within a conversation) is important for the bilingual adaptation of cognitive control processes and to tune the networks of control.

An inevitable characteristic of this study is the lack of data about monolinguals. This is a more practical issue, given that everyone in Belgium has at least knowledge of two languages. The positive consequence of this language context is that we were able to compare different groups of bilinguals from the same language pair (Prior & Gollan, 2011). We cannot, however, exclude that the unbalanced and balanced non-switching bilinguals in this study still show better performance than monolinguals. Nevertheless, note that also no differences were found between the monolinguals and the non-switching bilinguals in the Prior and Gollan study (2011).

As future studies are concerned, we argue that it is advisable to include an objective measure of proficiency, such as a picture naming test in both languages, to objectify the language proficiency. In addition, because this is only the second demonstration of effects of daily language switching on cognitive control, future research may evolve towards more detailed, continuous measures of language switching (see also Yim & Bialystok, 2012), to further elaborate the role of switching frequency in the development of a control advantage. It could also be interesting to broaden these results within the same language pair, to other executive functions, such as task shifting (e.g. Prior & Gollan, 2011), although this implies more shared task demands with language switching and is therefore a weaker demonstration of a general bilingual advantage.

To summarise, this study shows that language switching experience in daily life is a key determinant for the development of a stronger executive control system, underlying the alleged bilingual advantage on executive control tasks. We believe that the current demonstration of language switching experience effects demonstrates that this factor should not be neglected as a crucial determinant of the bilingual advantage, also not in further research assessing other cognitive control functions. As such, we believe that the current findings for interference tasks also contribute to this ongoing debate as a possible explanation for the inconsistent findings with other tasks.

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CHAPTER 4
VERBAL AND NON-VERBAL COGNITIVE CONTROL IN BILINGUALS AND INTERPRETERS[1]

The present study explored the relation between language control and non-verbal cognitive control in different bilingual populations. We compared monolinguals, Dutch-French unbalanced bilinguals, balanced bilinguals, and interpreters on the Simon task and Attention Network Test (ANT). All bilingual groups showed a smaller congruency effect in the Simon task than the monolingual group. They were also faster overall in the ANT. Furthermore, interpreters outperformed unbalanced, but not balanced, bilinguals in terms of overall accuracy on both tasks. In the ANT, the error congruency effect was significantly smaller for interpreters and balanced bilinguals. Using a measure of switching fluency in language production, this study also found direct evidence for a relation between language control and executive control. This relation was only observed in balanced bilinguals, where fluent switching was correlated with the Simon effect. These findings support the existence of a bilingual advantage and also indicate that different patterns of bilingual language use modulate the nature and extent of a cognitive control advantage in multilingual populations.

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[1]Woumans, E., Ceuleers, E., Van der Linden, L., Szmalec, A., & Duyck, W. (2015). Verbal and non-verbal cognitive control in bilinguals and interpreters. *Journal of Experimental Psychology: Learning, Memory, & Cognition*. doi: 10.1037/xlm0000107

INTRODUCTION

Recently, the literature on bilingualism has taken great interest in the impact of bilingualism on executive control outside the linguistic domain. Bilinguals have two languages that are activated simultaneously (Kroll, Bobb, & Wodniecka, 2006; Van Assche, Duyck, & Hartsuiker, 2012) and therefore require mechanisms to suppress the inappropriate language and activate the appropriate one. The constant competition for selection that takes place between languages may lead to enhanced cognitive control that is not language-specific, but domain-general (Green, 1998). Several studies have investigated the performance of bilinguals on different tasks that require executive processing and found that bilinguals often outperform monolinguals, responding faster overall and showing more rapid conflict resolution. These results have been observed throughout all stages of the bilingual lifespan (Bialystok, Martin, & Viswanathan, 2005); from childhood (Bialystok, 2005) over young adulthood (Bialystok, 2006; Costa, Hernández, & Sebastián-Gallés, 2008) to middle and old age (Bialystok, Craik, & Luk, 2008; Bialystok, Klein, Craik, & Viswanathan, 2004).

CHALLENGES

Although many studies yield compelling evidence for a bilingual advantage, there are others that do not (see Hilchey & Klein, 2011). For instance, Morton and Harper (2007) did not find any difference between monolingual and bilingual children on Simon task performance, but they did record an effect of socioeconomic status (SES). Both Duñabeitia et al. (2014) and Antón et al. (2014) compared large groups of well-matched monolingual and bilingual children on different measures of cognitive control and found no differences either. Kousaie and Phillips (2012) found the same for younger and older adults. In contrast, other studies controlling for SES, intelligence, and other variables did find evidence for a bilingual advantage (e.g. Engel de

Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012; Nicolay & Poncelet, 2013).

The reason for the discrepancies between studies is not yet clear. Paap and Greenberg (2013) suggested that different tasks used in bilingual studies might elicit different results. They employed 15 indicators of cognitive processing, but none yielded bilingual effects. It must be noted that their participants were classified as monolingual even when they had L2 knowledge, providing that L2 proficiency did not exceed the intermediate level. This rather subtle difference between bi- and monolinguals may have obscured the results. Bilingualism is a broad concept (Kroll & Bialystok, 2013) and language use parameters may influence the bilingual advantage. It may be sensitive to certain bilingual variables, such as L2 proficiency (Bialystok & Barac, 2012) and language switching experience (Green & Wei, 2014). With regard to the latter, Green and Abutalebi (2013) have stated in their ‘adaptive control hypothesis’ that the interactional context (e.g. contexts where frequent language switching is necessary) lead bilinguals to adapt their cognitive control processes and tune their control networks.

Some empirical studies provided evidence for this hypothesis by reporting an explicit link between language control and cognitive control. For instance, Prior and Gollan (2013) observed that task training led to a reduction in language-switching cost. They also demonstrated that Spanish-English bilinguals who reported frequent language switching in daily life exhibited smaller task-switching costs than monolinguals, while a group of Mandarin-English bilinguals who reported less frequent language switching did not show this advantage (Prior & Gollan, 2011). However, as this latter study confounded switching frequency with cross-language overlap (Spanish-English vs. Mandarin-English), Verreyt, Woumans, Szmalec, Vandelanotte, and Duyck (2015) recently generalised these results within a single-language pair. Only balanced Dutch-French bilinguals that switched languages often during the course of a day showed a bilingual advantage relative to unbalanced bilinguals. Together these findings reveal that different linguistic variables can modulate the magnitude of the bilingual advantage and even provide an explanation for the discrepancies in the results of different studies.

EXPERTS IN LANGUAGE CONTROL: THE CASE OF INTERPRETERS

Bilingual studies tapping into cognitive control have employed all sorts of bilingual populations. Surprisingly, a population that has not been extensively investigated is one in which extreme between-language control takes place; simultaneous interpreters. Simultaneous interpreting is the complex task of reformulating spoken messages from the source language (SL) into the target language (TL), while monitoring all produced output. This means that both language systems need to be simultaneously activated for comprehension and production (de Groot & Christoffels, 2006). Nevertheless, some sort of inhibition must take place in order for interpreters to produce the correct language. Christoffels and de Groot (2005) describe possible inhibition accounts of interpreting, assuming (functionally) distinct input and output lexicons that can be separately activated and inhibited. These accounts state that both SL and TL input lexicons should be activated, to allow for input comprehension and output monitoring, while the SL output lexicon should be strongly inhibited. Interpreting involves many cognitive processes (e.g. attention, memory, inhibition) at the same time and these may be trained due to the frequent usage.

Indeed, several studies have found evidence for enhanced working memory in this population. For instance, Köpke and Nespoulous (2006) compared expert interpreters, novice interpreter students, and two control groups (monolinguals and bilinguals) and ascertained superior performance of novice interpreters on memory span. The distinctive performance between novice and expert interpreters was explained in light of differences in age, screening processes, and memory training. In another study, Christoffels, de Groot, and Kroll (2006) compared trained interpreters to highly proficient English teachers and 20-year younger bilingual university students, and found that interpreters again performed notably better on memory.

Additionally, they included a basic non-verbal cognitive control task, but found no advantage for interpreters here. Yudes, Macizo, and Bajo (2011) further explored executive processes in interpreters, by comparing them to monolinguals and bilinguals on the Simon task and the Wisconsin Card Sorting Test (WCST – Grant & Berg, 1948). This study also disclosed a relation between interpreting and cognitive flexibility, as the interpreters outperformed bilinguals and monolinguals on the WCST. This was not the case for inhibitory control, as they did not do better on the Simon task.

Evidently, interpreters seem to be advantaged on measures of memory, but there have thus far been no strong indications that they also possess better inhibitory control. It must, however, be noted that both Christoffels et al. (2006) and Yudes et al. (2011) had similar age confound problems, as the interpreters were much older that the other participants. Nevertheless, when Yudes et al. performed the same analyses on a smaller group of interpreters and bilinguals matched on age, the same pattern of results was obtained. Even so, it is possible that better controlled studies may still yield control advantages for interpreters.

THE PRESENT STUDY

It recently became clear that bilingual control advantages are not consistently observed. This taken together with the fact that some studies reported effects of particular bilingual experiences led us to believe that it might be these experiences that modulate the bilingual advantage and determine its existence. Hence, we investigated the effect of bilingual proficiency and interpreter training; comparing monolinguals, unbalanced bilinguals, balanced bilinguals, and student interpreters matched for age, gender, and intelligence on cognitive control tasks. In addition, we directly relate a measure of language switching with domain-general conflict resolution.

Language-switching proficiency was measured through an adapted dual-language version of the semantic verbal fluency task, similar to Yim and

Bialystok (2012). In semantic fluency, participants retrieve as many words possible within a given category. Hence, performance is semantically and internally driven, like natural word production. Yim and Bialystok found a correlation between conversational language switching and switching costs in the fluency task, indicating that it is an accurate measure of natural switching proficiency. Our task consisted of two single-language conditions (French and Dutch) and a dual-language condition, in which participants were instructed to alternate constantly between languages. As switching languages is costly (Gollan & Ferreira, 2009), we expected our participants to generate fewer exemplars in the dual-language condition (switch cost). The two single-language conditions also served as an online indicator of L1 and L2 proficiency, adding to the results of the self-reported measures.

Miyake and Friedman (2012) noted that different types of control tasks often elicit diverse results, as they tap into other kinds of inhibitory control. Therefore, we employed both the Simon task (Simon & Rudell, 1967) and the ANT (Fan, McCandliss, Sommer, Raz, & Posner, 2002). The Simon task is based on stimulus-response compatibility, meaning that the difficulty lies in inhibiting a prepotent response. Coloured dots appear either on the left or right side of the screen, but participants are asked to ignore position and respond to colour by pressing either a left or right button. Inhibition is required when position and colour elicit different responses. In the ANT, participants must indicate the direction of the central of five arrows. Conflict takes place on screen when the central arrow points into the other direction as the other arrows and interference inhibition is needed.

We suspect that particular bilingual experiences modulate the bilingual control advantage and hypothesise that more language control practice leads to enhanced cognitive functioning. Firstly, we predict that bilinguals are better equipped to deal with conflict resolution than monolinguals. Secondly, we expect balanced bilinguals and interpreters to outperform unbalanced bilinguals, due to their extensive experience with language inhibition, and assume that interpreting practice leads to even greater advantages. Interpreters constantly handle both languages at the same time, but have a need to suppress the input language when they are busy producing the output language. Thirdly, within bilingual groups, we postulate that cognitive control is better in bilinguals with superior language-switching abilities. Frequently alternating between languages in daily life should improve language switching in the fluency task and yield an associated cognitive advantage, at least for balanced bilinguals and interpreters. Such association is less likely for unbalanced bilinguals, as they have virtually no or only limited experience in switching languages.

METHOD

PARTICIPANTS

We included a group of 30 French-speaking monolinguals and three groups of Dutch-French bilinguals; 34 unbalanced bilinguals, 31 balanced bilinguals, and 28 student Dutch-French interpreters. All participants were recruited at universities and colleges in Ghent, Brussels, and Louvain (Belgium). A language questionnaire and verbal fluency task were administered as a measure of proficiency. Balanced bilinguals were equally proficient in L1 and L2 and employed both languages to the same extent in daily life. Unbalanced bilinguals acquired their L2 through formal education and rarely used it outside school context, while monolinguals indicated they had no or very little knowledge of any other language. The inclusion criterion for the interpreter group was the completion (or near-completion) of a one-year Master programme in Dutch-French interpreting with 10 hours of interpreting per week. All balanced bilinguals were early L2 learners and reported lower L1 proficiency than monolinguals, unbalanced bilinguals, and interpreters. Interpreters indicated they were more proficient in L2 than unbalanced bilinguals, but less proficient than balanced bilinguals. There was no difference in age of L2 acquisition between interpreters and unbalanced bilinguals; both groups consisted mostly of late L2 learners. All groups were matched for age, gender, and intelligence. Detailed demographic information is reported in Table 1.

Table 1. Demographic data, *Mean* (*SD*), of the different bilingual populations.

	Monolingual	Unbalanced	Balanced	Interpreter	Test	*p*
N	30	34	31	28		
Male/female ratio	8/22	7/27	7/24	6/22	$Chi^2(3) = .380$	> .05
Age	22.1 (1.4)	22.3 (2.8)	21.1 (2.1)	22.5 (1.7)	$F_{3,119} = 1.78$	> .05
Raven	9.0 (2.5)	8.3 (2.7)	8.6 (2.1)	9.6 (1.6)	$F_{3,119} = 1.80$	> .05
L1 French/Dutch	30/0	0/34	13/18	2/26		
L1 Proficiency	5.0 (0.0)	5.0 (0.0)	4.8 (0.3)	5.0 (0.2)	$F_{3,119} = 4.95$	< .01
Age of acquisition	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	No differences	
Frequency of use (%)	98.0 (2.0)	92.3 (7.1)	64.6 (13.5)	70.2 (20.3)	$F_{3,119} = 40.97$	< .001
L2 Proficiency	1.8 (1.0)	2.6 (0.6)	4.2 (0.5)	3.7 (0.5)	$F_{3,119} = 72.76$	< .001
Age of acquisition	12.4 (2.4)	9.4 (1.3)	2.6 (3.0)	8.6 (3.3)	$F_{3,119} = 74.47$	< .001
Frequency of use (%)	2.0 (2.0)	7.7 (7.1)	35.5 (13.5)	25.6 (14.7)	$F_{3,119} = 53.33$	< .001
Fluency L1	20.2 (7.3)	17.7 (6.1)	16.7 (5.6)	18.2 (4.4)	$F_{3,119} = 1.88$	> .05
Fluency L2	N/A	5.9 (3.0)	12.8 (5.4)	14.0 (4.0)	$F_{2,90} = 34.48$	< .001
Fluency switching	N/A	8.2 (2.8)	11.4 (3.2)	11.9 (3.3)	$F_{2,90} = 13.69$	< .001
Switching cost	N/A	3.7 (4.6)	3.3 (3.9)	4.2 (4.4)	$F_{2,90} = 0.31$	> .05

MATERIALS AND PROCEDURE

Task instructions were given in French for monolinguals and in either Dutch or French for bilinguals, depending on which the participants preferred.

Language background. Participants completed a questionnaire about use and fluency in one or more languages. A 5-point Likert scale tapped into four language skills (comprehending, speaking, reading, and writing), ranging from 1 (very poor) to 5 (native speaker level). A composite proficiency score was calculated by averaging responses for all skills. All bilingual groups also reported knowledge of a third language, but this knowledge was similar in the three groups.

Raven's Advanced Progressive Matrices. Raven's Matrices is a test of analytic reasoning and is considered to be a good non-verbal index of general fluid intelligence. The Advanced Progressive Matrices (Raven, 1965) is a 48 item-version of the matrices intended for use with people of above average aptitude. We administered the short untimed 12 item-version, which correlates highly with the complete version (Bors & Stokes, 1998), in order to ascertain whether our groups obtained similar intelligence scores.

Semantic Verbal Fluency. Verbal fluency was administered as a measure of verbal language control. We used two single-language conditions (Dutch and French) and one dual-language (switch) condition. Participants were given 60 seconds to verbally produce as many exemplars as they could of a given semantic category. The categories used in this study were *animals*, *vegetables*, and *professions*. Monolinguals performed all three categories in French[1]. For bilinguals, categories were counterbalanced across language conditions. Participants could either be instructed to start with the French or

[1] The amount of exemplars given per semantic category was compared across monolinguals. No significant differences were found (p = .397).

Dutch condition; however, the dual-language condition was always performed last, in order to avoid continuing language switches in the single-language blocks. During this last condition, participants were required to constantly alternate between the two languages. Consecutively giving two exemplars in the same language was considered an error and translations of previously produced were also not allowed. Per participant, the results of the single-language L1 condition were then compared with the amount of L1 exemplars in the dual-language condition. The difference between the two was used as a cost for language switching (small difference = fluent switching, large different = non-fluent switching).

Simon task. A coloured Simon task was used to assess non-verbal executive functions. Coloured dots appeared either on the left or right side of the screen and participants were asked to press the left (right) key on the keyboard when a green dot appeared, and the right (left) key when the red dot appeared as quickly and as accurately as possible. Response mapping was counterbalanced across participants. Position and colour elicited either the same response (congruent trials) or different responses (incongruent trials).

Each trial began with a fixation cross that remained visible for 500 ms, followed by a clear screen, after which a red or green dot appeared either on the left or right side of the screen. The presentation of the coloured dot lasted until the participant's response or up to 900 ms. There was a 500 ms blank interval before the next fixation period. The experiment consisted of 10 randomised practice trials and two blocks of 100 randomised experimental trials. Half of all trials presented the coloured dot on the same side of the associated response key, and half on the opposite side. Stimuli were presented via Tscope software (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006) on an IBM-compatible laptop computer with a 15-inch screen, running XP.

ANT. A shortened ANT-version was employed, measuring the executive and orienting network. Participants were shown five arrows and asked to indicate the direction of the central one. The experimental design contained two within-subject factors: flanker type (congruent and incongruent) and cue type. Cues assessed orienting skills and were presented at the location of fixation (centre cue) or at the location of the upcoming target (spatial cue). Sometimes, no cue was presented. Comparing congruent and incongruent trials measured the executive network, comparing central and spatial cue trials quantified the orienting network.

A session consisted of a 6-trial demo block, a 12-trial full feedback practice block, and three experimental blocks of 48 randomised trials. Each condition was shown an equal amount of times (once during the demo, twice during practice, eight times per experimental block). Each trial consisted of five events: (1) a fixation of a random variable duration (400-1600 ms), (2) a cue for 100 ms, (3) another fixation of 400 ms, (4) target arrow and flankers above or below fixation until response or up to 1700 ms, (5) clearing the screen after response. In the no cue condition, there was no step two or three. Participants were instructed to focus on the fixation cross and respond as quickly and accurately as possible. They pressed the left button of a touchpad with their left hand when the target pointed to the left, and the right button of that touchpad with their right hand when the target pointed to the right. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP.

RESULTS

Verbal fluency. All data are reported in Table 1. The amount of exemplars produced in the L1 condition did not differ between groups. In the L2 condition, unbalanced bilinguals produced significantly fewer exemplars than balanced bilinguals ($t_{63} = 6.27$, $p < .001$) and interpreters ($t_{60} = 8.89$, $p < .001$). Balanced bilinguals and interpreters performed similarly ($t_{57} = -1.02$, $p = .312$). Results for the dual-language condition were analogous, with unbalanced bilinguals producing significantly fewer words than balanced bilinguals (t_{63} = 4.29, $p < .001$) and interpreters (t_{60} = 4.72, $p < .001$), while balanced bilinguals and interpreters did not differ (t_{57} = -0.60, p = .548).

Conflict tasks. For each participant, mean response latencies (RT) and mean error percentages were calculated. Table 2 shows all results for Simon and ANT. Two participants (one balanced and one unbalanced bilingual) were excluded from analysis, because they had an error rate of more than 50% for the Simon task (chance level), while the mean error rate was 2.0%. For the ANT, the error rate was on average 3.6%. RTs for incorrect responses were excluded from analyses. Outlier RTs were trimmed individually by calculating a mean RT across all trials and excluding any response 2.5 SD of the mean. This procedure eliminated 2.4% of all Simon data and 2.2% of all ANT data. The reliability of RTs as estimated using the intraclass correlation (ICC(C,k), to be specific, where *k* is the amount of raters) was 98.4% (95% CI = [91.66, 99.99]). Note that ICC(C,k) corresponds to the split-half reliability averaged over all possible data splits (Shrout & Fleiss, 1979). For both tasks, Congruency was manipulated within subjects, while Group was a between-subject variable. For the ANT, Cue effect was also analysed. Furthermore, significant correlations between conflict tasks and language-switching cost are reported.

Table 2. Mean RTs (ms) and error rates (%) for Simon and ANT by Group and broken for congruency, with standard deviations in parentheses.

	Simon				*ANT*			
	Monolingual	Unbalanced	Balanced	Interpreter	Monolingual	Unbalanced	Balanced	Interpreter
RT								
Congruent	383 (64)	393 (54)	415 (47)	409 (41)	521 (62)	474 (53)	497 (45)	496 (39)
Incongruent	422 (65)	422 (55)	442 (49)	437 (38)	614 (73)	562 (70)	577 (48)	587 (64)
Congruency effect	38 (18)	29 (12)	27 (15)	28 (21)	93 (45)	88 (26)	81 (16)	91 (34)
Orienting effect	N/A	N/A	N/A	N/A	38 (30)	48 (19)	59 (23)	65 (23)
Error rates								
Congruent	2.6 (2.5)	4.9 (4.7)	4.6 (3.9)	2.6 (2.3)	0.5 (0.9)	0.6 (0.9)	0.8 (1.2)	0.3 (0.8)
Incongruent	7.1 (4.5)	7.8 (5.5)	6.4 (5.4)	5.8 (4.2)	6.1 (5.3)	9.2 (8.2)	5.7 (6.0)	4.4 (3.8)
Congruency effect	4.4 (4.6)	3.0 (5.4)	1.7 (5.1)	3.1 (3.5)	5.6 (5.0)	8.6 (7.9)	4.9 (5.7)	4.1 (3.8)
Orienting effect	N/A	N/A	N/A	N/A	1.7 (3.3)	3.4 (6.4)	2.4 (4.3)	1.3 (2.2)

MONOLINGUALS VS. BILINGUALS

If a bilingual cognitive control advantage exists, it would translate into faster RTs and higher accuracy overall and a smaller congruency effect in both conflict tasks for all bilingual groups as opposed to the monolingual group.

Simon task. In the RT analysis, the effect of Congruency was significant ($F_{1,119}$ = 416.54, p < .001, ηp^2 = .778), with faster RTs for congruent trials. There was no main effect of Group ($F_{3,119}$ = 1.70, p = .171, ηp^2 = .041). Planned comparisons showed no differences between groups. There was, however, a significant Congruency*Group interaction ($F_{3,119}$ = 3.01, p = .033, ηp^2 = .070). Planned comparisons revealed a larger Simon effect for monolinguals compared with all other groups (t_{119} = 2.98, p = .004). Error analysis yielded an effect of Congruency ($F_{1,119}$ = 50.80, p < .001, ηp^2 = .299), with more errors on incongruent trials. No effect of Group was found ($F_{3,119}$ = 1.97, p = .123, ηp^2 = .047). Neither was there an interaction ($F_{3,119}$ = 1.67, p = .176, ηp^2 = .040) and planned comparisons did not reveal any significant differences.

ANT. RT analysis yielded a main effect of Congruency ($F_{1,119}$ = 937.14, p < .001, ηp^2 = .887), with smaller RTs for congruent trials, and of Group ($F_{3,119}$ = 4.34, p = .006, ηp^2 = .099). Planned comparisons showed that monolinguals had higher overall RTs than the other groups (t_{119} = 2.89, p = .005). No Congruency*Group interaction was found ($F_{3,119}$ = 0.84, p = .475, ηp^2 = .022) and planned comparisons revealed no differences between monolinguals and the other groups. The orienting analysis revealed an effect of Cue ($F_{1,119}$ = 593.63, p < .001, ηp^2 = .833), indicating faster responses on spatial cue trials. Planned comparisons indicated that bilinguals benefited more from the presence of a spatial cue than monolinguals (t_{119} = -3.96, p < .001). Error analysis produced an effect of Congruency ($F_{1,119}$ = 118.19, p < .001, ηp^2 = .498), with fewer errors in the congruent condition. There was also an effect of Group ($F_{3,119}$ = 3.18, p = .027, ηp^2 = .074) and a Group*Congruency interaction ($F_{3,119}$ = 3.55, p = .017, ηp^2 = .082). Planned comparisons did not show differences between monolinguals and the other groups. The orienting analysis for errors revealed an effect of Cue ($F_{1,119}$ = 30.38, p < .001, ηp^2 = .203), but no other effects.

Both tasks demonstrated a cognitive control advantage for bilinguals relative to monolinguals. It was reflected by a smaller RT congruency effect in the Simon task and faster overall RTs in the ANT for bilinguals.

BILINGUALS VS. INTERPRETERS

If interpreting experience modulates the bilingual advantage, we would expect better performance for interpreters on both the Simon task and the ANT as compared with the other two bilingual groups.

Simon task. In the RT analysis, the effect of Congruency was significant ($F_{1,90}$ = 279.87, p < .001, ηp^2 = .757). However, no effect of Group ($F_{2,90}$ = 1.68, p = .192, ηp^2 = .036) or Congruency*Group interaction ($F_{2,90}$ = .080, p = .923, ηp^2 = .002) was found. Error analysis yielded an effect of Congruency ($F_{1,90}$ = 27.18, p < .001, ηp^2 = .232), but not of Group ($F_{2,90}$ = 2.37, p = .099, ηp^2 = .050). Planned comparisons showed interpreters made significantly fewer errors than unbalanced bilinguals (t_{60} = -2.31, p = .025), but did not do better than balanced bilinguals (t_{57} = 1.43, p = .158). There was no significant difference between balanced and unbalanced bilinguals (t_{63} = -0.81, p = .421). Neither was there a Group*Congruency interaction ($F_{2,90}$ = 0.81, p = .448, ηp^2 = .018).

ANT. RT analysis yielded an effect of Congruency ($F_{1,90}$ = 997.88, p < .001, ηp^2 = .917), but no effect of Group ($F_{2,90}$ = 1.83, p = .167, ηp^2 = .039) or a Group*Congruency interaction ($F_{2,90}$ = 1.24, p = .294, ηp^2 = .027). The orienting analysis revealed an effect of Cue ($F_{1,90}$ = 657.32, p < .001, ηp^2 = .880). Planned comparisons showed that unbalanced bilinguals benefited less from the presence of a spatial cue than balanced bilinguals (t_{63} = -2.07, p = .042) and interpreters (t_{60} = -3.11, p = .003). Error analysis produced a significant effect of Congruency ($F_{1,90}$ = 83.61, p < .001, ηp^2 = .482) and of Group ($F_{2,90}$ = 4.39, p = .015, ηp^2 = .089). The total amount of errors was only marginally higher for unbalanced bilinguals compared with balanced bilinguals (t_{63} = -1.70, p = .093), and significantly higher compared with interpreters (t_{60} = -3.03, p = .004). Interpreters and balanced bilinguals did not differ (t_{57} = 1.29, p = .205). The Congruency*Group interaction was significant ($F_{2,90}$ = 4.83, p = .010, ηp^2 = .097), with unbalanced bilinguals having a larger congruency effect than balanced bilinguals (t_{63} = -2.15, p = .036) and interpreters (t_{60} = -2.94, p = .005). Interpreters did not differ from balanced bilinguals (t_{57} = 0.70, p = .490). The orienting analysis revealed a main effect of Cue ($F_{1,90}$ = 23.10, $p < .001$, ηp^2 = .204), but no other effects.

Interpreters showed cognitive control advantages on both tasks on overall accuracy scores, but only relative to unbalanced and not to balanced bilinguals. For the ANT, interpreters also had a smaller error congruency effect than unbalanced bilinguals.

LANGUAGE CONTROL VS. COGNITIVE CONTROL

If language control affects the bilingual advantage, language-switching abilities should be correlated to cognitive control in groups where L2 proficiency is high (i.e. balanced bilinguals and interpreters).

Simon task. Correlation analysis revealed a link between cost of switching languages in the fluency task and the Simon RT effect, but only in balanced bilinguals. Fluent switchers had a smaller effect (r = .530, p = .002). There were no correlations with error scores.

ANT. Only a weak relation was found between switch cost and the ANT error effect in interpreters (r = .347, p = .070), with lower switch costs relating to smaller error effects.

The results indeed indicate a relation between language switching and cognitive control, but only for balanced bilinguals on the Simon task, as better language switchers demonstrated smaller RT congruency effects.

DISCUSSION

Recently, research on the bilingual advantage began yielding diverging results, with some studies not finding any advantage at all (e.g. Duñabeitia et al., 2014; Paap & Greenberg, 2013). In addition, several studies provided evidence that it may not be bilingualism in itself, but specific bilingual experiences modifying the advantage (e.g. Bialystok & Barac, 2012; Prior & Gollan, 2011). For this reason, we set out to clarify how L2 variables such as L2 proficiency, language-switching abilities, and interpreter training may determine the magnitude of the bilingual advantage.

Accordingly, we compared monolinguals, unbalanced bilinguals, balanced bilinguals, and student interpreters on the Simon task and the ANT. L2 proficiency was scored through self-report scales and semantic verbal fluency. Language-switching abilities within bilingual groups were measured by comparing the single-language conditions to a dual-language condition in the fluency task. The difference in performance generated a cost value for switching. We hypothesised that enhanced bilingual language control leads to improved cognitive functioning. Specifically, we expected all bilinguals to outperform the monolinguals, but also assumed greater advantages for balanced bilinguals and the greatest advantages for interpreters. Furthermore, we predicted a correlation between language control, assessed by language-switching proficiency, and cognitive control within these different bilingual populations.

Our results revealed a smaller Simon effect and faster overall RTs in the ANT for bilinguals compared with monolinguals. They were also aided more by the presence of a spatial cue in the ANT, suggesting better orienting. The three bilingual groups did not differ on overall RTs or congruency effect, but interpreters and balanced bilinguals exhibited better orienting skills than unbalanced bilinguals. Furthermore, interpreters made significantly fewer errors than unbalanced bilinguals in both tasks and the ANT error effect was significantly smaller for both interpreters and balanced bilinguals. Within groups, we established that fluent switching was associated with a smaller Simon effect in balanced bilinguals.

THE BILINGUAL ADVANTAGE

The present study is in line with studies reporting a bilingual advantage (Bialystok et al., 2004; Costa et al., 2008), as it determined a smaller Simon effect and faster overall RTs in the ANT for bilinguals compared with monolinguals. The ANT results converge with those of Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009), who attributed the overall effect to a more efficient monitoring system in bilinguals.

Contrary to Costa et al. (2008, 2009), our results showed that bilingualism was also associated with better orienting. As we employed a shorter version of the same task, these discrepancies cannot be accounted for by the nature of the measures. Consequently, we propose that the difference lies in how attentive bilinguals are to cues. Costa's bilinguals all lived in Catalonia where almost everyone speaks both Spanish and Catalan. Since not everyone in Belgium is fluent in both Dutch and French, our bilinguals have a need to look for certain contextual cues to know which language they should use (cf. Poulisse & Bongaerts, 1994). It is feasible that this particular experience has made them more perceptive to all sort of orienting cues.

The fact that we did not consistently find better overall RTs and smaller congruency effects for bilinguals on both tasks supports Miyake and Friedman's (2012) argument that different executive measures may tap into different functions. This is an important finding, as it alerts us to be careful about comparing bilingual studies employing different measures. In fact, it may even provide a partial explanation for why the bilingual advantage is not consistently found over studies. We use the term 'partial', as it cannot account for all discrepant findings. For instance, Paap and Greenberg (2013) employed 15 measures, while none of them yielded any bilingual effects. Here, we like to propose that linguistic variables, such as L2 proficiency, play a role. Indeed, the current study found that balanced bilinguals and interpreters made fewer errors than unbalanced bilinguals on both control tasks, indicating superior control. In addition, they were also more skilled at orienting. Again, this could be due to the fact that they had more experience employing cues to select the correct language.

THE INTERPRETER ADVANTAGE

Up until now, only few studies have explored the effects of simultaneous interpreting on cognitive control (e.g. Christoffels et al., 2006; Yudes et al., 2011). Neither of these studies disclosed any inhibitory control advantages, although Yudes et al. (2011) did report better mental flexibility in interpreters. The current study did obtain evidence of an inhibitory advantage for interpreters relative to unbalanced bilinguals. The effect emerged consistently for accuracy, both for the Simon task and the ANT. It is not very clear whether this difference is due to a speed-accuracy trade-off in the unbalanced group (Simon: $r = -.154$, $p = .385$, ANT: $r = -.163$, $p = .357$). Task demands may have contributed to the differences being reflected in accuracy, rather than RT. In the Simon task, participants only had 900 ms to respond after onset of the stimulus, which may have encouraged them to respond quickly but less accurately. In the ANT, the intertrial interval changed constantly, which was for instance not the case in Costa et al. (2008). Our task thus required more attention and focus; possibly similar to the type of attention and focus related to interpreting. This view is supported by Marzecová et al. (2013a&b), who also reported higher accuracy for bilinguals and hypothesised that this advantage was due to the bilingual's ability to efficiently focus attention on the task at hand. Consequently, we do not believe that finding differences on accuracy rather than on RT fundamentally hampers the implications of the results; both measures reflect the ability of sustained attention and control.

All in all, the interpreter advantage is quite remarkable, as our participants were only student interpreters with limited experience; most of them were late L2 learners (82%) and used their L2 less frequently than balanced bilinguals. This suggests that even limited interpreter training induces the same positive effects on cognitive control as early L2 acquisition and frequent L2 use. Nevertheless, it is possible that the interpreter advantage will be more evident in, for instance, cognitive flexibility tasks (Yudes et al., 2011), as some studies claim that interpreting does not involve inhibitory processes after all (Ibáñez, Macizo, & Bajo, 2010), but other cognitive specialisations instead.

THE LANGUAGE CONTROL ADVANTAGE

So far, the direct relation between language control and executive control has been an elusive one. Yim and Bialystok (2012) were not able to determine any relation between language switching and non-verbal task switching, while Prior and Gollan (2011; 2013) did. So, what can be the reason for the discrepancy between these results? Prior and Gollan (2011, 2013) included only balanced bilinguals, while Yim and Bialystok analysed balanced and unbalanced bilinguals together. Now, we observed a strong correlation (r = .530) between fluent switching and cognitive control, but only in balanced bilinguals. Thus, a viable explanation may be that the effects are only present in balanced bilinguals, as they are the ones most in need of language control skills.

Unfortunately, our study design does not permit us to make any conclusive assertions about the causal direction of the relation; it is possible that language switching leads to better cognitive performance, but it may also be the other way around. However, as the correlation only occurred in balanced bilinguals, who have more experience with language switching, it seems plausible that it is the practice of language switching that drives cognitive control. Otherwise, one may argue that interpreters or unbalanced bilinguals with better cognitive control should be better language switchers as well.

IMPLICATIONS

The importance of this study is reflected in its three major findings. Firstly, it confirmed the hypothesis of a cognitive control advantage for bilinguals compared with monolinguals. Still, the advantage was not present on every measure of executive functioning, which may explain why studies employing different measures obtain different results. Secondly, this study demonstrated higher accuracy scores for interpreters in both Simon and ANT, hereby substantiating that language control training influences executive control and that this training surpasses the role of other linguistic variables, such as age of L2 acquisition. Thirdly, by ascertaining a correlation between language control and executive control in balanced bilinguals, this study showed that at least within one type of bilingual population, individual differences in language control abilities relate to cognitive advantages. This confirms that the magnitude and nature of any bilingual effects may depend on the typology of the bilingual population under investigation. All in all, this study revealed that both the nature of cognitive control measures and particular bilingual experiences modulate the magnitude of the bilingual advantage.

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CHAPTER 5
BILINGUALISM DELAYS CLINICAL MANIFESTATION OF ALZHEIMER'S DISEASE[1]

The current study investigated the effects of bilingualism on the clinical manifestation of Alzheimer's disease (AD) in a European sample of patients. We assessed all incoming AD patients in two university hospitals within a specified timeframe. Sixty-nine monolinguals and 65 bilinguals diagnosed with probable AD were compared for time of clinical AD manifestation and diagnosis. The influence of other potentially interacting variables was also examined. Results indicated a significant delay for bilinguals of 4.6 years in manifestation and 4.8 years in diagnosis. Our study therefore strengthens the claim that bilingualism contributes to cognitive reserve and postpones the symptoms of dementia.

[1]Woumans, E., Santens, P., Sieben, A., Versijpt, J., Stevens, M., & Duyck, W. (2014). Bilingualism delays clinical manifestation of Alzheimer's disease. *Bilingualism: Language and Cognition*. doi: 10.1017/S136672891400087X

INTRODUCTION

Recent studies into the prevalence of dementia estimate that the number of patients suffering from the disease worldwide will have tripled by the year 2050 (Prince, Bryce, Albanese, Wimo, Ribeiro, & Ferri, 2013). With these numbers on the rise, the amount of research into protective factors and cognitive reserve (i.e. functional compensation of brain degeneration; Stern, 2002) that may delay the manifestation of symptoms of dementia is of great importance. Factors such as socioeconomic status (SES), social network, and leisure activities all seem to contribute to behavioural brain reserve and a delay in incident dementia (Fratiglioni, Winblad, & von Strauss, 2007; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Valenzuela & Sachdev, 2006).

Bilingualism is another factor that contributes to cognitive reserve (Bak, Nissan, Allerhand, & Deary, 2014; Perquin, Vaillant, Schuller, Pastore, Dartigues, Lair, & Diederich, 2013) and enhances neural efficiency (Gold, Kim, Johnson, Kryscio, & Smith, 2013). For instance, bilinguals show increased density in both white (Luk, Bialystok, Craik, & Grady, 2011) and grey matter (Abutalebi, Canini, Della Rosa, Freen, & Weekes, 2015; Abutalebi, Canini, Della Rosa, Sheung, Green, & Weekes, 2014) compared with age-matched monolinguals. These studies provide a neural basis for a potential bilingual advantage in brain reserve, as cognitive decline has been associated with a decrease in white matter integrity (Madden, Spaniol, Costello, Bucur, White, Cabeza, Davis, Dennis, Provenzale, & Huettel, 2009) and reductions in grey matter volume (Fjell & Walhovd, 2010).

These efficient cognitive and neural networks in bilinguals are often assumed to result from the extensive functional integration of both languages. When processing a given language (either the first - L1 - or second - L2), other known, irrelevant languages always get active to a certain degree, and influence processing of the relevant language (Van Assche, Duyck, & Hartsuiker, 2012; Van Assche, Duyck, Hartsuiker, &

Diependaele, 2009). This constant competition requires considerable cognitive control (Green, 1998), specifically imposed on bilinguals. In this rationale, a new line of research has started to investigate the cognitive advantages of bilingualism and this associated cognitive control experience, also outside the verbal domain. Consequently, there are now strong claims that bilinguals show better executive functions and even increased brain plasticity (Bialystok, 2009). It is this enhanced executive functioning and plasticity that is assumed to lead to more cognitive reserve in older bilingual adults (Bialystok, Craik, Klein, & Viswanathan, 2004).

Accordingly, bilingualism has been suggested to delay the clinical manifestation of one frequent and serious manifestation of brain degeneration, namely Alzheimer's disease (AD). A recent neuroimaging study showed that bilinguals could match monolinguals on cognitive and memory tasks, even though bilingual patients had already suffered from significantly more cerebral atrophy through AD (Schweizer, Ware, Fischer, Craik, & Bialystok, 2011). Another Canadian study showed that this bilingual advantage translated into about a five-year delay in clinical AD manifestation (Bialystok, Craik, & Freedman, 2007), with a follow-up study confirming these results (Craik, Bialystok, & Freedman, 2010). Bialystok, Craik, Binns, Ossher, and Freedman (2014) determined the onset of AD and mild cognitive impairment (MCI) and the progression of cognitive decline in a monolingual and bilingual group of patients, controlling for diet, smoking, alcohol consumption, physical activity, and social activity. The results showed a comparable delay in MCI and AD manifestation (3.5 and 7.2 years, respectively). Moreover, monolinguals and bilinguals performed similarly on executive function tasks at time of diagnosis and did not differ in rate of decline, hereby indicating that deterioration was not more severe for bilinguals than monolinguals at the time of the first clinic visit and that the later symptom onset in bilinguals was not associated with a subsequently faster deterioration of cognitive abilities. It must, however, be noted that 47% of the AD patients in this study were also included in the study by Craik et al. (2010).

It is, however, striking that most of the patients in the abovementioned studies were a specific sample of immigrants living in an L2-dominant country (i.e. the regional language was English, which was their L2) and had very particular language experience. Bialystok et al. (2007) did report that the interval between onset of symptoms and time of appointment was the same for immigrants and non-immigrants, while Craik et al. (2010) also controlled for immigration by entering immigration status as a factor in the ANOVA model. They noted that the effect of language group remained, without a significant effect of immigration status. Nevertheless, their study included only few non-immigrant patients. Chertkow, Whitehead, Phillips, Wolfson, Atherton, and Bergman (2010) aimed to confirm the effect for non-immigrants in a large cohort of bilingual native Canadians and therefore compared 135 immigrant and 118 non-immigrant bilinguals to a group of monolinguals. They replicated the earlier results in their Canadian immigrant group, but did not find the same effect for the native group. This raises questions about the origin of the reported earlier effects. Immigrants are by definition not a random sample of the population in many ways (e.g. they may possess greater resilience), and any of these differences from the overall population may have caused the bilingual effect. Conversely, another study, conducted in India (Alladi, Bak, Duggirala, Surampudi, Shailaja, Shukla, Chaudhuri, & Kaul, 2013), did show a delay of dementia manifestation in bilingual non-immigrants. They compared 391 bilingual patients and 257 monolingual patients diagnosed with either AD, vascular dementia (VaD), frontotemporal dementia (FTD), diffuse Lewy body (DLB) or mixed dementia. Languages included Telugu, Dakkhini, English, and Hindu. In general, the results indicated that symptom onset was 4.5 years later for bilinguals than for monolinguals. Specifically for AD, this delay was estimated at 3.2 years. Furthermore, a similar difference between groups was observed for FTD and VaD, independent from confounding variables, such as SES. The effect was also found in a smaller sample of 98 illiterate patients, and there was no additional benefit to speaking more than two languages. Nevertheless, it should be noted the bilinguals' age of L2 acquisition (L2 AoA) and overall L2 proficiency were not mentioned. Therefore it is unclear which type of bilinguals exactly this study included. Additionally, the patient sample was very heterogeneous, including different minority groups, who were not immigrants, but had another dominant language than that of the environment in which they were living.

The present study aimed at testing the bilingual advantage in a non-immigrant sample of European patients. All studies demonstrating an effect of bilingualism on AD were conducted in Canada or India, which constitute truly bilingual environments, with a lot of language switching and mixing. To our knowledge, a similar study has never been carried out in a European context. Therefore, we investigated the supposed bilingual AD delay in a non-immigrant sample of Belgian patients. Belgium has three official regions; Dutch-speaking Flanders and French-speaking Wallonia are almost exclusively Dutch- and French-dominant, while Brussels as a whole is Dutch-French bilingual, but it is composed of regions that still have one dominant language, without noteworthy language mixing. A very small section of Wallonia is also German-speaking, but no participants came from this area. Our bilingual participants all lived in Flanders or in one of the Dutch- or French-dominant regions in Brussels and mainly acquired their L2 through one French- and one Dutch-speaking parent or going to an L2 school. Consequently, our bilinguals all master the same language combination (i.e. Dutch-French), live in an L1-dominant environment, and use one specific language for one specific context, without language mixing.

METHODS

STUDY POPULATION

We assessed all incoming new and clear AD subjects, systematically referred to us by two neurologists (co-authors A. Sieben and J. Versijpt) from Ghent University Hospital (83 patients) and Brussels University Hospital (51 patients), between March 2013 and May 2014. Ultimately, data were collected from 134 native Belgian patients diagnosed with probable AD (Jack, Albert, Knopman, McKhann, Sperling, Carrillo, Thies, & Phelps, 2011). Clinical AD diagnosis was made by the neurologist, in consultation with a neuropsychologist. The assessment included heteroanamnesis, physical examination, mental status evaluation (including Folstein Mini-mental State Examination – MMSE – at initial diagnosis), screening blood tests, and neuroimaging (SPECT, PET, CT, and/or MRI). Age of diagnosis was recorded at the hospitals, and the age of clinical symptom manifestation was formally assessed by the neurologists and based on (caregiver) interviews inquiring into the manifestation of memory complaints. Initial symptoms included onset of impaired short-term memory or other cognitive domain problems beyond age-related memory or cognitive impairment.

Language history and social background information were obtained from patient and caregiver interviews. During this interview, patients were asked to sum up all the languages that they had mastered and to estimate their proficiency for listening, speaking, reading, and writing. They were given the choice between 'perfect/native language', 'very good', 'good', 'moderate', 'poor', and 'non-existing'. These responses were registered on a 6-point Likert scale, ranging from 0 (= none) to 5 (= perfect). Patients were also asked how often they used these languages, early in life (when they were still at school and at work) and now. Here, the options were 'daily' (= 5), 'almost daily' (= 4), 'weekly' (= 3), 'monthly' (= 2), 'a few times a year or less' (= 1), and 'never' (= 0). A composite score was created for overall usage by averaging the scores for 'now' and 'early in life'.

Bilingualism was determined on the basis of L2 proficiency and frequency of use. A patient was considered bilingual if he/she rated him/herself as 'good' or higher for all four L2 skills and spoke this L2 at least weekly before and now. In total, 113 patients indicated that they had some level of proficiency in a second language. Only nine patients also reported relatively good knowledge of a third or fourth language. Ultimately, we identified 69 monolingual and 65 bilingual patients (see Table 1). The monolingual group consisted of 68 Dutch-speaking patients and one French-speaking patient. In the bilingual group, 45 patients reported Dutch as the native language (L1), 18 reported French, one reported Spanish, and another one English. The patients who indicated Spanish and English as their L1 were raised bilingually from birth and had Dutch as L2. For most patients, L2 was Dutch or French. For only two patients, it was German and English. In the bilingual group, L2 AoA ranged from birth to age 25; age 0-3 (18 patients), 3-6 (6 patients), 6-12 (21 patients), 12-18 (16 patients), and 18-25 (4 patients). The 38 monolinguals indicating basic L2 knowledge typically learnt this language at school (limited obligatory courses, around age 10), but did not use it in later life.

Furthermore, we assessed the education level (years) of each patient and determined his or her primary occupation. Occupation (also a proxy for socioeconomic status, SES) was assessed using five categories (ISCO, 2008), but because two occurred very infrequently in our sample (15 unemployed, 5 managers), this was recoded into three groups; lower (unemployed, unskilled workers), medium (skilled workers), and higher (professionals, managers). Analyses using the five original categories yielded the same pattern of results.

Table 1. Self-reported language data with standard deviation between parentheses.

	Monolingual	Bilingual
N	69	65
L1		
Dutch/French/Other	68/1/0	45/18/2
Age of acquisition	0.0 (0.0)	0.0 (0.0)
Proficiency*	5.0 (0.0)	5.0 (0.0)
Usage†	5.0 (0.0)	4.9 (0.2)
L2		
Dutch/French/Other/None	1/37/0/31	18/44/3/0
Age of acquisition	12.5 (6.5)	9.3 (6.2)
Proficiency*	1.3 (1.2)	4.2 (0.7)
Usage†	0.8 (1.0)	4.2 (0.8)

*L1 and L2 proficiency were indicated on a 6-point Likert scale (5 = perfect, 0 = non-existing).
†L1 and L2 usage were indicated on a 6-point Likert scale (5 = daily, 0 = never).

RESULTS

The data were analysed using linear regression models with AD Manifestation Age and Diagnosis Age as the dependent variables. The predictor of interest was Group (monolingual vs. bilingual) and the control variables were Gender (factor), Education (in years), and Occupation (three levels). We also controlled for L1 (three levels: Dutch, French, and other), as there was only one French monolingual, one L1-Spanish bilingual and one L1-English bilingual patient. Furthermore, we controlled for MMSE at diagnosis (score on 30) to ascertain that the effects were not due to one group seeking medical care at an earlier stage. Table 2 gives an overview of all abovementioned variables, including the recorded mean AD manifestation and diagnosis age for both language groups.

In the analysis of Manifestation Age, we found a significant effect of Group [F (1, 109) = 6.18, p = .014, Beta = 4.64 years], indicating that bilingualism delays the manifestation of symptoms by 4.6 years. The marginal expected age (i.e. average manifestation age when controlling for all other predictors) was 71.5 for monolinguals with 95% CI = [69.2; 73.8] and 76.1 for bilinguals with 95% CI = [73.6; 78.7] (see Figure 1). There was a linear decrease with Occupation [Beta = -3.41, t(109) = -2.00, p= .048], but no quadratic effect (u-shape) of Occupation [Beta = 0.82, t(109) = 0.55, p = .582] (see Figure 2). Taken together, Occupation did not yield any significant results [F (2, 109) = 2.19, p = .117]. We also found no effects of Gender [F (1, 109) = 0.17, p = .683], Education [F (1, 109) = 0.58, p = .449], MMSE [F (1, 109) = 0.47, p = .492] or L1 [F (2, 109) = 2.16, p = .120]. When taking into account L2 AoA, the effect of bilingualism was 4.1 years [t = 1.99, p < .05] and the additional effect of L2 AoA was non-significant [t = 0.13, p = .893].

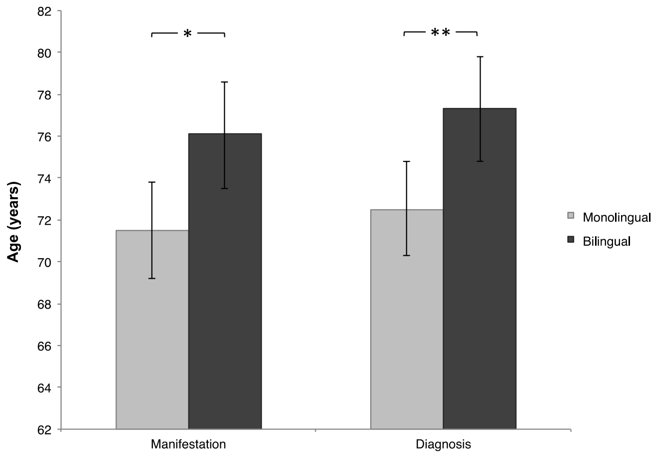

Figure 1. Marginal expected AD manifestation and diagnosis age per group. Marginal expected age of AD manifestation (left) and AD diagnosis (right) for monolinguals and bilinguals. Error bars reflect 95% CI. Horizontal bars indicate significant comparisons. *$p < .05$, **$p < .01$

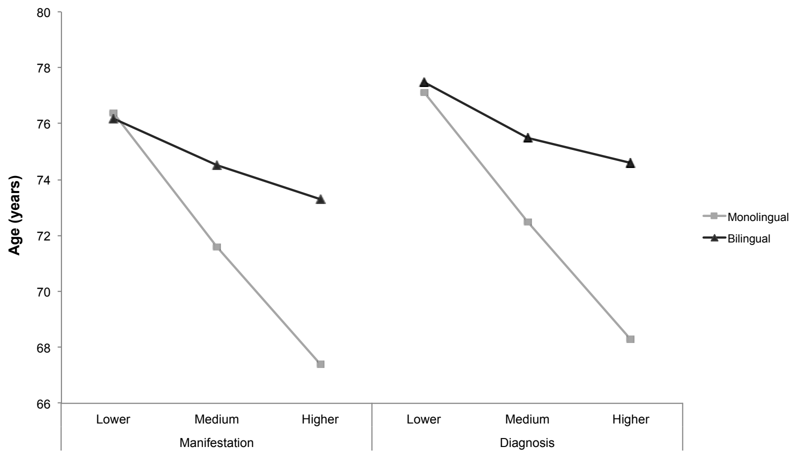

Figure 2. Age of AD manifestation and diagnosis for monolinguals and bilinguals per occupation category.

For Diagnosis Age, we observed a significant effect of Group [F (1, 109) = 7.05, p = .009, Beta = 4. 84 years], implying that bilingualism postpones the age of diagnosis by 4.8 years. Here, the marginal expected age was 72.5 for monolinguals, 95% CI = [70.2; 74.7], and 77.3 for bilinguals, 95% CI = [74.6; 79.8] (Figure 1). Occupation yielded no effect [F (2, 109) = 1.96, p = .145], neither linear [Beta = -3.12, t(109) = -1.87, p = .064] nor quadratic [Beta = 0.84, t(109) = 0.58, p = .562] (see Figure 2). There were no effects of Gender [F (1, 109) = 0.13, p = .717], Education [F (1, 109) = 0.80, p = .373], MMSE [F (1, 109) = 0.75, p = .389] or L1 [F (2, 109) = 2.10, p = .127]. Adding L2 AoA to the model, the effect of bilingualism dropped only slightly to 4.6 years [t = 2.23, p < .05]; the effect of L2 AoA was again non-significant [t = -0.21, p = .831].

Table 2. Means (and standard deviations) of dependent variables by language group, and occupation.

Group	*N*	Male/female	Age	Manifestation Age	Diagnosis Age	Initial MMSE	Education (years)
Monolingual	69	21/48	76.4 (8.5)	73.0 (8.9)	73.8 (8.8)	24.2 (3.1)	13.5 (2.8)
Lower	34	2/32	79.4 (7.2)	76.4 (7.0)	77.1 (7.0)	24.1 (3.6)	12.3 (1.4)
Medium	19	11/8	74.8 (8.8)	71.6 (9.3)	72.5 (9.7)	24.3 (2.1)	13.6 (1.9)
Higher	16	8/8	71.8 (8.5)	67.4 (9.2)	68.3 (8.8)	24.4 (3.1)	15.8 (4.2)
Bilingual	65	20/45	77.9 (7.8)	74.3 (8.7)	75.5 (8.2)	23.8 (3.4)	14.7 (3.1)
Lower	15	1/14	80.3 (6.1)	76.2 (6.6)	77.5 (6.8)	22.4 (2.3)	12.1 (2.0)
Medium	15	4/11	77.3 (10.0)	74.5 (10.9)	75.5 (10.4)	23.2 (4.9)	13.4 (2.0)
Higher	35	15/20	77.1 (7.4)	73.3 (8.5)	74.6 (7.8)	24.6 (2.7)	16.4 (2.8)

DISCUSSION

The purpose of this study was to determine whether bilingualism delays the clinical manifestation of dementia symptoms, and more specifically of AD. We investigated this in a homogeneous European non-immigrant population living in an L1-dominant environment, by comparing a systematic sample of 69 native Belgian monolinguals and 65 native Belgian bilinguals. These were all patients diagnosed with probable AD, systematically referred to us by two neurologists from the University Hospitals of Ghent and Brussels. Controlling for confounding variables (such as gender, education, occupation, initial MMSE, and L1), we observed a clear delay of 4.6 years for clinical manifestation age and 4.8 years for diagnosis age in our systematic sample of bilingual AD patients. Age of L2 acquisition did not influence this effect. We found no strong significant effects of control variables, although there was a linear effect between AD manifestation and occupation, with more demanding occupations yielding earlier AD manifestation. This may seem counterintuitive, but note that faster AD progression with higher education has also been reported earlier (Scarmeas, Albert, Manly, & Stern, 2006). Furthermore, other more demanding occupations may be associated with other factors, such as stress due to high job strain and sleep deprivation, which have been shown to speed up clinical AD manifestation (Di Meco, Joshi, & Praticò, 2014; Wang, Wahlberg, Karp, Winblad, & Fratiglioni, 2012).

Our findings strengthen the claim that bilingualism contributes to cognitive reserve and postpones the symptoms of dementia, even when AD patients are non-immigrants living in an L1-dominant environment, coming from a homogeneous population with regard to ethnicity, culture, environment, and patterns of language use. The Canadian studies found an onset delay only in immigrant groups (Bialystok et al., 2007; Craik et al., 2010; Schweizer et al., 2011), but not in non-immigrants (Chertkow et al., 2010). The former group is by definition not a random sample of the population in many ways, and their advantage, albeit interesting, may originate from a rather particular and demanding language (L2-dominant) context. It is for instance conceivable that immigrants who learn the main language of the community (as opposed to immigrants who do not, but also relative to non-immigrant community members) are less isolated and socially or cognitively active people, so that they are not a random sample of the population, comparable to the monolinguals. It is also feasible that later L2 acquisition or living in an L2-dominant environment requires greater cognitive effort, leading to more cognitive reserve. Studies demonstrated that this advantage would then only apply to people who immigrated during young adulthood (Bialystok et al., 2007; 2014), but not to those who did so later (i.e. over the age of 34; Zahodne, Schofield, Farrell, Stern & Manly, 2014). Although the current study did not find an effect of L2 AoA, it must be noted that the oldest L2 learners were only 25.

These findings are also consistent with a recent study conducted in India, also showing differences in dementia onset between monolingual and bilinguals (Alladi et al., 2013). In this study, the bilingual population was very heterogeneous, even containing illiterates, and a lot of different language combinations. These participants seemed to live in a truly bilingual environment, including minority groups with a different native language (i.e. Dakkhini) from the dominant language of the environment (i.e. Telugu). We were able to generalise this effect to a non-immigrant and non-minority bilingual population. Furthermore, unlike most previous studies, we took into account both age of L2 acquisition and extent of L2 language use, as reported measures of these two linguistic variables were also evaluated.

To conclude, our results are consistent with the body of literature started by Bialystok et al. (2007). Furthermore, they replicate the effect bilingualism has on a variety of dementias in non-immigrant patient samples (Alladi et al., 2013), specifically for AD. Additionally, these findings are not only important for cognitive wellbeing of patients, but also for health care policy. Brookmeyer, Johnson, Ziegler-Graham, and Arrighi (2007) forecasted the global burden of AD and evaluated the potential impact of interventions that delay disease onset and progression. They demonstrated that prevention programmes with two-year delays would decrease the prevalence of AD by 22.8 million cases. Even a modest one-year delay would result in 11.8 million fewer cases worldwide. It is staggering that bilingualism generates effects, to which no pharmacologic intervention up to date can aspire. This also implies that bilingualism could reduce health care cost and possibly postpone institutionalisation.

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CHAPTER 6
CAN FACES PRIME A LANGUAGE?[1,2]

Bilinguals have two languages that are activated in parallel. During speech production, language selection must occur on the basis of some cue. The present study investigated whether the face of an interlocutor can serve as such a cue. Spanish-Catalan and Dutch-French bilinguals were first familiarised with certain faces and their according speech language during simulated Skype conversations. Afterwards, they carried out a language production task, in which they generated words associated with the words produced by familiar and unfamiliar faces on screen. Participants reacted faster when the familiar face spoke the same language as previously in the Skype simulation as opposed to when they employed another language. Furthermore, the effect of familiar faces disappeared when it became clear that the interlocutor was actually a bilingual. This suggests that faces can prime a language, but their cueing effect disappears when it turns out that they are unreliable as language cue.

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[2]This study was co-authored by Clara D. Martin, Charlotte Vanden Bulcke, Eva Van Assche, Albert Costa, Robert J. Hartsuiker, and Wouter Duyck.

INTRODUCTION

A bilingual walks into a bar in Barcelona and starts up a conversation with a gentleman sitting at a table. Their conversation is interrupted by a phone call from the bilingual's Spanish-speaking mother. When putting down the phone, he wants to resume the conversation, but starts wondering which language he was speaking with the gentleman prior to the interruption. Was it Spanish or was it Catalan?

Bilinguals have two available languages and continuously need to select the appropriate one for the given context. They seem to do this quite effortlessly, despite their two languages being constantly activated in parallel during speech production (Costa, Caramazza, & Sebastián-Gallés, 2000; Van Hell & Dijkstra, 2002) and comprehension (Colomé, 2001; Dijkstra, Grainger, & van Heuven, 1999; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009) in both the first (L1) and the second (L2) language. For instance, Costa et al. (2000) asked Catalan-Spanish bilinguals to name pictures whose names were either cognates (i.e. words with the same meaning and similar orthography and phonology) or non-cognates in the two languages. They found that bilinguals displayed shorter naming latencies for cognates than for non-cognates. This cognate facilitation effect supports the notion that lexical access is language non-selective.

Because speech production requires language selection at some point during the production process, language non-selective access implies a control mechanism that activates the proper language. Several theories have been proposed to explain this mechanism (e.g. Costa, Miozzo & Caramazza, 1999; Dijkstra & van Heuven, 2002; Green, 1998; Poulisse & Bongaerts, 1994). For instance, Poulisse and Bongaerts' model assumes that L1 and L2 words are stored in a single network, lemmas are tagged with a language label (cf. Green, 1986) and language selection is driven by language cues in the conceptual input. Strikingly, none of these models are clear about which sort of cue initiates language selection. It is assumed that, in everyday life, language selection is determined by bottom-up information provided by context, such as the language in which the bilingual is being addressed. In experimental conditions, language selection can be driven through other contextual cues, such as prime words or sentences. Nevertheless, it seems that these linguistic cues are often not sufficient to regulate language activation.

Hermans, Bongaerts, de Bot, and Schreuder (1998) showed that Dutch-English bilinguals were unable to restrict language activation to the target language in a picture-word interference paradigm. Their participants had to name the pictures in English, appearing along with spoken English words that were to be ignored. When the English word distractors were phonologically similar to the Dutch picture names, naming latencies were significantly slower. Colomé and Miozzo (2010) presented Spanish-Catalan bilinguals with pairs of partially overlapping coloured pictures and were instructed them to name the green picture in Spanish and ignore the red picture, which was either a cognate or non-cognate in Catalan. They determined that distractor pictures with cognate names interfered more with picture naming than those with non-cognate names.

These studies demonstrate that linguistic cues are not sufficient to restrict activation to a single language. Therefore, a number of other studies proposed that visual cues, which are extrinsic to the stimuli that are processed, might be able to do so, such as the sociocultural identity of a face. When Chinese-English bilinguals were instructed to name pictures of objects, their responses were facilitated when the picture of the object was preceded by an image of a face consistent with the target language (e.g. an Asian face for a Chinese response) (Li, Yang, Scherf, & Li, 2013). In contrast, face identity has also been found to impede speech production. This was demonstrated when Chinese immigrants' fluency in English was reduced when speaking to a Chinese instead of a Caucasian face (Zhang, Morris, Cheng, & Yap, 2013).

In the same line, Molnar, Ibañez-Molina, and Carreiras (2015) recently suggested that face familiarity facilitates language comprehension. The authors established that proficient Basque-Spanish bilinguals were faster to comprehend words delivered in the language previously associated with the interlocutors. Furthermore, according to Hartsuiker and Declerck (2009), face familiarity also influences language production. They asked Dutch-English bilinguals to describe what was happening with pictures of famous native English-speaking or native Dutch-speaking people (e.g. "Jennifer Aniston and Elvis Presley move up"), they found that participants experienced more non-target language intrusions when the language of the famous person's face and name was inconsistent with the language they were instructed to employ. For instance, participants instructed to reply in Dutch would utter the English instead of the Dutch conjunction (e.g. "Jennifer Aniston *and* Elvis Presley gaan naar boven").

The present study investigated whether a familiar face can serve as a language cue and subsequently affect language selection and production. Previous studies demonstrated a relation between the cultural identity of a face and a language, but does the relation between a face and a language persist when there is no cultural cue? In other words, can the face of the gentleman in the bar help the bilingual in selecting the appropriate language? If so, language selection should be facilitated in any linguistic task where the target language is congruous with the language linked to the familiar face, while overriding this link (i.e. having to speak in a language not associated with the face) may result in costly top-down effects.

In order to test this hypothesis, we performed a language production task in Spanish-Catalan (Experiment 1) and Dutch-French (Experiment 2) bilinguals who were primed by familiar faces. First, participants were familiarised with 12 previously unknown faces through simulated Skype interactions (six spoke one language, six the other). In the subsequent test phase, participants were required to generate words semantically related to the stimuli produced by both familiar and unfamiliar faces. Familiar faces could utter words either in the same language as during the Skype interactions (congruent trials) or in the language that was used by the other half of the interlocutors (incongruent trials). The unfamiliar faces served as baseline. Congruent, incongruent, and baseline trials were mixed and could appear in either language. To avoid effects of language switching (Costa & Santesteban, 2004; Meuter & Allport, 1999), we also included filler trials produced by other unfamiliar faces to precede language switches. Thus, both congruent and incongruent trials were always non-switch trials.

If familiar faces can indeed serve as language cues, participants would be faster in responding to congruent trials as opposed to baseline and incongruent trials. To ensure there was enough time for language selection, all faces started speaking two seconds after they appeared on screen.

EXPERIMENT 1

METHOD

Participants

Twenty-four Spanish-Catalan participants, all early bilinguals, were recruited from the University of Pompeu Fabra in Barcelona. All participants were naive to the purpose of the experiment. Instead, they were told the study explored the interactions between people via social media, such as Skype. Participants completed a questionnaire about their language proficiency and usage. A 5-point Likert scale was employed to tap into four language skills (comprehending, speaking, reading, and writing), ranging from 1 (rather bad) to 5 (native speaker level) in both Spanish and Catalan. A composite score was created to measure first language (L1) and second language (L2) proficiency. All means are reported in Table 1.

Table 1. Demographic data for Experiment 1 and 2.

	Experiment 1	Experiment 2
N	24	30
Male/female ratio	10/14	9/21
Age	21.7 (3.3)	24.4 (6.0)
First language (L1)		
Age of acquisition	0.0 (0.0)	0.2 (0.8)
Proficiency	4.9 (0.3)	4.9 (0.3)
Second language (L2)		
Age of acquisition	0.0 (0.0)	5.6 (4.5)
Proficiency	4.8 (0.4)	3.8 (0.6)

Materials and procedure

All participants were tested individually and the entire experiment lasted about 1.5 hours per participant. Tasks were presented via E-Prime 2 on an IBM-compatible laptop computer with a 15-inch screen, running XP. A voice key recorded all response latencies.

Exposure phase. This phase consisted of simulated Skype conversations with 12 different interlocutors and four interaction scenes per interlocutor. All scenes were recorded beforehand and superimposed on a Skype chat frame. A movie frame contained the face and shoulders of the interlocutor centred on screen in front of a white background. There were no ethnic differences between the interlocutors' faces.

The interaction scenes were divided into two fragments, in which the interlocutor provided some information about him/herself and asked a question. The first fragment of each interaction always contained the interlocutor's Skype name (e.g. *Nube Blanca* [White Cloud]). The scenes were ordered by interaction; first all interlocutors introduced themselves through the first interaction scene, afterwards all second interactions were completed and so on. Two interaction lists were created, in which half of the interlocutors spoke Spanish and the other half Catalan. Although all interlocutors were recorded in both languages, participants only heard them speak one of the two languages. The interlocutors' language was counterbalanced across lists.

Participants were seated in front of the computer and presented with one of the interaction lists. Skype windows appeared on screen and participants were asked to engage in conversation by answering the interlocutors' questions. Participants were not aware that their responses did not matter for the rest of the experiment. They were allowed to use any language during the interactions, but in most of the cases they used the one chosen by the interlocutor.

Test phase. The test phase was composed of a noun-verb association task, consisting of 72 Catalan nouns or their Spanish translation equivalent

(Appendix A), each used in one of three conditions (congruent, incongruent, and baseline). Only nouns that could easily be related to a verb were chosen, while cognates and false friends were excluded. Mean log frequency per million words was matched for Catalan and Spanish target words (M_{Catalan} = 1.15, M_{Spanish} = 1.14; p = .89) using NIM, an online stimuli search engine for Spanish, Catalan, and English (Guasch, Boada, Ferré, & Sánchez-Casas, 2013).

A total of 12 randomisation lists was created with four types of stimuli. Each list included 24 nouns produced by the interlocutors from the exposure phase (i.e. familiar faces) in the same language (congruent trials) and 24 in the other language (incongruent trials). Furthermore, a list comprised 24 baseline and 13 to 16 filler words. Therefore the total amount of trials per list varied from 85 to 88. Filler and baseline words were produced by unfamiliar faces. Each familiar face appeared four times; twice as a congruent and twice as an incongruent trial. The unfamiliar faces also appeared four times; twice in Catalan and twice in Spanish.

Faces appeared one by one, centred on screen in front of a white background. After 2000 ms, the face produced the stimulus in Catalan or Spanish. Participants were asked to respond to these stimuli as quickly as possible, producing the first verb they associated with and in the same language as the given stimulus. They were given up until 5000 ms to respond, then the programme automatically moved on to the next trial.

Post-test phase. A face-language association task served as a manipulation check. Participants were presented with the 12 familiar faces and had to indicate whether these spoke Catalan or Spanish during the Skype simulation. That way, we were able to determine whether the exposure phase was sufficient for the participants to memorise both the face and its language.

RESULTS

Association task. Analyses were performed on reaction times (RTs) of correct responses. These included all verbs that could in some way be associated with the stimulus, even when the response was unexpected. All RTs deviating more than 2.5 SD from an individual's mean were excluded from further analyses. This procedure eliminated 0.02% of all data. Omissions (0.04% of all data) and errors (e.g. responding in the incorrect language; 0.01% of all data) were not included in the analysis.

We performed a within-subject 2 (Language: Spanish, Catalan) x 3 (Condition: baseline, congruent, incongruent) ANOVA on mean RTs; which yielded a main effect of Language ($F_{1,23}$ = 16.71, p < .001, ηp^2 = .421) and Condition ($F_{2,23}$ = 75.76, p < .001, ηp^2 = .767). Participants responded faster in Spanish than in Catalan. There was no Language*Condition interaction ($F_{2,23}$ < 1.00, *ns*). Paired-samples *t*-tests revealed a significant difference between baseline and congruent trials (t_{23} = 10.42, p > .001) and between baseline and incongruent trials (t_{23} = 9.93, p > .001). Participants responded slower to baseline compared with both congruent and incongruent trials (see Table 2). There was no difference between congruent and incongruent trials (t_{23} = 0.14, p = .892). Nouns appeared only in one condition, so a between-item analysis on them was performed to validate the within-subject results. A 2 x 2 ANOVA with Language (Spanish, Catalan) as within-subject and Condition (baseline, congruent) as between-subject factor revealed no main effect of language ($F_{1,70}$ = 3.09, p = .083, ηp^2 = .042), but a significant main effect of Condition ($F_{1,70}$ = 5.91, p = .018, ηp^2 = .078) and no Language*Condition interaction ($F_{1,70}$ < 1.0, *ns*). The difference between baseline and congruent trials was 280 ms on average.

Table 2. Reaction times (SD) in Experiment 1 and 2.

	Experiment 1	Experiment 2
Baseline	1885 (283)	2187 (375)
Congruent	1578 (271)	2196 (419)
Incongruent	1575 (258)	2348 (498)

A follow-up analysis tested for the possibility that any effect of congruency dissipated over the course of the experiment. Position was taken into account and the 42 trials were divided into the first six (Position 1) and the remainder (Position 2) of the congruent and incongruent trials. The cut-off between Position 1 and 2 was placed at the first six trials, in order to have sufficient data points in both languages and to make sure the participants had seen every speaker once (either in the congruent or incongruent condition). A 2 (Language) x 2 (Condition: congruent and incongruent) x 2 (Position) ANOVA was conducted and produced significant main effects of Language ($F_{1,19} = 18.53$, $p < .001$, $\eta p^2 = .446$), but not of Condition ($F_{1,19} = 3.05$, $p = .094$, $\eta p^2 = .117$) or Position ($F_{1,19} = 1.05$, $p = .316$, $\eta p^2 = .044$). Crucially, the Condition*Position interaction was significant ($F_{1,19} = 6.71$, $p = .016$, $\eta p^2 = .226$), the Language*Condition and Language*Condition*Position interactions were not (all *F*s < 1.0). Paired-samples *t*-tests revealed that there was a significant difference between congruent and incongruent trials at Position 1 ($t_{23} = -2.38$, $p = .026$), with faster RTs on congruent trials. There was no congruency effect at Position 2 ($t_{23} = 1.65$, $p = .113$) (Figure 1). Adding Position to the between-item ANOVA did not yield any significant effects, possibly due to too few observations.

Face-language association. The mean of correct face-language associations was 85.5% (Catalan: 83.3%, *SD* = 15.1%; Spanish: 87.7, *SD* = 12.5). No significant effects of Language appeared in remembering the language associated with a face.

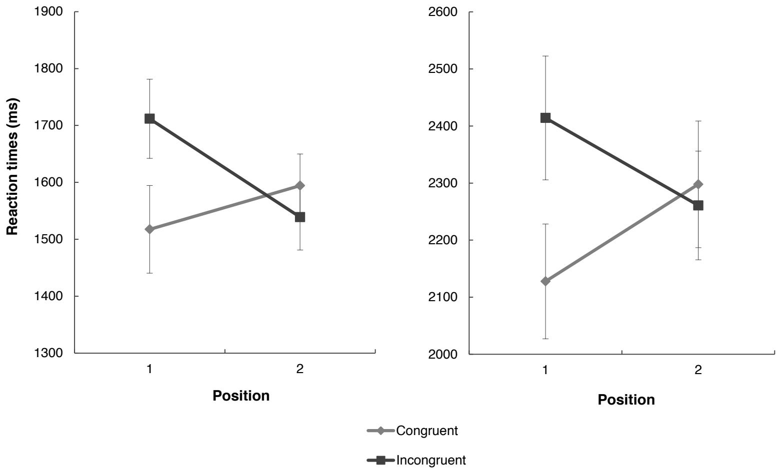

Figure 1. RTs (ms) for congruent and incongruent trials by position. RTs by position for Experiment 1 (left) and RTs by position for Experiment 2 (right).

DISCUSSION

Overall, the noun-verb association task yielded no effect of congruency. However, when looking only at the first six trials of the experiment, participants clearly responded much faster to congruent trials. These results suggest that faces can serve as a cue for a specific language. Moreover, the face-language association task confirmed that participants actually related an interlocutor's face to a certain language. The fact that the congruency effect disappeared rather quickly in the test phase was probably due to the early mixture of congruent and incongruent trials, since there was an interaction between congruency and position. This demonstrates that while faces can prime a language, their effect rapidly vanishes when it turns out they are unreliable as language cue (i.e. when it becomes clear that the face at hand speaks more than one language.

Throughout the experiment, participants were faster responding to Spanish nouns, even though they claimed to be balanced bilinguals. Nevertheless, language never interacted with the effect of interest, namely that of condition.

All in all, the results of Experiment 1 demonstrate a priming effect of face, albeit only on the first trials. Because participants already experienced early on in the test phase that the familiar faces actually spoke two languages, we modified our design in Experiment 2. This was conducted among Dutch-French bilinguals and the association task comprised two blocks. Block 1 contained only baseline and congruent trials, while Block 2 consisted of both congruent and incongruent trials. Additionally, a noun-noun instead of a noun-verb association was employed, because of the availability of a normed database to control for association frequency in both French and Dutch.

Our hypothesis remained that familiar faces have the ability to prime language. We assumed RTs on congruent trials in Block 1 to be faster than the RTs on incongruent trials in Block 2. Furthermore, we expected the congruency effect to persist only in the beginning of Block 2 and to quickly disappear, analogous to the results in Experiment 1, as the incongruent trials again will have modified the participants' expectations.

EXPERIMENT 2

METHOD

Participants

We tested 30 highly proficient Dutch-French bilinguals recruited in Ghent and Brussels. All participants were naive to the purpose of the experiment. There were 7 participants bilingual from birth, 8 early bilinguals (L2 acquired between 1 and 6), and 15 late bilinguals (L2 acquired after age 6). Five participants indicated French as L1, while the others indicated Dutch. Participants completed a questionnaire about their language proficiency and usage. Again, a 5-point Likert scale was used to tap into four language skills in both Dutch and French and a composite score was created (see Table 1).

Materials and procedure

The procedure was the same as in Experiment 1. Oral responses were recorded via Edirol R-1 and RTs were determined manually in Praat (Boersma & Weenink, 2013).

Exposure phase. Materials were the same as in Experiment 1, except that all interaction scenes contained Belgian interlocutors speaking Dutch and French.

Test phase. The test phase was composed of a noun-noun association task, consisting of 48 French and Dutch nouns (Appendix B), appearing in all conditions (baseline, congruent, and incongruent). Only nouns that could easily be related to another and with the highest association frequency were chosen. Association frequency (M_{Dutch} = .18, M_{French} = .18), calculated using the database of De Deyne and Storms (2008), and number of phonological syllables (M_{Dutch} = 1.35, M_{French} = 1.45) were matched between Dutch target words and their French translation equivalents. Mean log frequency per million was also matched for Dutch and French targets (M_{Dutch} = 1.78, M_{French} = 1.80), using the WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004) on the basis of the Dutch CELEX corpus (Baayen, Piepenbrock, & Van Rijn, 1993) and the French Lexique corpus (New, Pallier, Brysbaert, & Ferrand, 2004). Paired samples t-tests showed that Dutch target words and their French translation equivalents were similar with respect to all these variables (all *p*-values > .13).

Eight randomisation lists of 66 trials were created and each contained two blocks. Block 1 consisted of 12 baseline words, 9 filler words, and 12 congruent words; Block 2 of another 9 filler words, 12 congruent words, and 12 incongruent words.

Post-test phase. The face-language association task was the same as in Experiment 1.

RESULTS

Association task. Analyses were performed on correct response RTs only. RTs were measured from the onset of the stimulus until the onset of the associated word produced by the participant. All RTs deviating more than 2.5 SD from an individual's mean RT were excluded from further analyses. This procedure eliminated 2.9% of all data. Error rates were high and included omissions (2.4%), responses in the incorrect language (2.1%) and grammatical category errors (i.e. responses that were not nouns) (7.4%). Stimuli that led to misinterpretations due to homophony (e.g. the French word 'bouche' was often interpreted as the English name 'Bush') were also excluded (2.9% of the data).

A 2 (Language: Dutch, French) by 2 (Condition: baseline, congruent) within-subject ANOVA was performed on mean RTs. There was a main effect of Language ($F_{1,29}$ = 8.63, p = .006, ηp^2 = .229), but not of Condition ($F_{1,29}$ < 1.0, *ns*) (Table 2). Participants responded faster in Dutch. There was no significant Language*Condition interaction ($F_{1,29}$ = 3.56, p = .069, ηp^2 = .109). Block 2 was the critical one for comparison with Experiment 1. A 2

(Language) x 2 (Condition: congruent, incongruent) ANOVA was performed on mean RTs in Block 2. Again, there was a main effect of Language ($F_{1,29}$ = 8.46, p = .007, ηp^2 = .226), but not of Condition ($F_{1,29}$ = 3.16, p = .086, ηp^2 = .098) and no interaction ($F_{1,29}$ < 1.0, *ns*). The same ANOVA was done within-item and produced a main effect of Language ($F_{1,20}$ = 11.56, p = .003, ηp^2 = .366), not of Condition ($F_{1,20}$ < 1.0, *ns*), and a Language*Condition interaction ($F_{1,20}$ = 5.37, p = .031, ηp^2 = .212).

A follow-up analysis tested for the possibility that any effect of Condition vanished over the course of Block 2. The position of congruent and incongruent trials was taken into account. The 24 trials were divided into the first half (Position 1) and the second half (Position 2) of congruent trials. The same was done for the incongruent trials. Then, a 2 (Language) x 2 (Condition) x 2 (Position) was conducted and yielded a main effect of Condition ($F_{1,25}$ = 4.68, p = .040, ηp^2 = .158) and Language ($F_{1,25}$ = 5.82, p = .024, ηp^2 = .189), but not of Position ($F_{1,25}$ < 1.0, *ns*). Critically, the Condition*Position interaction was significant ($F_{1,25}$ = 8.03, p = .009, ηp^2 = .243). No other interactions were significant (all Fs < 1.0). Paired-samples t-tests revealed a significant difference between congruent and incongruent trials at Position 1 (t_{29} = -3.16, p = .004), but not at Position 2 (t_{29} = 0.44, p = .666) (Figure 1). The within-item analysis also revealed a significant Condition*Position interaction ($F_{1,18}$ = 5.45, p = .031, ηp^2 = .232). No other effects were significant. Paired-samples showed a significant congruency difference at Position 1 (t_{23} = -4.54, p < .001), not at Position 2 (t_{23} = 0.33, p = .743).

To test the congruency effect when congruent and incongruent trials were not mixed, we applied a 2 Language x 2 (Condition: Block 1 congruent, Block 2 incongruent) ANOVA. This yielded an effect of Language ($F_{1,29}$ = 6.83, p = .014, ηp^2 = .191) and Condition ($F_{1,29}$ = 6.94, p = .013, ηp^2 = .193), but no interaction ($F_{1,29}$ < 1.0, *ns*). Participants responded slower in French and to incongruent trials.

Face-language association. Due to a technical malfunction, responses of three participants were not recorded. We performed analyses on the responses of the remaining 27 participants. The mean of correct face-language associations was 92.9% (Dutch: 94.4%, *SD* = 8.0%; French: 91.4%, *SD* = 14.2), which again validates the face-language manipulation. There were no significant effects of Language.

DISCUSSION

Experiment 2 verified the congruency effect found in Experiment 1. Participants reacted much faster to congruent trials than to incongruent trials, but this effect disappeared when trials were mixed. These outcomes confirm the hypothesis that faces can prime a language as long as they are associated only with one language. When it became clear in Block 2 that the faces spoke both Dutch and French, participants were slower to respond to congruent trials and eventually also became faster on incongruent trials. Hence, a supplemental analysis comparing the congruent trials in Block 1 and the incongruent trials (which were only presented in Block 2) was performed. This analysis validated the congruency effect with faster RTs for congruent trials overall. Throughout the entire experiment, participants were faster responding to Dutch nouns. Still, this effect of language never interacted with that of condition.

The results of Experiment 2 indeed confirm that participants responded faster to familiar faces speaking the language with which it was initially associated. Again, the post task asserted that participants correctly related the interlocutors' faces to the language they employed during the Skype interactions.

GENERAL DISCUSSION

As a bilingual's two languages are constantly activated in parallel during speech production (e.g. Colomé & Miozzo, 2010; Costa et al., 2000; Van Hell & Dijkstra, 2002), language selection must occur on the basis of some type of cue. The current study aimed to investigate whether familiar faces that are specifically associated with one language could constitute such cues and consequently affect language selection. We therefore recruited Spanish-Catalan and Dutch-French bilinguals to carry out a language production task, in which they had to generate words associated with the words produced by the familiar and unfamiliar faces on screen. Prior to this task, participants were acquainted with the familiar faces by interacting with them in simulated Skype conversations. Each face was associated with only one specific language. The stimuli in the language production task consisted of congruent trials (familiar faces uttering words in the same language as during the Skype conversations), incongruent trials (familiar faces speaking in the other language), baseline trials (unfamiliar faces) and filler trials (unfamiliar faces) to precede language switches. If faces can serve as language cues, we predicted that bilinguals should be faster in responding to congruent trials as opposed to baseline and incongruent trials.

The first experiment was conducted among Spanish-Catalan bilinguals and provided evidence that a face could prime a language, as a congruency effect revealed itself and demonstrated that participants responded faster to congruent trials than to incongruent trials. Nevertheless, this effect quickly disappeared over time. Until the first incongruent trial, participants did not expect that a Spanish interlocutor could suddenly speak Catalan and vice versa. But the early mixing of congruent and incongruent trials in our design led to the participants experiencing from the beginning that familiar faces actually spoke both Catalan and Spanish. This may have influenced the congruency effect after the first couple of incongruent trials. We therefore modified the design in the second experiment carried out among Dutch-French bilinguals.

In this second experiment two blocks were created, with a first block containing only baseline and congruent trials and the second block containing both congruent and incongruent trials. An overall congruency effect with faster RTs for congruent trials was found when comparing congruent trials from the first block with incongruent trials form the second block. We also looked at the second block, where congruent and incongruent trials were again mixed. Once more, the congruency was present at the beginning, but then disappeared. This confirmed the hypothesis that language selection can be triggered by a face prime. As the congruency effect vanished in the second block after presenting the first incongruent trials, we also obtained confirmation that faces can serve as prime as long as they are associated only with one language. As soon as faces lose their predictive consistency, they are no longer used as a language cue.

In general, Spanish-Catalan bilinguals were faster and made fewer errors than Dutch-French bilinguals, perhaps due to different task requirements in association. Participants may have found it easier to generate a verb-noun association than a noun-noun association. This possibility is supported by the fact that many Dutch-French bilinguals made this type of grammatical error, producing a verb when a noun was requested. We also found that participants reacted faster in Spanish and Dutch, but type of language never interacted with the effect of condition. Additionally, Dutch-French bilinguals reported lower L2 proficiency scores than Spanish-Catalan bilinguals. We believe this is due to the fact that almost everyone in Catalonia is bilingual and therefore, there are no monolinguals for comparison. Contrastingly, in Belgium, there are plenty of monolinguals or low proficient bilinguals, and our bilinguals may compare their skills to those of these native speakers. To ascertain that L2 proficiency or age of acquisition did not affect the results, we correlated the self-reported L2 data with the congruency effects in both experiments and found no relation (all ps > .19).

To conclude, we have found that an interlocutor's face modulates language selection. Li et al. (2013) had already established that the sociocultural identity of a face primes bilingual language activation. Now, the current study has provided evidence that face familiarity without cultural bias has a similar effect. However, faces seem to lose their cueing ability the moment it becomes clear that interlocutors speak more than one language. In Molnar et al. (2015), the facilitation effect was not present either when interlocutors were associated with two languages. This suggests that faces can cue language, as long as there is a one-to-one relationship between the two, at least in non-culturally identifiable faces. Still, in both Molnar's study and our own, language could not be linked to ethnicity, as there are no facial differences between Basque and Spanish speakers, Spanish and Catalan speakers, and Dutch and French speakers. Hence, it may be that the faces in for instance Zhang et al. (2013) would hold there cuing ability for the sociocultural congruent languages, even after they have been associated with multiple languages.

Finally, our results can be unified with models of bilingual language selection. Most notably, they concur with the theories set forth by Poulisse and Bongaerts (1994), which state that language selection is determined during conceptualisation. So, a face that is linked to a particular language could activate word representations tagged with that language label. When words in the irrelevant language reach a higher level of activation (such as in incongruent trials, when the face elicits the incorrect language), it will take time to activate representations in the other language and therefore lead to longer RTs.

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APPENDIX A

Catalan	Spanish	English translation
aixeta	grifo	*tap*
ànec	pato	*duck*
armilla	chaleco	*vest*
arracada	pendiente	*earring*
banya	cuerno	*horn*
barret	sombrero	*hat*
boira	niebla	*fog*
bolquer	pañal	*nappy*
butxaca	bolsillo	*pocket*
cadira	silla	*chair*
caixa	caja	*bank*
calaix	cajón	*box*
cantonada	esquina	*corner*
catifa	alfombra	*carpet*
cendra	ceniza	*ash*
cendrer	perro	*dog*
cervell	cerebro	*brain*
cistella	cesta	*cart*
claveguera	cloaca	*sewer*
colze	codo	*elbow*
cor	corazon	*heart*
crossa	muleta	*crutch*
cuc	gusano	*worm*
dit	dedo	*finger*
dona	mujer	*woman*
emprempta	huella	*trace*
encenedor	mechero	*lighter*
escacs	ajedrez	*chess*
espatlla	hombro	*shoulder*
espelma	vela	*candle*
estovalles	mantel	*tablecloth*
estruç	avestruz	*ostrich*
ferro	hierro	*iron*
fetge	hígado	*liver*
finestra	ventana	*window*
floc	copo	*flock*
galta	mejilla	*cheek*
galteres	paperas	*mumps*
ganivet	cuchillo	*knife*
genoll	rodilla	*knee*

gos	cenicero	*ashtray*
got	vaso	*glass*
granota	rana	*frog*
guardiola	hucha	*money box*
guineu	zorro	*fox*
guix	tiza	*chalk*
ham	anzuelo	*hook*
llar de foc	chimenea	*fireplace*
llauna	lata	*tin*
llençol	sábana	*sheet*
matalàs	colchón	*mattress*
migdiada	siesta	*nap*
mirall	espejo	*mirror*
misto	cerilla	*lucifer*
mitja	media	*half*
ocell	pájaro	*bird*
pastanaga	zanahoria	*carrot*
pebrot	pimiento	*pepper*
penjador	percha	*perch*
pit	pecho	*breast*
roure	roble	*oak*
safata	bandeja	*tray*
suro	corcho	*cork*
tasca	tarea	*task*
taula	mesa	*table*
tauró	tiburón	*shark*
tempesta	tormenta	*storm*
teulada	tejado	*roof*
tisores	tijeras	*scissors*
ulleres	gafas	*glasses*
vaixell	barco	*ship*
veu	voz	*voice*

APPENDIX B

Dutch	French	English translation
aap	singe	*monkey*
appel	pomme	*apple*
baard	barbe	*beard*
beer	ours	*bear*
blad	feuille	*leaf, sheet*
bloem	fleur	*flower*
boek	livre	*book*
dorst	soif	*thirst*
eend	canard	*duck*
ei	oeuf	*egg*
fles	bouteille	*bottle*
gevaar	danger	*danger*
hond	chien	*dog*
hoofd	tête	*head*
ijs	glace	*ice*
jongen	garçon	*boy*
kaas	fromage	*cheese*
kers	cerise	*cherry*
keuken	cuisine	*kitchen*
knie	genou	*knee*
koning	roi	*king*
koorts	fièvre	*fever*
lepel	cuiller	*spoon*
maan	lune	*moon*
mantel	manteau	*coat*
melk	lait	*milk*
mond	bouche	*mouth*
oog	oeil	*eye*
oorlog	guerre	*war*
peper	poivre	*pepper*
regen	pluie	*rain*
rok	jupe	*skirt*
schaap	mouton	*sheep*
schoen	chaussure	*shoe*
school	école	*school*
sleutel	clé	*key*
station	gare	*station*
stoel	chaise	*chair*
ui	oignon	*onion*
vader	père	*father*
verkeer	trafic	*traffic*
vis	poisson	*fish*
voet	pied	*foot*

vogel	oiseau	*bird*
wekker	réveil	*alarm*
zomer	été	*summer*
zon	soleil	*sun*
zus	soeur	*sister*

CHAPTER 7
General conclusions

The aim of the research presented in this doctoral dissertation was to assess the bilingual cognitive advantage across the lifespan, taking into account the factors that may influence its development. In the first section, we set up a longitudinal field study among children to determine how acquiring a second language influences cognitive development. In the second section, we aimed at identifying how specific bilingual experiences contribute to the advantage. Particularly, we considered L2 proficiency, L2 switching frequency, switching proficiency, and interpreter training. The third section dealt with how bilingualism affects Alzheimer's disease in a non-immigrant patient sample, while the fourth section assessed whether faces can serve as a cue for language control in bilinguals. In this final chapter, the main empirical findings of this dissertation are recapitulated and the implications for the existing body of research are set forth. Finally, the chapter is concluded with some directions for future empirical endeavours.

RESEARCH OVERVIEW

COGNITIVE DEVELOPMENT IN BILINGUALS: EFFECTS ON GENERAL COGNITION

Previous research on how bilingualism affects cognition focused both on intelligence (earlier studies) and cognitive control (recent studies). Whereas the earlier studies followed an evolution from a negative (e.g. Darcy, 1946) to a positive view on bilingualism (e.g. Peal & Lambert, 1962), the recent literature is showing an almost opposite progress from positive effects (e.g. Bialystok, Craik, Klein, & Viswanathan, 2004) to null results (e.g. Paap & Sawi, 2014). The problem with this previous work is that bilingual effects were assessed by cross-sectional group comparisons, which leaves room for confounding variables. This may explain the divergent findings.

The problem of insufficient control over confounding variables is inherent to this type of cross-sectional comparisons, but can be solved by employing within-participant methods. In CHAPTER 2, we report a longitudinal field study among five-year old children, set up to assess their cognitive development. The purpose was to see whether the process of becoming a bilingual affected general cognitive development. To this end, half of the children remained monolingual after the first test moment, while the other half acquired another language through L2 immersion. Both groups were initially matched for SES, L1 proficiency, intelligence, and cognitive control, so also for the dependent variables of interest. One school year later, the groups were tested again for the same measures. With regard to L1 proficiency, the children from both groups again performed the same on a semantic fluency task, indicating that learning an L2 is not necessarily and noticeably detrimental to vocabulary acquisition in L1, even in critical stages of development. Looking at the measure of cognitive control (i.e. the Simon task), it became clear that both groups had progressed similarly once again, with faster reaction times on both congruent and incongruent trials, but no smaller congruency effects. It seemed that bilingualism had not specifically influenced cognitive control. Nevertheless, the results of Raven's Coloured Progressive Matrices, a measure on non-verbal fluid intelligence, depicted a different story. We found that initially the two groups obtained similar scores, around the 50th percentile indicating a normal IQ, but that after one school year, the L2 immersion group attained a significant 17-percentile-point gain, whereas the monolingual group only improved numerically, but not significantly. This outcome presents evidence for a bilingual advantage on non-verbal intelligence.

Ours was the first longitudinal study assessing the domain-general cognitive effect of becoming a bilingual WITHIN participants, over a longer time span. Our two groups of initially monolingual children had not yet been exposed to another language, and this remained true fact for one of the groups while the other one gradually became bilingual through L2-immersion. Even though the frequently reported cognitive control advantage was absent in our study, we believe that the observed intellectual advantage has the same origins, as the two are concepts strongly correlated (e.g. Dempster, 1991). It is possible that the Simon task was not sufficiently reliable to detect any individual cognitive ability differences (cf. Miyake & Friedman, 2012), while the intelligence test was. Of course, standardised and normed intelligence tests are more reliable and valid measures of cognitive individual differences than the Simon task, which is primarily used as an online measure of cognitive processing, rather than as a measure of cognitive ability. Furthermore, it may be that the children in our L2 immersion group had not yet been exposed long enough to an L2 for it to affect their cognitive control abilities. Indeed, length of L2-exposure has previously been shown to influence the effects of cognitive control. Poarch and van Hell (2012) demonstrated that children with three years of L2 immersion did show a cognitive control advantage, whereas those with only 1.5 years, like the children in our study, did not. Moreover, it is also conceivable that the cognitive control advantage may depend on specific bilingual experience, such as frequent language switching (Prior & Gollan, 2011). In this view, the children in our study would not show this advantage, as they spoke their L2 only at school, L1 at home, and hence, virtually never switched languages.

Still, the effect on intelligence in our longitudinal field study suggests that the process of becoming bilingual may have positive, long-term effects on general cognitive abilities, even outside the linguistic domain.

POWER OF THE BILINGUAL EXPERIENCE

A multitude of studies have been carried out on the bilingual advantage, but only few of those studies actually took into account the fact that bilingualism is not a fixed concept, but encompasses many different linguistic variables, which combine into different types of bilinguals. Lately, there have been an increasing amount of contradictory studies, either confirming (e.g. Costa, Hernández, & Sebastián-Gallés, 2008) or refuting (e.g. Paap & Greenberg, 2013) the existence of a bilingual advantage. We considered that differences in the bilingual populations under investigation might have been at the source of those contradictory findings. Hence, we inspected several these different variables to further explore their influence on the bilingual advantage.

The study presented in CHAPTER 3 was centred on how language switching frequency in daily life affects cognitive control. To that end, three different bilingual populations were compared on two different measures of inhibitory control (i.e. on versions of the flanker and the Simon task). These three populations consisted of balanced bilinguals who reported frequent language switching, balanced bilinguals who reported infrequent language switching, and unbalanced bilinguals serving as controls. The results of both tasks largely pointed into the same direction. That is, frequent switchers showed faster overall reaction times and smaller congruency effects than infrequent switchers and unbalanced bilinguals. Previous research by Prior and Gollan (2011) had already demonstrated the importance of language switch frequency in finding an advantage on switch tasks, but this study confounded switching frequency with language pair dissimilarity. In effect, the frequent switchers were all Spanish-English bilinguals, while the non-frequent switchers were Mandarin-English bilinguals. Therefore, it was unclear whether the authors found a pure effect of language switching, especially since Coderre and van Heuven (2014) recently showed that bilinguals whose two languages have a larger degree of orthographic overlap require more effective domain-general control, as high orthographic overlap creates more cross-linguistic activation and increases the daily demands on cognitive control. Our study now generalised Prior and Gollan's findings to groups with the same single language (i.e. Dutch-French) and also to inhibition tasks.

The study described in CHAPTER 4 further explored the effect of language switching on cognitive control, but the emphasis there was more on an online measure of language switching proficiency than on language switching frequency. Additionally, we conducted our research among four different language groups, namely monolinguals, unbalanced bilinguals, balanced bilinguals, and interpreters, who have undergone a very specific, extreme bilingual switching experience. To measure cognitive control, we employed the Simon task and the ANT. Switching proficiency was measured through an adapted dual-language version of the semantic verbal fluency task, in which we measured to what extent imposed constant language switches in the fluency task hindered production. The study led to three major findings. Firstly, following the research by Bialystok and colleagues, we were able to confirm a cognitive control advantage for our bilingual populations over our monolingual population. This was reflected in smaller congruency effects on the Simon task and faster overall reaction times on the ANT. Secondly, our study demonstrated higher accuracy scores for interpreters in both tasks, substantiating our hypothesis that language control training influences cognitive control. Thirdly, with regard to language switching, we demonstrated a correlation between language switching proficiency and non-verbal cognitive control in balanced bilinguals, showing that at least within one type of bilingual population, individual differences in language control abilities relate to cognitive advantages.

The results of the two studies presented in CHAPTER 3 and CHAPTER 4 confirm that the magnitude and nature of any bilingual effect may depend on the typology of the bilingual population under investigation. Specifically, we determined the role of language switching frequency in daily life, language switching proficiency, and language control experience after interpreting practice.

COGNITIVE RESERVE IN NON-IMMIGRANT BILINGUALS

Several Canadian studies conducted among non-immigrant monolingual and immigrant bilingual patients diagnosed with probable Alzheimer's disease (AD) have shown a delay in the onset of AD symptoms for the latter population (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, Binns, Ossher, & Freedman, 2014; Chertkow et al., 2010; Craik, Bialystok, & Freedman, 2010; Schweizer, Ware, Fischer, Craik, & Bialystok, 2011). The purpose of the study described in CHAPTER 5 was to investigate whether a similar delay exists in (European) non-immigrant bilingual AD patients. Hence, we compared the recorded ages of clinical manifestation of Alzheimer symptoms and the ages of diagnosis for both monolinguals and bilingual patients originating from Belgium. All incoming probable AD patients at the University Hospital of Ghent (mainly monolinguals) and the University Hospital of Brussels (mainly bilinguals) were systematically recruited. Medical assessments were made by two neurologists at the respective hospitals. We carried out patient and caregiver interviews to gain knowledge into the patients' linguistic background, paying specific attention to L2 proficiency, L2 AoA, and L2 use.

Eventually, a total of 69 native Belgian monolingual and 65 native Belgian bilingual probable AD patients participated in the study. Analyses on their ages of clinical AD manifestation and AD diagnoses revealed a clear delay of 4.6 years for manifestation age and 4.8 years for diagnosis age in our sample of bilingual AD patients. Age of L2 acquisition did not influence this effect. In these analyses, we carefully controlled for confounding variables, such as patient education, occupation, initial MMSE scores, and gender. No significant effects of control variables were found, apart from a linear effect between AD manifestation and occupation, with more demanding occupations yielding earlier AD manifestation. This may be the result of more demanding occupations being associated with stress due to high job strain and sleep deprivation, which have been shown to speed up clinical AD manifestation (Di Meco, Joshi, & Praticò, 2014).

Consequently, our findings are consistent with the AD delay observed in the Canadian immigrant bilingual samples. Moreover, they replicate the effects reported by Alladi et al. (2013). This study demonstrated an effect of bilingualism on a variety of dementias in non-immigrant Indian patient samples.

FACES AS A CUE FOR LANGUAGE CONTROL

The majority of studies presented in this dissertation is concerned with how managing two competing languages affects cognition, but the final study described in CHAPTER 6 was set up to look beyond the cognitive consequences of bilingualism and focus on how this coping with two languages is achieved. A number of bilingual speech production and comprehension models have been proposed (e.g. Dijkstra & van Heuven, 2002; Green, 1998; Poulisse & Bongaerts, 1994), which all hypothesise some type of activation of the relevant language during lexical selection, and inhibition of the relevant language. However, none of them specifies the factors that actually trigger this selection. From a few empirical explorations, we know that linguistic cues seem to be insufficient to restrict activation to a single language (cf. Dijkstra, Grainger, & van Heuven, 1999; Marian, Spivey, & Hirsch, 2003). Van Assche, Duyck, Hartsuiker, and Diependaele (2009), for instance, showed that even the (unilingual) language of a sentence in which a to-be-recognised word occurs does not suffice to restrict lexical search to lexical representations of the language of the sentence. Because linguistic cues seem ineffective, our last empirical chapter explored whether non-linguistic cues, such as the face of an interlocutor, can direct language activation.

Our study comprised two experiments, one conducted among Spanish-Catalan bilinguals in Spain and the other among Dutch-French bilinguals in Belgium. All participants first completed a number of simulated Skype conversations in their two languages, during which they were familiarised with certain faces and their according speech language, and then carried out an oral word association task. The words in this task were produced by both familiar (previously seen during the Skype simulation) and unfamiliar faces in the bilinguals' two languages. Results showed that participants in both experiments were faster to produce an associated word when a familiar face used the same language associated with that face during the Skype simulation. Nonetheless, this effect of congruency disappeared over time, when the faces also began speaking the other language and hence lost their predictive value for language. This outcome suggests that the face of an interlocutor can serve as a cue for language selection, as long as the face is associated with only one language. When a face loses its predictive consistency, it is no longer used as a language cue.

Our results are in line with Li, Yang, Scherf, and Li (2013) and Zhang, Morris, Cheng, and Yap (2013); who found that the sociocultural identity of a face also influences language activation. Now, we obtained evidence that faces affect language activation, independent of their sociocultural identity. Furthermore, they mirror the effect recently found by Molnar, Ibañez-Molina, and Carreiras (2015) that face familiarity drives language selection during comprehension. These authors demonstrated that proficient Basque-Spanish bilinguals were faster to comprehend words when interlocutors delivered them in the same language with which they were previously associated and not in another.

Our findings can also be unified with the theories set forth by Poulisse and Bongaerts (1994), which propose that language selection is determined during conceptualisation and that the presence of a language cue in the preverbal message suffices to produce speech in the intended language by activating lemmas of the appropriate meaning and language. In other words, the speaker's intention to use one language would activate the words of that language more than the word equivalents in the other language. The results from our study showed that a non-linguistic cue, such as a face that is linked to one particular language could activate word representations tagged with that language label.

IMPLICATIONS

The current dissertation aimed at exploring whether and how bilingualism affects cognition. In doing so, we discovered that different language experiences are actually able to modulate the cognitive effects associated with bilingualism. Hence, the empirical findings presented here bring about theoretical implications for past and future research.

First of all, we want to point out that every study we conducted on the bilingual cognitive advantage yielded some confirmation of the phenomenon, throughout different stages in the bilingual lifespan. This, in itself, is of great importance as its existence has been increasingly questioned in recent literature (Kousaie & Phillips, 2012; Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014; Paap & Greenberg, 2013; Paap & Sawi, 2014). A recent study by de Bruin, Treccani, and Della Sala (2014) even suggested that the idea of a bilingual advantage might be the result of a publication bias favouring studies with positive results. Their findings indicate that this is in fact partly the case; studies lending support to the advantage theory were most likely to be published. Still, their meta-analysis based on published studies showed a positive effect of bilingualism and when the results of unpublished studies were included, the effect was still present, albeit smaller. In Table 1, we present our own comprehensive list of all bilingual advantage studies that could be found on Web of Science on 28th October 2014, with their respective tasks and measures. We only included studies reporting on non-verbal cognitive tasks, which still included a wide variety of paradigms. Out of the 456 measures reported over all studies, a total of 95 measures showed a bilingual advantage. These 95 measures consist both of overall effects and congruency effects, on reaction times as well as on accuracy scores. The results of current dissertation are therefore in line with these studies reporting benefits for bilinguals. Secondly, our results once more highlight the importance of controlling for different linguistic variables and of taking into account task differences. Thirdly, beyond cognitive control and with regard to language control, we established that cues outside the linguistic domain serve as a trigger for language selection in bilinguals.

IMPORTANCE OF LINGUISTIC PARAMETERS

Bialystok and Barac (2012) had already demonstrated in a sample of bilingual children that executive control performance improved with increased experience in a bilingual education environment. Similarly, Poarch and van Hell's (2012) factor analysis had shown a cognitive advantage for children with three years of L2 immersion, but not for those with only 1.5 years. Furthermore, Kapa and Colombo (2013) had demonstrated that, even when L2 proficiency is matched, L2 AoA could still play a role, as only early bilinguals in their study exhibited better cognitive skills. The studies presented here in CHAPTER 3 and 4 add to these previous findings by verifying the influence of L2 proficiency and establishing effects of language control practice, such as language switching and interpreter training. The fact that we found an effect of language switching frequency (CHAPTER 3) and of language switching proficiency (CHAPTER 4) in bilinguals with the same language combination (i.e. Dutch-French) provides strong evidence that bilingual language control modulates the cognitive advantage.

Another aspect that we investigated in this dissertation was immigration status, and this with respect to delays in onset of dementia. The results of our dementia study carried out here in Europe (Belgium) and presented in CHAPTER 5 demonstrated that even non-immigrant bilinguals display later manifestation of AD than monolinguals. This study thus strengthens the assumption that bilingualism stimulates formation of white and grey matter in the brain (Abutalebi, Canini, Della Rosa, Freen, & Weekes, 2015;

Abutalebi, Canini, Della Rosa, Sheung, Green, & Weekes, 2014; Luk, Bialystok, Craik, & Grady, 2011). Due to this increased white and grey matter density, bilinguals would have more brain reserve, translating into better cognitive functioning even during old age (i.e. they would have more cognitive reserve; Stern 2002), and coping better and longer with cognitive degeneration.

THEORETICAL IMPLICATIONS

Overall, the studies presented in this dissertation produced results in favour of a bilingual cognitive advantage. This suggests that bilingualism must imply some sort of cognitive training that leads to these benefits. Our findings can be connected to Green's model of Inhibitory Control (IC, 1998), which proposes bilingual language activation takes place through activation of words in the relevant language and active inhibition of those in the unintended language (Figure 1). According to the model, these processes of language activation and language inhibition are governed by domain-general mechanisms. It is conceivable that the constant need to suppress one language and the practice of having to switch frequently between languages also trains the non-verbal mechanisms of control leading to the cognitive advantage in bilinguals.

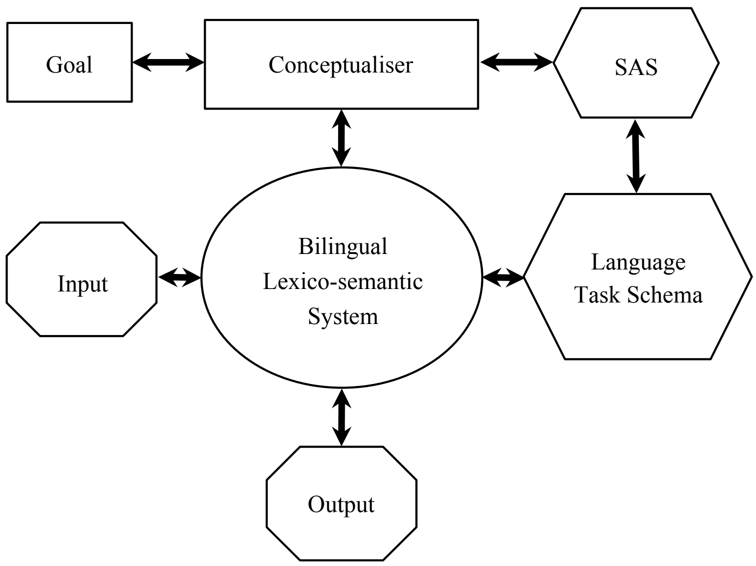

Figure 1. Green's model of Inhibitory Control (1998). The bilingual advantages found here provide evidence that language activation and inhibition mechanisms are indeed domain-general.

A neural basis for these assertions was given by Abutalebi and Green (2007). They determined that cognitive control emerges from the integration of separable neural systems, including the anterior cingulated cortex, the basal ganglia, the inferior parietal lobule and most prominently the prefrontal cortex. Crucially, their neuroimaging data suggested that bilingual language control during word production relies on the same mechanisms (Figure 2). The left basal ganglia and the anterior cingulate cortex were found to modulate activity in the left prefrontal cortex, providing a normal modulatory influence on the left prefrontal cortex and inferior parietal cortex; i.e. the systems mediating word production.

The cognitive advantages found in this dissertation verify the theories set forth by the IC model. In CHAPTER 2, we discovered that children enrolled in bilingual school programmes actually improved on tasks of logic reasoning, whereas monolingual children did not. It is conceivable that learning a second language led to this enhanced cognitive development. Additionally, CHAPTER 4 demonstrated that groups of bilinguals displayed cognitive control benefits over a group of monolinguals. This was probably due to their experience in dealing with a second language, hereby training their mechanisms of inhibition. Furthermore, both CHAPTER 3 and 4 showed that more experience with bilingual language control due to frequent language switching leads to greater advantages. This suggests that practising language switching also practises the general control mechanisms.

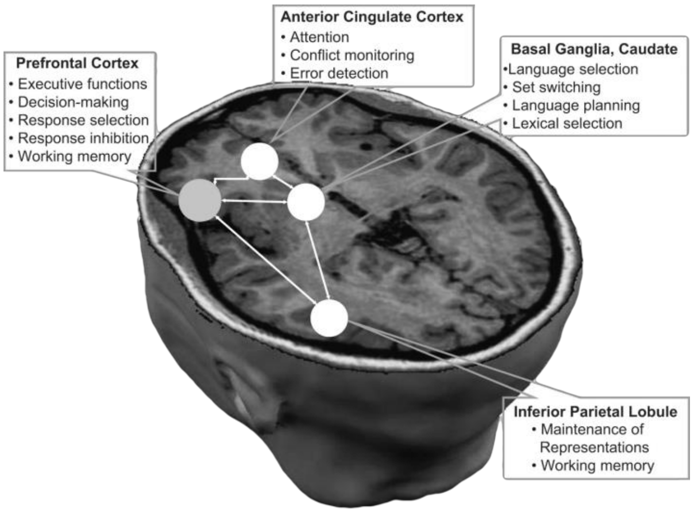

Figure 2. A schematic representation of the neural devices responsible for cognitive control (Abutalebi & Green, 2007). Bilingual language control was shown to rely on the same mechanisms.

Our results from CHAPTER 4 also portrayed an interpreter advantage, suggesting that this type of language experience leads to even better cognitive functioning. Christoffels and de Groot (2005) described possible inhibitory accounts specifically to explain the cognitive processes of interpreting. These accounts assume (functionally) distinct input and output lexicons that can be separately activated and inhibited. One account that is based on Green's IC model suggests that the output lexicon for the source language (SL) is strongly suppressed during simultaneous interpreting, so that only target language (TL) elements will be selected. On the side of the input lexicon, both languages are activated. The difference in degree of activation between the two languages allows for optimal comprehension of the input and monitoring of the produced output (Grosjean, 1997). On the side of the output lexicon, only the TL is activated for production of the translation without interference of the SL (Figure 3).

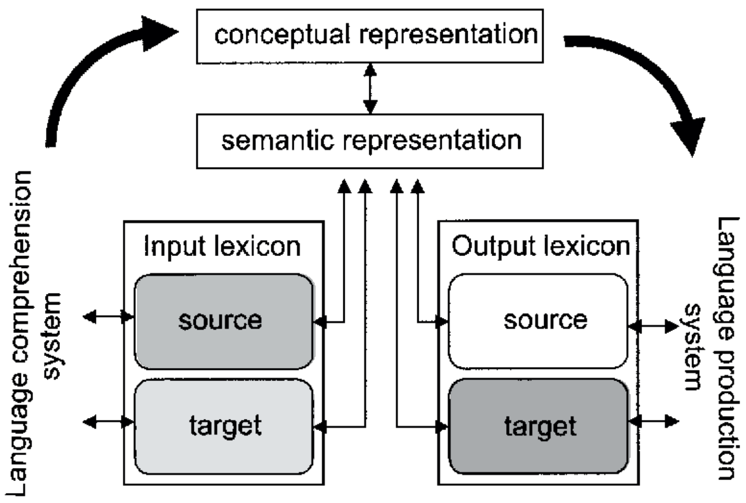

Figure 3. Separate input and output lexicons with varying degrees of activation for target and source language (see also Christoffels & de Groot, 2005). Dark grey suggests higher degrees of activation.

The other account does not assume that global activation or inhibition of language systems controls language output. Instead, it simulates only specific activation of the relevant elements in the lexicon. Based on Poulisse and Bongaerts (1994), this scheme proposes that a number of relevant semantically related lexical elements are selectively activated in both languages, but due to the language cue present in the conceptual message, the appropriate element in the TL will receive the most activation and will therefore be selected (Figure 4). The separation of input and output lexicons here is imperative, because if integrated lexicons were assumed, the elements of the SL that received a lot of activation by the input might be inadvertently selected for production.

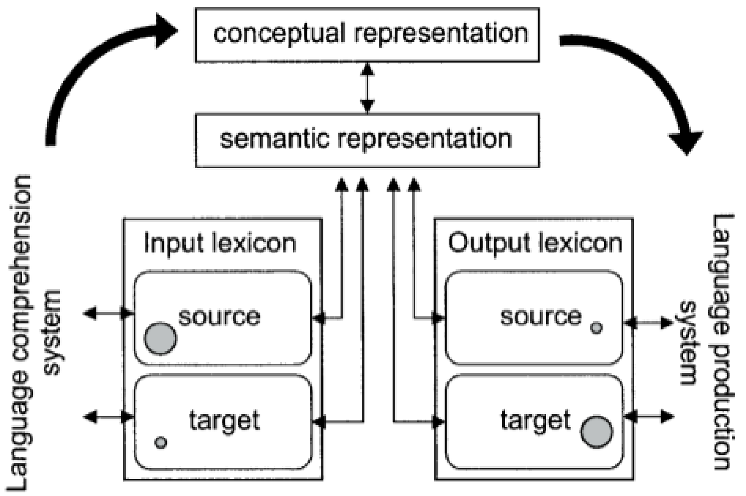

Figure 4. Separate input and output lexicons with specific activation of the relevant elements in the lexicon (see also Christoffels & de Groot, 2005). The circles depict activation of a subset of appropriate elements.

This dissertation not only focused on bilingual cognitive control, but also bilingual language control. The study described in CHAPTER 6 determined whether extralinguistic cues, such as the face of an interlocutor, could serve as a cue for language activation and found that faces can indeed prime a language. These results hold strong implications for the existing models of bilingual language selection, which, up until now, did not include any theories of how language selection is triggered. At the moment, our findings best fit the theories proposed by Poulisse and Bongaerts (1994), as their model postulates that the presence of a language cue in the preverbal message, which was a face in this particular case, suffices to produce speech in the intended language by activating the words of that language more than the word equivalents in the other language.

A NEED FOR STANDARDISED MEASURES

The entire bilingual advantage debate also raised questions about the cognitive tasks that are used. For instance, Paap and Greenberg (2013) challenged the cross-validity of these different tasks that have been employed in the myriad of bilingual studies and proposed that they may elicit different results. Miyake and Friedman (2012) similarly noted that different types of control tasks tap into different kinds of inhibitory control. Our comprehensive list (Table 1) showed a great variance in task application across studies. Additionally, all (or certainly most) of these studies also employed different parameters in their procedures. This not only complicates comparisons between studies implementing different tasks (e.g. flanker vs. Simon), but also makes it difficult to compare studies employing tasks of the same kind, but with different parameters (e.g. the percentage of congruent trials or various stimulus-onset asynchrony – SOA). In CHAPTER 2, we therefore argued that the research field would benefit from standardised tests. Our own longitudinal study among monolingual and immersion children failed to find any group differences for the cognitive control tasks, but instead, established a positive effect of bilingualism on intelligence, as measured by an age-normed test. Therefore, we believe that employing these types of test will shed more light on the effects of bilingualism on cognition and will make comparisons between studies much more straightforward.

FUTURE RESEARCH

The current dissertation provides substantial evidence that bilingualism indeed affects cognition. For instance, it demonstrates that children learning a second language (L2) through immersion become better at solving the problems set forth in Raven's test of analytical reasoning than their initial scores would suggest, an effect that was not found in their monolingual peers. Nevertheless, in our one-year study, we were not able to exclude the possibility that the monolingual children would eventually catch up. In order to determine whether this is or is not the case, a lengthier longitudinal field study is required. A more extensive design would also be able to verify whether the advantages found on Raven's test for the immersion children would also transfer to other types of intelligence tests, and to which components of intelligence. Such a study would furthermore allow us to see whether the advantage eventually shows on different cognitive control tasks as well, as observed in the adult studies.

It has also become clear from this dissertation's introduction that the effects of different linguistic parameters on cognitive control are not easy to disentangle. L2 proficiency is a factor that has recently been taken into account more often. The most difficult to extricate are L2 proficiency, L2 age of acquisition (L2 AoA), amount of L2 exposure, and duration of L2 experience. Two of the studies presented in this dissertation provided evidence that L2 proficiency indeed interacts with the magnitude of the bilingual advantage. Balanced bilinguals seem to procure more benefits than unbalanced bilinguals. Nevertheless, the unbalanced bilinguals were mostly late learners, while balanced bilinguals were early learners. We were therefore unable to exclude the possible effects of L2 AoA. And this L2 AoA has also been shown to affect cognitive control. For instance, Kapa and Colombo (2013) demonstrated that only early bilinguals (who acquired their L2 before age 3) exhibited a cognitive advantage over monolinguals, and not late bilinguals (who acquired their L2 after age 3). While these authors were able to determine no differences in L2 proficiency between the two bilingual groups, they could not exclude that the duration of the bilingual experience and the exposure did not play a role. Bialystok and Barac (2012) had similar problems, when they showed that increased bilingual experience correlated with improved cognitive control. It is unclear whether is actually L2 proficiency, amount of L2 exposure, or duration of the L2 experience that drives this effect.

In order to disengage L2 AoA from L2 proficiency, there are two possibilities. On the one hand, you can keep the L2 AoA constant (e.g. all early or all late bilinguals) while L2 proficiency varies among participants. Conversely, you can keep L2 proficiency constant while varying L2 AoA.

This is, in essence, what Kapa and Colombo (2013) did. Their difficulty lay in extrapolating the effects from L2 AoA from those of amount of L2 exposure and duration of the L2 experience. This can be solved by examining, for instance, bilinguals who have been speaking their L2 from birth and have similar L2 proficiency and dividing them up in different age groups. These age groups then reflect the duration of the L2 experience. For instance, participants of 12 years old will have had 12 years of experience while those of 20 will have had 20 years of experience. Each of those different bilingual groups could then be compared to a control group of monolingual peers. The effects obtained from these comparisons could then be analysed for their magnitude, and so we would be able to find out whether the possible advantages in groups with 12 years of experience are similar to those of groups with 20 years of experience. If so, then duration does not play a role, but if not, then it is possible that duration also modifies the effect size.

Nevertheless, there would still be the question of whether amount of L2 exposure also fits into the equation. It is of course very tricky to disentangle exposure from duration. Self-reported measures could tap into the amount of time a person spends employing their L2, but a more objective measure would be preferable. A way of controlling this is to compare a group of monolingual children with two groups of children, both enrolled in L2 immersion, but with different L2 class programmes (e.g. immersion given 25% of the time vs. immersion given 50% of the time). Certainly, it would be imperative to ensure that the children participating in this type of research do not employ their L2 out of school context. Naturally, the difficulty here will lie in matching both groups for L2 proficiency.

Another linguistic parameter that has been proved to modulate cognitive control is language switching. This parameter was explored in two studies of this dissertation. One study determined the effect of language switching frequency in the bilingual advantage, and a second one established that language switching proficiency also plays a role. In order to find out which of the two aspects of language switching actually has the greatest effect, the two should be investigated together. For future research, we therefore suggest employing both language switching frequency and language switching proficiency measures among the same participants to see how the two interact with the bilingual advantage and with each other.

Another factor that could be taken into account for future research is multilingualism, i.e. the knowledge of more than two languages. This multilingualism always causes difficulties when aiming to determine an effect of interpreter training on the bilingual advantage, which was the case in one of the studies of this dissertation. Through their training and experience, interpreters always have mastery of more than two languages. Hence, it is difficult to determine whether any effects of interpreter training are the result of interpreting itself or of employing at least three (and often four to five) languages. Solving this problem would require a group of regular multilinguals that are as proficient in as many languages as the interpreters.

The rationale behind the assumption that interpreters enjoy increased cognitive benefits comes from the fact that they their two languages need to be activated for comprehension and production. Additionally, inhibition must take place in order for interpreters to produce the correct language. Hence, they would perform better on inhibitory tasks. Yet, the tasks that are employed in such interpreter studies are typically visual tasks, such as the colour Simon or the flanker. This was also the case in this dissertation. Nevertheless, interpreting is mostly an auditory task. Therefore it would be interesting to see how interpreters perform on auditory control tasks, such as the task that first demonstrated the Simon effect (Simon & Rudell, 1967). Here, participants needed to respond to the words LEFT and RIGHT that were randomly presented to the left or right ear. The auditory location was irrelevant and yet, participants responded faster when location and semantics required the same response.

To conclude this section of the dissertation, we would like to address the aspect of language control. In the Alzheimer's study, we showed that bilingualism affects the evolution of the disease by slowing symptom onset. Interesting would be to establish longitudinally whether Alzheimer's also specifically affects the use of the two languages in bilinguals and whether proficiency in both degenerates similarly or not and whether a difference between language degeneration exists between monolinguals and bilinguals. A longitudinal study would also allow us to determine whether AD progression is slower, faster, or similar in bilinguals as in monolinguals. While structural MRI scans would be able to detect brain volume differences between the two languages groups, functional MRIs could tell us if bilingual patients require less or more brain activation during cognitive control tasks. Another interesting question is whether we can actually train monolingual patients on cognitive control tasks to bring them to the same level as bilinguals. We could actually overtrain both groups of patients to see if bilinguals can also still improve. In that respect, a clinical trial in which monolinguals acquire a second language could determine whether language learning decelerates cognitive decline in patients just as it accelerates cognitive development in children.

Furthermore, this dissertation did take a closer look at bilingual language control by demonstrating that an interlocutor's face can prime language selection in bilinguals. This is an important finding for extending and clarifying the existing models of bilingual language control. To verify the strength of the relation between an interlocutor's face and language, future research could also determine whether language can prime a face by ascertaining whether a bilingual hearing or speaking a specific language links this to a certain face or certain faces.

CONCLUSION

The five empirical studies presented in this dissertation contribute to both bilingual language control research and to research on the bilingual cognitive advantage. Specifically, it demonstrated that language selection in bilinguals can be triggered by non-linguistic cues. Furthermore, it provided substantial evidence to support the theory of a bilingual cognitive advantage. In addition, it underlined the importance of different linguistic variables that may modify the magnitude of the effect and the need for standardised tasks in order to obtain more reliable results and be able to compare the outcome of different studies.

Table 1. Bilingual advantage studies with their groups, tasks, measures, and results.

Study		Group	N[1]	Age group	Languages	Task	Measure	Adv.[1]
Antón et al. (2014)		Monolinguals	180	Children	Spanish, Spanish-Basque	Child ANT	Overall ACC	no
		Bilinguals	180				ACC congruency effect	no
							ACC alerting	no
							ACC orienting	no
							Overall RT	no
							RT alerting	no
							RT orienting	no
							RT congruency effect	no
Bialystok (1999)		Monolinguals	30	Children	English, English-Chinese	DCCS	Postswitch condition	yes
		Bilinguals	30				Knowledge-action condition	yes
Bialystok (2006)		Monolinguals	40	Adults	English, English-other language	Simon	Overall ACC	no
		Bilinguals	57				RT Low switch condition	no
							RT High switch condition	no
						Simon Arrow	Overall ACC	no
							RT Low switch condition	no
							RT High switch condition	yes
Bialystok (2010)	Exp 1	Monolinguals	25	Children	English, English-other language	Trail making	Trail A	yes
		Bilinguals	26				Trail B	yes
						Global-local task	Overall RT	yes
							RT congruency effect	no
	Exp 2	Monolinguals	25	Children	English, English-other language	Trail making	Trail A	yes
		Bilinguals	25				Trail B	yes
						Global-local task	Overall RT	yes
							RT congruency effect	no

	Exp 3	Monolinguals Bilinguals	25 25	Children	English, English-other language	Bow completion Trail making Global-local task	Overall RT Trail A Trail B Overall RT RT congruency effect	no yes yes yes no
Bialystok (2011)		Monolinguals Bilinguals	32 31	Children	English, English-other language	Dual-modality classification task	Single task RT Dual task RT Congruency effect Single task ACC Dual task ACC RT congruency effect	no no no no yes no
Bialystok, Barac, Blaye, & Poulin-Dubois (2010)		French monolinguals English monolinguals Bilinguals	37 69 56	Children	French, English, English-other language	Child ANT	Overall ACC ACC congruency effect ACC alerting ACC orienting Overall RT RT congruency effect RT alerting RT orienting	no no - - no no - -
Bialystok & DePape (2009)		Monolinguals Bilinguals	24 24	Adults	English, English-other language	Simon Arrow	Overall ACC RT control overall RT control condition congruency RT conflict condition overall RT conflict condition congruency	no no no yes no
Bialystok & Martin (2004)	Exp 1	Monolinguals Bilinguals	36 31	Children	English, Chinese-English	DCCS	Overall RT Game*Group Phase*Group	yes yes yes

	Exp 2	Monolinguals	15	Children	English, French-English	DCCS	Overall RT	yes
		Bilinguals	15				Phase*Group	yes
	Exp 3	Monolinguals	27	Children	English, Chinese-English	DCCS	Perceptual condition overall	no
		Bilinguals	26				Perceptual Phase*Group	yes
							Semantic condition overall	no
							Semantic Phase*Group	no
Bialystok et al. (2005)		Monolinguals	10	Adults	English, Cantonese/French-English	Simon	Overall ACC	-
		French-English bilinguals	10				ACC congruency effect	-
		Cantonese-English bilinguals	10				Overall RT	yes
							RT congruency effect	no
Bialystok, Craik, Klein, & Viswanathan (2004)	Exp 1	Younger monolinguals	10	Adults	English, Tamil-English	Simon	Overall ACC	-
		Older monolinguals	10				ACC congruency effect	yes
		Younger bilinguals	10				Overall RT	yes
		Older bilinguals	10				RT congruency effect	yes
	Exp 2	Younger monolinguals	32	Adults	English, Cantonese/French/Tamil-English	Simon (2 colours)	Overall ACC	no
		Older monolinguals	15				ACC congruency effect	no
		Younger bilinguals	32				Neutral RT	no
		Older bilinguals	15				Overall RT	yes
						Simon (4 colours)	Overall ACC	no
							ACC congruency effect	no
							Neutral RT	yes
							Overall RT	yes
						Both	Overall RT congruency effect	yes
	Exp 3	Monolinguals	10	Adults	English, French-English	Simon (2 colours)	Overall ACC	no
		Bilinguals	10				ACC congruency effect	no
							Neutral RT	no
							Overall RT	no
							RT congruency effect	yes

						Simon (4 colours)	Overall ACC	no
							ACC congruency effect	no
							Neutral RT	yes
							Overall RT	no
							RT congruency effect	no
Bialystok, Craik, & Luk (2008)		Young monolinguals	24	Adults	English, other languages	Simon Arrow	Overall ACC	no
		Older monolinguals	24				ACC congruency effect	no
		Young bilinguals	24				Overall central RT	no
		Older bilinguals	24				RT central congruency effect	no
							Overall RT	no
							RT congruency effect	no
Bialystok, Craik, & Ryan (2006)	Exp 1	Young monolinguals	24	Adults	English, other languages	Faces (antisaccade)	Overall ACC	no
		Older monolinguals	24				ACC congruency effect	no
		Young bilinguals	24				Neutral RT	yes
		Older bilinguals	24				Overall RT (congruent + incongruent)	no
							RT congruency effect	no
							Mix cost RT	no
							Switch cost RT	no
	Exp 2	Younger monolinguals	24	Adults	English, other languages	Faces	Overall ACC	no
		Older monolinguals	24				ACC congruency effect	no
		Younger bilinguals	24				Neutral RT	no
		Older bilinguals	24				Overall RT (congruent + incongruent)	yes
							RT congruency effect	yes
							Mix cost RT	yes
							Switch cost RT	yes
Bialystok, Martin, &	Exp 1	Monolinguals	17	Children	English, French-English	Simon	Overall ACC	-
		Bilinguals	17				ACC congruency effect	-

Viswanathan (2005)							Overall RT	yes
							RT congruency effect	no
	Exp 2	Monolinguals	22	Children	English, French-English	Simon	Overall ACC	no
		Bilinguals	18				ACC congruency effect	no
							Overall RT	yes
							RT congruency effect	no
	Exp 3	Monolinguals	40	Young adults	English, English-other language	Simon	Overall ACC	no
		Bilinguals	56				ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
	Exp 4	Younger monolinguals	10	Adults	English, English-other language	Simon	Overall ACC	-
		Older monolinguals	10				ACC congruency effect	-
		Younger bilinguals	10				Overall RT	yes
		Older bilinguals	10				RT congruency effect	no
	Exp 5	Younger monolinguals	-	Adults	English, English-other language	Simon	Overall ACC	-
		Older monolinguals	-				ACC congruency effect	-
		Younger bilinguals	-				Neutral RT	no
		Older bilinguals	-				Overall RT	yes
							RT congruency effect	no
Bialystok & Viswanathan (2009)		Monolinguals	30	Children	English, other languages	Faces	Overall ACC	no
		Canadian bilinguals	30				ACC congruency effect	no
		Indian bilinguals	30				Neutral RT	yes
							Overall RT	yes
							RT congruency effect	no
							Mix cost RT	yes
							Switch cost RT	yes
Calvo & Bialystok (2014)		Working class monolinguals	20	Children	English, English-other language	Flanker	Overall ACC	yes
		Middle class monolinguals	46				ACC congruency effect	no
		Working class bilinguals	44				Overall RT	no

		Middle class bilinguals	65				RT congruency effect	no
						EF	Composite score	yes
Carlson & Meltzoff (2008)		Monolinguals Bilinguals Immersion bilinguals	12 17 21	Children	English, English-Spanish, English-Spanish/Japanese	Conflict Delay	Composite score Composite score	yes no
Colzato et al. (2008)	Exp 1	Monolinguals Bilinguals	16 16	Young adults	Spanish, Dutch-English	Stop signal	Overall ACC Overall RT SSRT	no no no
	Exp 2	Monolinguals Bilinguals	18 18	Young adults	Spanish, Dutch-English	Inhibition of return	Overall ACC ACC cue effect Overall RT RT cue effect	no no no yes
	Exp 3	Monolinguals Bilinguals	18 18	Young adults	Spanish, Dutch-English	Attentional blink (reactive inhibition)	Overall ACC T1 ACC condition effect T1 Overall ACC T2 ACC condition effect T2	no no no yes
Costa, Hernández, Costa-Faidella, & Sebastián-Gallés (2009)	Exp 1	Monolinguals Bilinguals	60 60	Young adults	Spanish, Spanish-Catalan	ANT 92% congruent	Overall ACC ACC congruency effect ACC alerting ACC orienting Overall RT RT congruency effect RT alerting RT orienting	no no no no no no no no
	Exp 2	Monolinguals Bilinguals	62 62	Young adults	Spanish, Spanish-Catalan	ANT 50% congruent	Overall ACC ACC congruency effect ACC alerting ACC orienting Overall RT	no no no no yes

						RT congruency effect	no
						RT alerting	no
						RT orienting	no
					ANT 75% congruent	Overall ACC	no
						ACC congruency effect	no
						ACC alerting	no
						ACC orienting	no
						Overall RT	yes
						RT congruency effect	yes
						RT alerting	no
						RT orienting	no
Costa, Hernández, & Sebastián-Gallés, N.(2008)	Monolinguals	100	Young adults	Spanish,	ANT	Overall ACC	no
	Bilinguals	100		Spanish-Catalan		ACC congruency effect	no
						ACC alerting	no
						ACC orienting	no
						Overall RT	yes
						RT congruency effect	yes
						RT alerting	yes
						RT orienting	no
Duñabeitia et al. (2013)	Monolinguals	252	Children	Spanish,	Stroop	Overall RT	no
	Bilinguals	252		Spanish-Basque		RT congruency effect	no
					Numerical Stroop	Overall RT	no
						RT congruency effect	no
Emmorey, Luk, Pyers, & Bialystok (2008)	Monolinguals	15	Adults	English, English-Cantonese/Italian / Vietnamese, English-sign	Flanker	Overall ACC	no
	Unimodal bilinguals	15				ACC congruency effect	no
	Bimodal bilinguals	15				Control condition	no
						Go/no-go condition	yes
						Conflict condition	yes
						RT congruency effect	no

Engel de Abreu et al. (2012)		Monolinguals Bilinguals	40 40	Children	Portuguese, Portuguese-Luxembourgish	Flanker	Overall ACC	no
							ACC congruency effect	no
							Overall RT	yes
							RT congruency effect	-
Esposito, Baker-Ward, & Mueller (2013)		Monolinguals Bilinguals	25 26	Children	English, Spanish, English-Spanish	Bivalent shape	Overall ACC	-
							ACC congruency effect	yes
							Overall RT	-
							RT congruency effect	-
Garbin et al. (2010)		Monolinguals Bilinguals	21 19	Young adults	Spanish, Spanish-Catalan	Shape-colour switch	Overall ACC	-
							ACC switching	yes
							Overall RT	-
							RT switching	yes
Hernández et al. (2010)	Exp 1	Monolinguals Bilinguals	41 41	Young adults	Spanish, Spanish-Catalan	Numerical Stroop	Overall ACC	no
							ACC congruency effect	no
							ACC facilitation	no
							ACC interference	no
							Overall RT	yes
							RT congruency effect	yes
							RT facilitation effect	yes
							RT interference	yes
	Exp 2	Monolinguals Bilinguals	28 28	Young adults	Spanish, Spanish-Catalan	Visual cuing (orienting)	Overall ACC	no
							ACC cue effect	no
							Overall RT	no
							RT cue effect	no
Hernández, Martin, Barceló, & Costa (2013)	Exp 1a	Monolinguals Bilinguals	50 50	Young adults	Spanish, Spanish-Catalan	Choice-card	Overall ACC	no
							ACC implicit vs. explicit cue	no
	Exp 1b	Monolinguals Bilinguals	37 37	Young adults	Spanish, Spanish-Catalan	Choice-card	ACC switching	no
							ACC cue*switching	no

							Overall RT	no
							RT implicit vs. explicit cue	no
							RT switching	no
							RT cue*switching	yes
	Exp 2	Monolinguals	21	Young adults	Spanish, Spanish-Catalan	Bivalent switch	Overall ACC	no
		Bilinguals	20				ACC valence	yes
							ACC switching	no
							ACC valence*switching	no
							Overall RT	yes
							RT valence	no
							RT switching	no
							RT valence*switching	no
	Exp 3	Monolinguals	39	Young adults	Spanish, Spanish-Catalan	Shape-colour switch	Overall ACC	no
		Bilinguals	38				ACC switching	no
							Overall RT	no
							RT switching	no
Kapa & Colombo (2013)		Monolinguals	22	Children	English, English-Spanish	Child ANT	Overall ACC	no
		Early bilinguals	21				ACC congruency effect	-
		Late bilinguals	36				ACC alerting	-
							ACC orienting	-
							Overall RT	yes
							RT congruency effect	no
							RT alerting	no
							RT orienting	no
Kousaie, et al. (2014)		Young monolinguals	70	Young and older adults	French, English, French-English	Simon	Overall ACC	no
		Older monolinguals	51				ACC congruency effect	no
		Young bilinguals	61				Overall RT	no
		Older bilinguals	36				RT congruency effect	no
Kousaie &		Monolinguals	25	Young	English, French-	Simon	Overall ACC	no

Phillips (2012)		Bilinguals	26	adults	English		ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						Flanker	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
Luk, et al. (2011)		Monolinguals Bilinguals	10 10	Young adults	English, English-other language	Flanker	Overall ACC	-
							ACC congruency effect	-
							Overall RT	no
							RT congruency effect	no
Luk, De Sa, & Bialystok (2011)		Monolinguals Early bilinguals Late bilinguals	38 43 42	Young adults	English, English-other language	Flanker	Overall ACC	-
							ACC control trials	-
							ACC congruency effect	-
							Overall RT	no
							RT control trials	no
							RT congruency effect	yes
Martin-Rhee & Bialystok (2008)	Exp 1	Monolinguals Bilinguals	17 17	Children	English, French-English	Simon immediate	Overall ACC	no
							ACC congruency effect	no
							Overall RT	yes
							RT congruency effect	no
						Simon short delay	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						Simon long delay	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no

	Exp 2	Monolinguals Bilinguals	20 21	Children	English, English-French/Cantonese/Spanish	Simon	Overall ACC	no
							ACC congruency effect	no
							Overall RT	yes
							RT congruency effect	no
	Exp 3	Monolinguals Bilinguals	19 13	Children	English, English-other language	Univalent Simon Arrow	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						Bivalent Simon Arrow	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
Marzecová, Asanowicz, Krivá, & Wodniecka (2013)		Monolinguals Bilinguals	17 18	Young adults	Slovak, other languages	LANT	Overall ACC	yes
							ACC congruency effect	yes
							ACC alerting	no
							ACC orienting	no
							Overall RT	no
							RT congruency effect	yes
							RT alerting	yes
							RT orienting	no
Marzecová, et al. (2013)		Monolinguals Bilinguals	22 22	Young adults	Hungarian, Hungarian-Polish	Temporal orienting	Overall ACC	-
							ACC SOA	-
							ACC validity	-
							ACC SOA*validity	-
							Overall RT	no
							RT SOA	no
							RT validity	no
							RT SOA*validity	no
Morales,		Monolinguals	29	Children	English, English-	Non-conflict	Overall ACC	no

Calvo, & Bialystok, E. (2013)	Bilinguals	27		other language	Simon-type	ACC WM level	no
						Overall RT	yes
						RT WM level	-
					Conflict Simon-type	Overall ACC	-
						ACC WM level	-
						ACC congruency effect	yes
						ACC WM*congruency	-
						Overall RT	yes
						RT WM level	no
						RT congruency effect	no
						RT WM*congruency	no
Moreno et al. (2014)	Monolinguals Monolingual musicians Bilinguals	18 14 18	Young adults	English, English-other language	Go/no go	Overall ACC	no
Morton & Harper (2007)	Monolinguals Bilinguals	17 17	Children	English, English-French	Simon	Overall RT	no
						RT congruency effect	no
Nicolay & Poncelet (2013)	Monolinguals Immersion bilinguals	51 53	Children	French, French-English	Child ANT	Overall ACC	no
						ACC congruency effect	no
						ACC alerting	-
						ACC orienting	-
						Overall RT	no
						RT congruency effect	no
						RT alerting	-
						RT orienting	-
					KITAP	ACC alerting	no
						ACC auditory select attention	no
						ACC divided attention	no
						ACC mental flexibility	no

							ACC response inhibition	no
							RT alerting	yes
							RT auditory select attention	yes
							RT divided attention	yes
							RT mental flexibility	yes
							RT response inhibition	no
Paap & Sawi (2014)		Monolinguals Bilinguals	62 58	Young adults	English, English-other language	Antisaccade	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						ANT	Overall ACC	-
							ACC congruency effect	-
							ACC alerting	-
							ACC orienting	-
							Overall RT	no
							RT congruency effect	yes
							RT alerting	-
							RT orienting	-
						Simon	Overall ACC	-
							ACC congruency effect	-
							Overall RT	no
							RT congruency effect	no
						Shape-colour switch	Overall ACC	-
							ACC switching	-
							Overall RT	-
							RT switching	no
							RT mixing	no
Paap & Greenberg	Exp 1	Monolinguals Bilinguals	46 34	Young adults	English, English-other language	Simon	Overall ACC	no
							ACC congruency effect	no

(2013)							Overall RT	no
							RT congruency effect	no
						Antisaccade	Overall ACC	-
							ACC congruency effect	no
							Overall RT	-
							RT congruency effect	no
						Shape-colour switch	Overall ACC	-
							ACC switching	no
							ACC mixing	no
							Overall RT	-
							RT switching	no
							RT mixing	no
	Exp 2	Monolinguals Bilinguals	50 36	Young adults	English, English-other language	Simon	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						Shape-colour switch	Overall ACC	-
							ACC switching	no
							ACC mixing	no
							Overall RT	-
							RT switching	no
							RT mixing	no
	Exp 3	Monolinguals Bilinguals	52 55	Young adults	English, English-other language	Simon	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	no
						ANT	Overall ACC	no
							ACC congruency effect	no
							ACC alerting	-

							ACC orienting	-
							Overall RT	no
							RT congruency effect	no
							RT alerting	no
							RT orienting	no
						Shape-colour switch	Overall ACC	-
							ACC switching	no
							ACC mixing	no
							Overall RT	-
							RT switching	no
							RT mixing	no
Pelham & Abrams (2014)		Monolinguals Bilinguals early Bilinguals late	30 30 30	Young adults	English, English-Spanish	ANT	Overall ACC	no
							ACC congruency effect	no
							ACC alerting	-
							ACC orienting	-
							Overall RT	no
							RT congruency effect	yes
							RT alerting	-
							RT orienting	-
Poarch & van Hell (2012)	Exp 1	Monolinguals L2 learners Bilinguals Trilinguals	20 19 18 18	Children	German, German-English, German-English-other language	Simon	Overall ACC	no
							ACC congruency effect	no
							Overall RT	no
							RT congruency effect	yes
	Exp 2	L2 learners Bilinguals Trilinguals	19 19 18	Children	German-English, German-English-other language	Child ANT	Overall ACC	no
							ACC congruency effect	no
							ACC alerting	no
							ACC orienting	no
							Overall RT	no
							RT congruency effect	yes

						RT alerting	no
						RT orienting	no
Prior & Gollan (2011)	Monolinguals	47	Young adults	English, Spanish-English, Mandarin-English	Shape-colour switch	Overall ACC	no
	Bilingual switchers	41				ACC switching	no
	Bilingual non-switchers	43				Overall RT	yes
						RT switching	yes
Prior & MacWhinney (2010)	Monolinguals	44	Young adults	English, English-other language	Shape-colour switch	Overall ACC	no
	Bilinguals	44				ACC switching	no
						ACC mixing	no
						Overall RT	no
						RT switching	yes
						RT mixing	no
Salvatierra & Roselli (2010)	Younger monolinguals	66	Younger and older adults	Spanish, Spanish-English	Simon (2 colours)	Overall ACC	no
	Older monolinguals	42				ACC congruency effect	-
	Younger bilinguals younger	67				Overall RT	-
	Older bilinguals	58				RT congruency effect	yes
					Simon (4 colours)	Overall ACC	no
						ACC congruency effect	-
						Overall RT	-
						RT congruency effect	no
Tao et al. (2011)	Monolinguals	34	Adults	English, Chinese-English	LANT	Overall ACC	no
	Early bilinguals	36				ACC congruency effect	yes
	Late bilinguals	30				ACC alerting	no
						ACC orienting	no
						Overall RT	yes
						RT congruency effect	yes
						RT alerting	no
						RT orienting	no
Yang, Yang, &	Korean monolinguals (US)	13	Children	Korean, English,	Child ANT	Overall ACC	yes

Lust (2011)	Korean monolinguals (Korea)	13	Korean-English	ACC congruency effect	no
	English monolinguals	15		ACC alerting	no
	Bilinguals	15		ACC orienting	no
				Overall RT	yes
				RT congruency effect	no
				RT alerting	no
				RT orienting	no

[1] A dash (-) indicates that the numbers or results were not reported.

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CHAPTER 8
NEDERLANDSTALIGE SAMENVATTING[1]

Het doel van het onderzoek in dit proefschrift was het tweetalige cognitieve voordeel onder de loep te nemen. We wilden hoofdzakelijk nagaan hoe linguïstische variabelen dit fenomeen kunnen beïnvloeden. Het eerste empirische gedeelte beschrijft een longitudinaal veldonderzoek dat naging hoe het aanleren van een tweede taal de cognitieve ontwikkeling van kinderen kan beïnvloeden. Er werd een vergelijking gemaakt tussen een groep kinderen in het traditioneel eentalig onderwijs en een groep kinderen in tweetalig immersieonderwijs. Het tweede gedeelte omvat twee studies die beide als doel hadden het cognitieve voordeel-effect te bepalen in verschillende tweetalige populaties. Er werd specifiek gekeken naar vaardigheid in de tweede taal, taalswitchen (zowel de frequentie ervan als de vaardigheid erin) en een typerende vorm van taaltraining, namelijk tolken. In het derde gedeelte onderzochten we of tweetaligheid al dan niet de symptomen van de Ziekte van Alzheimer kan uitstellen, meer bepaald in een autochtone tweetalige patiëntenpopulatie. In het vierde en laatste onderzoeksgedeelte lag de nadruk meer op hoe tweetaligen de juiste taal selecteren en gingen we na of het gezicht van de gesprekpartner hierin een bepalende rol speelt. Ten slotte hebben we alle bevindingen nog eens op een rijtje gezet en verwijzen we naar mogelijke verdere onderzoekspistes die het tweetalige cognitieve voordeel nog meer kunnen verduidelijken.

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[1]Partial adaptation of Woumans, E. & Duyck, W. (2015). De effecten van tweetaligheid op cognitie. In Ceuleers, E., Eyckmans, J. & De Smet. HJ. (red.), *Meertaligheid onder de loep*. *Perspectieven op meertalige mensen in een globaliserende samenleving*. Antwerpen: Garant.

INLEIDING

Beïnvloedt tweetaligheid de werking van onze hersenen? Deze vraag brandt reeds honderd jaar op de lippen van psychologen, pedagogen en linguïsten. Al sinds het begin van de 20^{e} eeuw worden eentaligen en tweetaligen vergeleken op allerlei cognitieve testen om zo de vraag te kunnen beantwoorden. Bij het uitvoeren van de eerste onderzoeken was er een consensus dat opgroeien met twee talen schadelijk was voor de cognitieve ontwikkeling van een individu. Verschillende onderzoekers vonden namelijk dat tweetaligen het slechter deden op zowel verbale als niet-verbale intelligentietesten (o.a. Arsenian, 1937; Darcy, 1946; McCarthy, 1930). Algemeen werd daarom aangenomen dat tweetaligen een mentale achterstand hadden, bovenop een taalachterstand. In 1962 nam het onderzoek rond tweetaligheid echter een onverwachte wending. In dat jaar publiceerden Peal en Lambert een studie waarin zij vonden dat tweetalige kinderen beter scoorden dan hun eentalige leeftijdsgenoten op zowel verbale als niet-verbale intelligentietesten. Een bevinding die later zou worden bevestigd door Ben-Zeev (1977). De onderzoekers opperden dat het constante taalswitchen (aldus, het omschakelen van de ene taal naar de andere) de mentale flexibiliteit van de tweetalige kinderen had geoptimaliseerd, waardoor zij zowel verbale als niet-verbale voordelen genoten. Met deze uitzonderlijke bevindingen begon een lange zoektocht naar de waarheid achter het zogenaamde TWEETALIGE VOORDEEL.

De discrepantie tussen deze studie en de studies die eraan vooraf gingen, kan te wijten zijn aan het feit dat de prille studies kampten met een gebrekkige methodologie. Ze hielden vaak geen rekening met bepaalde factoren die de onderzoeksresultaten konden beïnvloeden. Een voorbeeld van dergelijke factor is socio-economische status (SES). Deze was vaak lager voor tweetalige kinderen (McCarthy, 1930), en een lagere SES gaat gewoonlijk gepaard met lagere intelligentiescores (Fischbein, 1980). Bovendien werd het begrip TWEETALIGHEID amper gedefinieerd. Soms werden kinderen gewoon onderverdeeld op basis van hoe buitenlands hun familienaam klonk of waar hun ouders vandaan kwamen (zie Darcy, 1953). Zo werden ook kinderen die absoluut (nog) niet tweetalig waren toch als tweetalig aanschouwd. Zij hadden bovendien het nadeel dat de meeste testen in hun tweede taal werden uitgevoerd, terwijl ze die nog niet goed beheersten (Hakuta, 1986). Andere studies hanteerden dan weer té strikte normen, en controleerden de variabelen die ze eigenlijk wilden testen. Zo waren de eentaligen en tweetaligen in de studie van Hill (1935) niet enkel gelijkaardig qua leeftijd, geslacht, taalbegrip en scholing, maar ook qua mentale leeftijd en intelligentie. Er werden dan ook geen verschillen gevonden tussen de groepen wanneer hun verbale en cognitieve functies werden getest via andere taken.

Het probleem van te veel of te weinig controleren is inherent aan dit soort onderzoek. Hoe kan je het effect van tweetaligheid op cognitie meten en er tegelijk voor zorgen dat de resultaten niet te wijten zijn aan andere variabelen, maar toch niet zo streng controleren dat er sowieso geen verschillen meer worden gevonden? Een mogelijke oplossing is het uitvoeren van longitudinale studies met twee groepen die volledig identiek zijn, ook op het vlak van taalgebruik, en waarvan één groep dan uiteindelijk tweetalig wordt. Wanneer wordt uitgegaan van twee groepen eentaligen kan je deze gelijkstellen op alle variabelen die mogelijks een invloed op cognitie kunnen hebben, zonder dat tweetaligheid reeds een rol speelt. Achteraf, wanneer één van de groepen een tweede taal heeft verworven, zullen verschillen tussen groepen pure effecten van tweetaligheid zijn en niet van genetica of opvoeding. Jammer genoeg zijn dergelijke onderzoeken tot op heden zeer schaars. Uiteindelijk bereikte het onderzoek rond tweetaligheid en intelligentie een hoogtepunt, maar geen consensus in de jaren ’60 en ’70. Het was wel zo dat de negatieve opvattingen over tweetaligheid grotendeels waren verdwenen en hadden plaatsgemaakt voor een meer positief beeld. Nadien doofde het onderwerp wat uit, tot een twintigtal jaar geleden plots herleefde in de meer gespecialiseerde psycholinguïstische literatuur. Het brede concept van intelligentie werd overboord gegooid en de focus werd verlegd naar het concept EXECUTIEVE FUNCTIES (ook wel COGNITIEVE

CONTROLE genoemd). Hiermee worden de hogere controlefuncties in de hersenen bedoeld en deze bestaan onder meer uit werkgeheugen, plannen, redeneren en probleemoplossend denken. Ze maken allen deel uit van het EXECUTIEF SYSTEEM, een concept uit de psychologie dat de cognitieve processen zou beheren en kan worden gelokaliseerd in de prefrontale cortex, vooraan in onze hersenen. Deze prefrontale delen zijn betrokken bij het plannen van complex cognitief gedrag, het nemen van beslissingen en het modereren van sociaal gedrag. Ook persoonlijkheid kan in deze regio worden gelokaliseerd.

TWEETALIGHEID EN TAALCONTROLE

Het verband tussen tweetaligheid en executieve functies kwam voort uit de bevinding dat beide talen in een tweetalige persoon constant en gelijktijdig zijn geactiveerd en interageren (Brysbaert, 1998; Dijkstra, Grainger, Van Heuven, 1999; Martin, Dering, Thomas, & Thierry, 2009). Doch, deze visie was niet altijd dominant. Lang werd gedacht dat beide talen van een tweetalige waren opgeslagen in twee aparte lexicons in de hersenen (bv. Krashen, 1973; Kroll & Stewart, 1994; Paradis, 1997). Recentere studies hebben nu aangetoond dat het tweetalige lexicon geïntegreerd is en dat lexicale toegang niet selectief gebeurt.

Costa, Caramazza en Sebastián-Gallés (2000) vonden bijvoorbeeld dat tweetaligen sneller prenten konden benoemen wanneer de namen ervan cognaten waren in beide talen dan wanneer dat niet het geval was. Verder werd gevonden dat cognaten ook sneller worden gelezen (Van Assche, Duyck, & Hartsuiker, 2012; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009). Ook stelden Marian en Spivey (2003) vast dat wanneer tweetaligen de instructie krijgen te kijken naar objecten die worden benoemd in de ene taal, zij vaak worden afgeleid door objecten waarvan de naam in de andere taal ongeveer hetzelfde klinkt. Bijvoorbeeld, wanneer Russisch-Engelse tweetaligen het woord MARKA (Russisch voor POSTZEGEL) hoorden, ging hun blik vaak naar de MARKER (Engels voor STIFT). Aldus, deze studies tonen aan dat wanneer tweetaligen spreken, lezen of luisteren in een taal (zelfs wanneer dit de moedertaal is), hun andere taal ook steeds wordt geactiveerd. Dit kan zowel positieve (bv. het sneller benoemen van prenten waarvan de naam een cognaat is) als negatieve (bv. afgeleid zijn door gelijkaardige woorden in de andere taal) gevolgen hebben.

Tweetaligen moeten daarom elke gesprekssituatie goed monitoren, zodat de correcte taal meer wordt geactiveerd en de op dat moment overbodige taal wordt onderdrukt om interferentie ervan te vermijden. Momenteel zijn er verscheidene modellen van tweetalige taalcontrole die proberen te verduidelijken welke processen aan deze taalselectie te pas komen (o.a. Dijkstra & van Heuven, 1998; Dijkstra & van Heuven, 2002; Paradis, 1997; Poulisse & Bongaerts, 1994). Een verklarend model dat echter vaak terug komt in de literatuur rond het tweetalige cognitieve voordeel is het Inhibitory Control (IC) model van Green (1998). Dat model stelt dat competitie tussen twee talen wordt opgelost door de woorden van de (op dat moment) irrelevante taal te onderdrukken en die van de relevante taal te activeren. Het regelen van taalactivatie en -onderdrukking gebeurt volgens het IC model niet door een taalspecifiek systeem in de hersenen, maar door het executief systeem. Daarom zou het beoefenen van dergelijke vorm van taalcontrole ook andere (niet-talige) executieve processen verbeteren.

Hoewel het IC model op bepaalde vlakken verschilt van de andere modellen die warden opgesomd, hebben ze toch allemaal een gemeenschappelijke factor. Ze stellen namelijk allemaal dat taalselectie gebeurt door het activeren van de juiste taal. Toch is het nog niet geheel duidelijk wat deze activering precies teweegbrengt. De studies van Marian et al. (2003), Dijkstra et al. (1999) en Van Assche et al. (2009) tonen namelijk aan dat linguïstische cues niet voldoende zijn om taalactivering te beperken tot een enkele taal. Recentelijk werd er gesteld dat visuele cues misschien een antwoord konden bieden. Uit deze studies bleek onder andere dat de socioculturele identiteit van het gezicht van een spreker de taalproductie van een andere spreker kon beïnvloeden door verbale vlotheid te verbeteren wanneer identiteit en taal overeen kwamen (bv. wanneer een Aziatisch gezicht Chinees sprak) en door verbale vlotheid te reduceren wanneer identiteit en taal niet overeen kwamen (bv. wanneer een Aziatisch gezicht Engels sprak) (Li, Yang, Scherf, & Li, 2013; Zhang, Morris, Cheng, & Yap, 2013).

TWEETALIGHEID EN COGNITIEVE CONTROLE

Hoe dan ook, als gevolg van het constant uitoefenen van taalcontrole (aldus, het activeren van de ene taal en het onderdrukken van de andere) zouden tweetaligen ook een beter algemeen controlesysteem hebben. Deze assumptie wordt vaak getest aan de hand van executieve taken, zoals de zogenaamde Simon-taak (Simon & Rudell, 1967). In deze taak worden bijvoorbeeld rode en groene bolletjes links of rechts op een computerscherm getoond. Participanten krijgen dan de instructie een knop links op het toetsenbord in te drukken wanneer een groen bolletje verschijnt, en een knop rechts op het toetsenbord wanneer een rood bolletje verschijnt. De bedoeling is dat zij dit zo snel en zo accuraat mogelijk doen. In principe moeten ze de locatie waar het bolletje verschijnt negeren en enkel reageren op de kleur. Omdat dit negeren een vorm van inhibitie vergt, worden dergelijke taken ook wel inhibitietaken genoemd. De moeilijkheid van het negeren van locatie wordt weerspiegeld in de reactietijden. Die zijn steeds sneller op zogenaamde CONGRUENTE TRIALS, aldus wanneer kleur en locatie overeen komen (bv. wanneer het groene bolletje links staat). Wanneer kleur en locatie niet overeen komen (bv. wanneer het groene bolletje rechts staat), wordt er gesproken van INCONGRUENTE TRIALS. Het verschil in reactietijd tussen beide soorten trials wordt het CONGRUENTIE-EFFECT genoemd.

Nu blijkt dat tweetaligen vaak een kleiner congruentie-effect vertonen en dus sneller het conflict dat zich op het scherm voordoet (bv. links moeten drukken wanneer het bolletje rechts staat) kunnen oplossen dan eentaligen. En dit vermoedelijk dankzij een beter getraind executief systeem (Bialystok, 2006; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Martin, & Viswanathan, 2005; Costa, Hernández, & Sebastián-Gallés, 2008). Toch zouden tweetaligen niet enkel beter zijn in het oplossen van conflict. Costa, Hernández, Costa-Faidella en Sebastián-Gallés (2009) vonden namelijk dat tweetaligen vaak ook sneller en beter waren in het oplossen van trials zonder conflict, aldus de zogenaamde congruente trials. Zij verklaarden dit fenomeen aan de hand van het MONITORING SYSTEEM, dat deel zou uitmaken van het executieve systeem. Wanneer een tweetalige in eender welke gesprekssituatie zit, moet deze constant monitoren welke taal er wordt aangewend. Zeker als hij of zij in gesprek is met andere tweetaligen die hetzelfde talenpaar hebben. Op deze manier zou ook dit monitoring systeem worden getraind en zou het voor tweetaligen makkelijker zijn snel uit te maken of er in executieve taken al dan niet een conflict aanwezig is. Dit zou een verklaring kunnen zijn voor hun snellere reactietijden op zowel congruente als incongruente trials.

COGNITIEVE VOORDELEN DOORHEEN DE TWEETALIGE LEVENSSPAN

COGNITIEVE ONTWIKKELING IN TWEETALIGEN

De laatste jaren is het onderzoek naar de cognitieve effecten van tweetaligheid in een stroomversnelling terecht gekomen en veel studies richten zich op de invloed van tweetaligheid op de cognitieve ontwikkeling van kinderen. Wat uit dit onderzoek blijkt, is dat tweetalige kinderen zich sneller cognitief lijken te ontwikkelen dan hun eentalige leeftijdsgenoten (Bialystok, 2011; Bialystok & Martin, 2004; Poulain-Dubois, Blaye, Cautya, & Bialystok, 2011). Dit verschil kan al heel vroeg worden opgemerkt, zelfs voor de kinderen zelf taal kunnen produceren. Zo voerden Kovács en Mehler (2009a&b) twee studies uit met kinderen van zeven maanden en twaalf maanden oud en vonden dat kinderen waartegen de ouders en familie meer dan een taal spraken, meer cognitieve flexibiliteit vertoonden. De onderzoekers konden dit nagaan aan de hand van oogbewegingen en demonstreerden dat enkel kinderen met tweetalige opvoeding aan de hand van de gepresenteerde stimuli (zoals figuurtjes en klanken) hun anticiperende blik naar de juiste kant van een scherm konden wenden.

Voorts lijken ook peuters en kleuters voordeel te halen uit hun tweetalige opvoeding. Bialystok (1999) vergeleek eentalige en tweetalige vier- en vijfjarigen en controleerde hierbij voor receptieve Engelse taalvaardigheid en werkgeheugencapaciteit. Ze liet beide groepen een dimensionele kaartsorteertaak uitvoeren. Dimensioneel verwijst hier naar de verschillende dimensies (aldus, specifieke kenmerken) waarop de kaarten kunnen worden gesorteerd. De tweetaligen bleken minder fouten te maken wanneer de sorteerregels veranderden. Daarom concludeerde Bialystok dat tweetaligheid leidt tot het beter kunnen oplossen van problemen die gebaseerd zijn op aandacht en conflict. Aangezien de sorteertaak niet talig was, bevestigde dit resultaat dat het voordeel van tweetaligen algemeen is en niet taalgebonden.

Om na te gaan of de context waarin een tweede taal wordt aangeleerd ook een rol speelt in de cognitieve ontwikkeling, vergeleken Carlson en Meltzoff (2008) kinderen met een verschillend niveau van blootstelling aan die tweede taal. In hun studie werkten ze met een groep eentaligen, een groep vroeg-tweetaligen (tweetalig vanaf de geboorte) en een groep eentaligen die reeds zes maanden les volgden in een tweede taal-immersieschool. Dit is een school waarin tweetalig onderwijs wordt gegeven en dus de helft van de lessen in de eerste taal en de andere helft in de tweede taal plaatsvindt. De leeftijd van de kinderen varieerde van 4,8 tot 6,9 jaar. De groepen werden gecontroleerd voor leeftijd, taalvaardigheid en socio-economische status. De onderzoekers gebruikten verschillende maten die de executieve functies testten en vonden dat de vroeg-tweetaligen het steeds beter deden dan de andere twee groepen. De immersiegroep deed het even goed als de eentalige groep. Om deze resultaten te verklaren, verwezen de onderzoekers naar eerder werk van Bialystok en Majumder (1998), dat stelt dat het voordeel van tweetaligen op meta-linguïstische taken afhangt van de vaardigheid in de tweede taal. Calson en Meltzoff concludeerden dat zes maanden immersie niet genoeg is om voldoende vaardig te zijn in een tweede taal en daarom werd het executieve voordeel in deze groep niet gevonden.

Deze redenering werd nadien bevestigd door Poarch en van Hell (2012). Zij gingen na of de leeftijd van tweedetaalverwerving de prestaties op de Simon-taak en een kinderversie van de Attention Network Test (ANT, Rueda et al., 2004) beïnvloedt. In deze versie van de ANT krijgen de participanten vijf gele visjes op een blauwe achtergrond te zien en moeten zij aanduiden welke richting het middelste visje uit zwemt. De andere vier visjes kunnen zowel dezelfde kant uitzwemmen (congruente trials) als de andere kant (incongruente trials). De visjes verschijnen niet in het midden van het scherm, maar telkens boven of onder een fixatiekruis. De kinderen moeten dan heel aandachtig zijn, zodat ze snel hun blik naar de juiste locatie op het scherm kunnen wenden. Poarch en van Hell vergeleken vier groepen van vijf- tot zesjarige Duitse kinderen: eentaligen, tweetaligen die ongeveer anderhalf jaar tweetalig immersieonderwijs volgden, tweetaligen die reeds drie jaar tweetalig immersieonderwijs volgden en drietaligen, die vroeg-tweetalig waren en reeds twee tot drie jaar tweetalig immersieonderwijs in een derde taal volgden. Uit de studie bleek dat zowel de tweetaligen met drie jaar tweetalig onderwijs als de drietaligen het beter deden op de executieve taken dan de tweetaligen met anderhalf jaar tweetalig onderwijs en de eentaligen. Tussen deze laatste twee groepen was geen verschil terug te vinden. Verder haalden de drietaligen geen extra executieve voordelen uit hun bredere talenkennis.

EXPERTEN IN TAALCONTROLE

Tweetaligen moeten wel eens omschakelen van de ene naar de andere taal, afhankelijk van hun gesprekspartner. Stel, je bent zelf Frans-Nederlands tweetalig en op het werk moet je zowel tegen Nederlandstalige als Franstalige collega's praten. Dan gebeurt dat omschakelen veel vaker dan wanneer je als Frans-Nederlands tweetalige bijvoorbeeld op het werk enkel Nederlands spreekt en thuis enkel Frans. Het is dan ook aannemelijk dat het constante taalswitchen op het werk meer cognitieve inspanning vereist dan je talen mooi gescheiden te kunnen houden. Je moet namelijk telkens de ene taal inhiberen en dan weer activeren. Green en Abutalebi (2013) hebben hieromtrent een hypothese vooropgesteld die onder andere aangeeft dat de interactionele context waarin tweetaligen zich bevinden de adaptatie van het cognitieve netwerk en de cognitieve processen bepaalt.

Een dergelijke rationale spoorde onderzoekers aan ook de effecten van taalswitchen op de executieve controle van het werkgeheugen na te gaan. Prior en Gollan (2011) konden een expliciet verband vaststellen tussen taalswitchen en taakswitchen. Zij vergeleken namelijk Engelse eentaligen met Spaans-Engels tweetaligen die vaak taalswitchten en Mandarijns-Engelse tweetaligen die niet vaak taalswitchten. De groepsverdeling gebeurde op basis van gerapporteerde switchscores, die nadien werden bevestigd in een tweetalige switchtaak waarin cijfers werden benoemd. De Spaans-Engelse tweetaligen konden hierin sneller wisselen van taal. Het taakswitchen werd gemeten door middel van een perceptuele switchtaak. In deze switchtaak dienden de participanten te reageren op de vorm of de kleur van een figuur die op een computerscherm verscheen. Het antwoord was afhankelijk van het woord dat zij net voor de figuur te zien kregen, SHAPE (vorm) of COLOUR (kleur), en werd gegeven door zo snel mogelijk de corresponderende knoppen in te drukken. In een eerste fase van het experiment dienden de participanten enkel te reageren op vorm of kleur en moesten ze aangeven of een figuur rond of vierkant en blauw of rood was. In een tweede fase werd er constant afgewisseld tussen beide. Het verschil in reactietijd en foutenpercentage tussen deze eerste fase en de tweede fase wordt de SWITCH COST (wisselkost) genoemd. Participanten zijn namelijk trager en maken meer fouten wanneer zij telkens een andere instructie krijgen. Uit de studie van Prior en Gollan bleek dat slechts de tweetaligen die vaak wisselden van taal een executief voordeel vertoonden ten opzichte van de eentaligen, aangezien zij een kleinere wisselkost vertoonden in de switchtaak.

Het onderzoek van Prior en Gollan toont aan dat een bepaalde taalexpertise het tweetalige cognitieve voordeel kan beïnvloeden. Daarom achtten onderzoekers het ook nodig een heel speciale groep van experten in taalcontrole te bestuderen, namelijk de simultaantolken. Simultaantolken hebben de complexe taak gesproken boodschappen uit een bepaalde brontaal meteen te herformuleren in een bepaalde doeltaal. Dit betekent dat hun beide taalsystemen simultaan zijn geactiveerd om op hetzelfde moment de ene taal te begrijpen en de andere te produceren (de Groot & Christoffels, 2006). Verschillende studies met focus op hoe tolken cognitie beïnvloedt, toonden dan ook aan dat aandacht en werkgeheugen meer ontwikkeld zijn in tolken (Köpke & Nespoulous, 2006; Köpke & Signorelli, 2012; Padilla, Bajo, & Macizo, 2005). Voorts zijn er zelfs een aantal studies die vonden tolken ook andere cognitieve voordelen vertonen, zoals meer cognitieve flexibiliteit (Yudes, Macizo, & Bajo, 2011) en betere cognitieve controle (Dong & Xie, 2014; Timarová et al., 2014).

TWEETALIGHEID EN COGNITIEVE RESERVE

Ouder worden houdt de eerste decennia van ons leven in dat we onze cognitieve capaciteiten ontwikkelen. Toch, op het moment dat we de leeftijd van 20 à 30 bereiken, gaat ouder worden voornamelijk gepaard met cognitieve aftakeling (Salthouse, 2009). De zogenaamde GEKRISTALLISEERDE INTELLIGENTIE, zoals woordenschat en algemene kennis, blijven vaak bewaard, maar de executieve functies zijn heel vatbaar voor aftakeling. Toch zouden bepaalde factoren een bescherming kunnen bieden tegen cognitieve aftakeling. Er wordt dan gesproken over COGNITIEVE RESERVE (Stern, 2002). Opleiding, socio-economische status, sociaal netwerk, sport en hobby's zouden bijdragen aan deze cognitieve reserve (Scarmeas, Levy, Tang, Manly, & Stern, 2001; Valenzuela & Sachdev, 2006) en zouden zelfs de symptomen van dementie kunnen uitstellen (Fratiglioni, Winblad, & von Strauss, 2007). Heel interessant voor dit onderzoeksveld is dat tweetaligheid ook een beschermende factor blijkt te zijn.

Heel wat studies toonden reeds aan dat ook in seniorenpopulaties, tweetaligen een cognitief voordeel vertonen ten opzichte van eentaligen (o.a. Bak, Nissan, Allerhand, & Deary, 2014). Het eerste bewijs van een neuronale basis voor cognitieve reserve als gevolg van tweetaligheid werd voorgelegd in een studie van Gold, Kim, Johnson, Kryscio en Smith (2013). Eentalige en tweetalige jonge en oudere volwassenen voerden een perceptuele switchtaak uit, terwijl de onderzoeker gebruik maakten van functional Magnetic Resonance Imaging (fMRI). Tijdens de taak werden er dus functionele hersenscans genomen van de participanten, waaruit duidelijk werd welke hersendelen op welk moment waren geactiveerd. Een effect van leeftijd werd gevonden, aangezien jonge volwassenen over het algemeen beter scoorden op deze taak. Ook werd in de oudere volwassenen een verhoogde hersenactivatie geobserveerd, wat te wijten was aan de grotere inspanning die zij moesten leveren. Verder werd het tweetalige voordeel bevestigd: zowel de tweetalige jonge volwassenen als de tweetalige oudere volwassenen vertoonden een kleinere wisselkost dan hun eentalige leeftijdsgenoten. Bovendien vereiste het oplossen van de taak minder hersenactivatie voor tweetaligen in verschillende frontale hersenregio's, wat duidde op een verhoogde neuronale efficiëntie.

Voorts blijkt tweetaligheid ook een effect te hebben om de symptomen van dementie. In een aantal Canadese studies is immers aangetoond dat tweetaligen de symptomen van de Ziekte van Alzheimer vier tot vijf jaar later vertonen dan eentaligen (Bialystok, Craik, Binns, Ossher, & Freedman, 2014; Bialystok, Craik, & Freedman, 2007; Craik, Bialystok, & Freedman, 2010). Gelijkaardige effecten konden zelfs worden vastgesteld in een studie die gebruik maakte van neuronale beeldvorming. Schweizer, Ware, Fischer, Craik en Bialystok (2011) onderzochten namelijk een groep eentaligen en tweetaligen die leden aan de ziekte van Alzheimer, maar die volledig gelijkgesteld waren op het gebied van executieve functies en van geheugen. Wanneer zij daarna de hersenen van deze patiënten scanden door middel van een structurele MRI, bleek dat de hersenen van de tweetaligen al veel meer waren aangetast door de ziekte. Kort gezegd, betekent dit dat deze tweetaligen eigenlijk evenveel konden met veel minder.

De tweetalige patiënten die deelnamen aan deze studies waren echter veelal inwijkelingen die hun tweede taal hadden aangeleerd nadat ze in het land van migratie toekwamen. Maar de ervaringen die deze mensen hebben met hun tweede taal zijn niet te vergelijken met die van mensen die met twee talen zijn opgegroeid. Migranten leren hun tweede taal vaak pas laat aan, maar worden hierin dan ook meteen ondergedompeld, aangezien zij nu leven in een omgeving waarin deze tweede taal dominant is. Bijgevolg probeerden Chertkow en collega's (2010) te achterhalen of de ziekte van Alzheimer zich ook later manifesteert in niet-migrantenpopulaties. Ook zij konden het effect van tweetaligheid vaststellen in de migrantenpopulatie, maar dat lukte niet voor de niet-migrantenpopulatie. Alladi et al. (2013) slaagden daar echter wel in. Hun studie werd uitgevoerd in Indië en vond een latere onset van symptomen in tweetalige patiënten en dit niet alleen voor de Ziekte van Alzheimer, maar ook voor andere dementies.

OBSTAKELS

Hoewel uit deze opsomming van studies duidelijk wordt dat tweetaligheid cognitieve voordelen biedt, brengt het onderzoek errond toch nog een aantal vragen met zich mee. Zo zijn er bijvoorbeeld een aantal studies die geen enkel verschil konden vinden tussen eentaligen en tweetaligen. Morton en Harper (2007) waren een van de eersten die het tweetalige executieve voordeel in vraag stelden. Zij schreven de resultaten die tot op dat moment werden gevonden toe aan verschillen tussen de groepen op het gebied van etniciteit en socio-economische status. Anders dan honderd jaar geleden, zouden het nu de tweetaligen zijn die werden bevoordeeld. Daarom vergeleken zij zes- tot zevenjarige eentalige en tweetalige kinderen met een gelijke socio-economische status én met dezelfde etnische achtergrond. Verder controleerden zij ook voor woordenschat en intelligentie. Executieve functies werden gemeten door middel van de Simon-taak. De resultaten toonden echter geen verschil tussen de twee taalgroepen, maar wel een effect van socio-economische status, wat het vermoeden van de onderzoekers bevestigde. Een hoge socio-economische status bleek immers gerelateerd aan een kleiner congruentie-effect in de Simon-taak.

Ook Antón et al. (2014) kon geen verschillen vinden tussen een groep eentalige en een groep tweetalige kinderen op de Attention Network Test.

De groepen in deze studie waren opnieuw goed gecontroleerd voor allerlei andere variabelen die de resultaten op de executieve taak konden beïnvloeden. Gelijkaardige resultaten kwamen voort uit de studie van Kousaie en Phillips (2012). Zij vergeleken geen kinderen, maar jonge en oudere volwassen eentaligen en tweetaligen en controleerden hierbij voor een aantal socio-culturele variabelen. Ook deze studie vond geen groepseffect. Omwille van deze tegenstrijdige uitkomsten, stelden Paap en Greenberg (2013) niet enkel het tweetalige cognitieve voordeel in vraag, maar ook de cross-validiteit van de taken die in al deze voorgaande studies werden aangewend. Hoewel alle taken op de één of andere manier een aspect van inhibitie meten, zijn de resultaten ervan niet altijd even vergelijkbaar (Miyake & Friedman, 2012). Daarom testten Paap en Greenberg zowel eentalige als tweetalige studenten op 15 verschillende maten van executieve functies, maar konden op geen enkele maat een effect van tweetaligheid terugvinden.

HUIDIGE BEVINDINGEN

Dit doctoraal proefschrift had voornamelijk als doel wat duidelijkheid te scheppen in het TWEETALIG VOORDEEL, wat het gevolg zou zijn van de constante taalcontrole die tweetaligen dienen uit te voeren. Enerzijds werd er in de voorbije decennia met blijkbare consistentie een cognitief voordeel gevonden voor mensen die tweetalig zijn. Anderzijds werd dit voordeel in recentere literatuur sterk in vraag gesteld. Met dit proefschrift wilden we nagaan of bepaalde factoren en parameters (linguïstische en andere) dit tweetalig voordeel konden moduleren en op die manier misschien ook een verklaring konden bieden voor de uiteenlopende bevindingen. Voorts werd ook gekeken naar taalcontrole op zich en wilden we vaststellen hoe tweetalige taalselectie wordt geïnitieerd.

COGNITIEVE ONTWIKKELING IN TWEETALIGEN: EFFECTEN OP ALGEMENE COGNITIE

Aanvankelijk richtte het onderzoek naar tweetaligheid en cognitie zich op intelligentie-effecten. Pas jaren later werd een shift gemaakt naar cognitie controle. Het probleem zowel de intelligentie- als de controlestudies is dat zij telkens cross-sectionele vergelijkingen maakten. Dit soort vergelijkingen bevatten vaak variabelen die je amper of niet kan controleren, wat ook meteen een verklaring kan bieden voor uiteenwijkende resultaten over studies heen. In dit doctoraat stelden wij in HOOFDSTUK 2 een longitudinaal onderzoek voor bij eentalige en tweetalige kinderen dat beide hun intelligentie en cognitieve controle naging.

Het doel van deze studie was nagaan of tweetalig worden de cognitieve ontwikkeling kan beïnvloeden. Daarom testten wij de twee taalgroepen toen alle kinderen nog eentalig Frans waren, aldus voordat de helft van hen aan een tweetalig immersieprogramma met Nederlands op school begon. De groepen werden aanvankelijk gecontroleerd op verschillen in socioeconomische status (SES), vaardigheid (verbale vlotheid) in hun eerste taal (L1 - Frans), intelligentie en cognitieve controle. Er werden voor deze variabelen geen verschillen gevonden in de vijfjarigen. Na één schooljaar van traditionele eentalige lessen voor de eentaligen en dezelfde lessen in twee talen voor de immersiekinderen werden de twee groepen nogmaals getest met dezelfde testbatterij.

Beide groepen leken gelijkaardig vooruit te zijn gegaan voor verbale vlotheid in hun L1, waaruit we kunnen afleiden dat het aanleren van een tweede taal (L2) niet gepaard hoeft te gaan met het achteruitgaan of stagneren van vaardigheid in de L1. Op onze maat van cognitieve controle, die werd gescoord aan de hand van de Simon-taak, werden echter ook geen verschillen gevonden tussen de twee groepen, hoewel opnieuw beide beter waren geworden in het uitvoeren van de taak. We kunnen dus stellen dat het aanleren van een L2 (nog) geen invloed had op cognitieve controle. Toch vonden we wel een heel significant verschil voor niet-verbale intelligentiescores, gemeten door de test Raven's Coloured Progressive Matrices. Initieel scoorden beide groepen gelijkaardig rond het vijftigste percentiel (normale intelligentie), maar na een jaar immersie bleken die kinderen het veel beter te doen op de analytische test (ze scoorden nu rond het zeventigste percentiel) terwijl de eentalige kinderen slechts een numerieke vooruitgang boekten. Deze uitkomst suggereert dat het aanleren van een L2 (hier door immersieonderwijs) de cognitieve ontwikkeling positief beïnvloedt.

Onze resultaten geven ook aan dat het tweetaligheidsvoordeel niet steeds terug te vinden is op controletaken, zoals de Simon-taak. Wij vermoeden dat dergelijke taken niet gewoon niet betrouwbaar genoeg zijn om consistente resultaten te leveren. Enerzijds is bestaan er al zo veel soorten controletaken die vaak heel andere processen meten (cf. Miyake & Friedman, 2012) en anderzijds is het design van gelijkaardige taken ook heel uiteenlopend over studies heen. Daarom is het volgens ons heel belangrijk genoeg aandacht te geven aan de taken die worden aangewend in dergelijk onderzoek, aangezien zij de uitkomsten kunnen vertekenen. Het lijkt aangewezen gestandaardiseerde taken te gaan gebruiken, zoals de Raven-test, voor meer betrouwbare en vergelijkbare resultaten.

INVLOED VAN TWEETALIGHEIDSERVARING

In dit proefschrift probeerden we ook te bepalen of specifieke linguïstische parameters het tweetalig voordeel kunnen beïnvloeden. In HOOFDSTUK 3 en 4 keken we daarom naar het effect van taalswitchen (frequentie en vaardigheid) en de invloed van tolkentraining.

In HOOFDSTUK 3 vergeleken we drie verschillende taalgroepen op twee maten van cognitieve controle (een flanker- en een Simon-taak). De groepen bestonden uit niet-gebalanceerde tweetaligen (zie die een taal veel beter beheersen dan de andere), gebalanceerde tweetaligen die niet frequent wisselden van taal en gebalanceerde tweetaligen die dat wél deden. De resultaten van beide taken wezen in dezelfde richting: de frequente switchers reageerden in het algemeen sneller en hadden een kleiner congruentie-effect dan de niet-frequente switchers en de niet-gebalanceerde tweetaligen. Gelijkaardig aan de studie van Prior en Gollan (2011), vonden wij extra bewijs dat taalswitchgedrag een invloed heeft op cognitieve controle. Terwijl de participanten van Prior en Gollan bestonden uit Spaans-Engelse (frequente switchers) en Mandarijns-Engelse (niet-frequente switchers) tweetaligen, waren al onze tweetaligen Nederlands-Frans. Een effect van taalcombinatie is hiermee dus uitgesloten en we kunnen concluderen dat vaak taalswitchen leidt tot betere cognitieve controle.

In HOOFDSTUK 4 onderzochten we het effect van taalswitchen verder en keken we naar switchvaardigheid (aldus, hoe goed iemand van taal kan wisselen). Voorts wilden we nagaan of bepaalde taaltraining, zoals tolken, een invloed heeft op cognitieve controle. Daarom bestonden onze groepen uit tolken, gebalanceerde tweetaligen, niet-gebalanceerde tweetaligen en eentaligen. Alle tweetaligen (inclusief de tolken) hadden Nederlands-Frans als talencombinatie. De eentaligen spraken enkel Frans. We gebruikten twee maten van cognitieve controle, nl. de Simon-taak en de Attention Network Test (ANT). Taalswitchvaardigheid werd gemeten aan de hand van een geadapteerde verbale vlotheidstaak, waarin participanten steeds dienden te wisselen van taal. De resultaten kunnen worden opgesomd in drie voorname bevindingen. Eerst en vooral konden we het voordeel dat tweetaligen vertoonden in studies van Bialystok en collega's bevestigen. Al onze tweetalige groepen scoorden namelijk beter op beide taken dan onze eentalige groep. Voorts vonden we ook dat tolken accurater waren op de ANT, waaruit we kunnen afleiden dat tolkentraining cognitie op ene positieve manier beïnvloedt. Ten slotte konden we een correlatie aantonen tussen taalswitchvaardigheid en cognitieve controle, maar wel slechts in de gebalanceerd-tweetalige populatie. In deze populatie bleek beter taalswitchen gepaard te gaan met een kleiner congruentie-effect op de Simon-taak. Dit toont aan dat taalswitchvaardigheid, net zoals taalswitchfrequentie, cognitieve controle beïnvloedt.

COGNITIEVE RESERVE IN NIET-MIGRANTE TWEETALIGEN

Een aantal Canadese studies toonden reeds aan dat tweetaligheid de symptomen van dementie (en meer specifiek van de Ziekte van Alzheimer) tot vier à vijf jaar kan uitstellen (Bialystok et al., 2007; Bialystok et al., 2014; Chertkow et al., 2010; Craik et al., 2010; Schweizer et al., 2011). In deze Canadese studies werd dit voordeel van tweetaligheid wel slechts teruggevonden in migrantenpopulaties. Het doel van de studie beschreven in HOOFDSTUK 5 was nagaan of een gelijkaardig voordeel ook bestaat in niet-migrantenpopulaties.

We vergeleken daarom de leeftijd van manifestatie en diagnose van Alzheimer voor eentalige en tweetalige patiënten die zich aanmeldden bij het UZ Gent en het UZ Brussel. In totaal namen 69 Belgische eentaligen en 65 Belgische tweetaligen deel aan onze studie. Uit onze analyses op de leeftijd van manifestatie diagnose bleek inderdaad dat tweetaligen 4,6 jaar later de symptomen van Alzheimer kregen dan eentaligen en dat zij ook pas 4,8 jaar later werden gediagnosticeerd. In deze analyses namen we ook opleiding, beroep, initiële mini-mental scores en geslacht op als controlevariabelen. Deze variabelen leken in het algemeen geen significante rol te spelen in de manifestatie- en diagnoseleeftijd. We vonden wel een lineair effect tussen manifestatie en beroep, waarbij hogere beroepen leidden tot snellere manifestatie. Dit kan te verklaren zijn door het gepaard gaan van deze beroepen met meer stress en slaapdeprivatie, welke ook de klinische manifestatie van Alzheimer versnellen (Di Meco, Joshi, & Praticò, 2014).

Onze studie vond dus dat, ook in niet-migrantenpopulaties, tweetaligheid een bescherming kan bieden tegen de Ziekte van Alzheimer. Onze resultaten zijn hiermee ook in lijn met de resultaten van een recente studie van Alladi et al. (2013). Zij vonden ook dat tweetaligheid verschillende soorten van dementie, waaronder Alzheimer, kan uitstellen in tweetalige niet-migranten.

GEZICHTEN ALS CUE VOOR TAALSELECTIE

In HOOFDSTUK 6 namen we even wat afstand van tweetalige cognitieve controle en legden we de nadruk op taalcontrole. Het doel was vast te stellen hoe taalselectie in tweetaligen tot stand komt. In de huidige tweetalige comprehensie- en productiemodellen (o.a. Dijkstra & van Heuven, 2002; Green, 1998; Poulisse & Bongaerts, 1994) wordt telkens gesteld dat de relevante taal steeds moet worden geactiveerd. Toch wordt in deze modellen geen duidelijke trigger voor activering beschreven, en uit eerder onderzoek blijkt dat enkel talige informatie (zoals context) niet genoeg is om taalselectie te beperken tot de relevante taal (cf. Dijkstra et al., 1999; Marian et al., 2003). Daarom onderzochten we of het gezicht van een gesprekpartner ook als taalcue kan dienen.

Onze studie omvatte twee experimenten uitgevoerd bij Spaanse-Catalaanse en Nederlands-Franse tweetaligen. Eerst leerden de participanten een aantal nieuwe gezichten kennen via Skype-simulaties. Deze gezichten spraken een van de twee talen die de tweetaligen ook beheersten. Daarna voerden zij een verbale associatietaak uit, waarbij de stimuli werden in beide talen geproduceerd door zowel bekende (uit de Skype-gesprekken) als onbekende gezichten. De resultaten toonden aan dat participanten uit beide experimenten sneller reageerden in de associatietaak, wanneer een bekend gezicht het stimuliwoord produceerde in de taal die zij ook hadden aangewend tijdens de Skype-gesprekken (congruente trials) dan wanneer zij gebruik maakten van de andere taal (incongruente trials). Dit congruentie-effect was wel slechts kortstondig. Wanneer het voor de participanten duidelijk werd dat de bekende gezichten eigenlijk tweetalig waren, verdween het effect. Dit toont aan dat het gezicht van een gesprekspartner aanleiding geeft tot correcte taalselectie in tweetalingen, zolang dat gezicht wordt geassocieerd met slechts één taal.

Onze resultaten zijn gelijkaardig aan die van Li et al. (2013) en Zhang et al. (2013), die eerder al een verband vaststelden tussen taalselectie en de socioculturele identiteit van een gezicht. Onze studie breidt nu deze bevindingen uit door te stellen dat het effect niet afhankelijk van cultuur moet zijn.

CONCLUSIE

De vijf empirische studies die in dit proefschrift werden voorgesteld dragen bij tot het onderzoek rond tweetaligheid en cognitieve controle, maar ook tot het veld van tweetalige taalcontrole. Enerzijds, op het gebied van taalcontrole toonde het proefschrift aan dat tweetalige taalselectie kan gebeuren aan de hand van het gezicht van de gesprekspartner. Anderzijds, op het gebied van cognitieve controle, wees het proefschrift uit dat tweetaligheid inderdaad een positief effect heeft op het cognitief functioneren. Specifiek werd er ook gekeken naar de verschillende linguïstische parameters die dit effect beïnvloeden. Zo werd het belang van taalswitchgedrag en tolkentraining aangetoond. Verder werd duidelijk dat meer gestandaardiseerde taken, zoals intelligentietests, voor meer betrouwbare resultaten en betere vergelijkingen tussen studies kunnen zorgen.

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APPENDIX
DATA STORAGE FACT SHEETS

```
% Data Storage Fact Sheet

% Name/identifier study: Children attending bilingual kindergarten
school become smarter
% Author: Evy Woumans
% Date: 26 February 2015


1. Contact details
=============================================================

1a. Main researcher
-------------------------------------------------------------
- name: Evy Woumans
- address: Henri Dunantlaan 2, 9000 Gent
- e-mail: evy.woumans@ugent.be

1b. Responsible Staff Member (ZAP)
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- name: Wouter Duyck
- address: Henri Dunantlaan 2, 9000 Gent
- e-mail: wouter.duyck@ugent.be

If a response is not received when using the above contact details,
please send an email to data.pp@ugent.be or contact Data Management,
Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2,
9000 Ghent, Belgium.


2. Information about the datasets to which this sheet applies
=============================================================
* Reference of the publication in which the datasets are reported:

* Which datasets in that publication does this sheet apply to?: The
sheet applies to all data reported in the study



3. Information about the files that have been stored
=============================================================


3a. Raw data
-------------------------------------------------------------

* Have the raw data been stored by the main researcher? [x] YES /
[ ] NO
If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [ ] research group file server
  - [ ] other (specify): ...
```

```
% Data Storage Fact Sheet

% Name/identifier study: The influency of language switching
experience on the bilingual executive control advantage
% Author: Evy Woumans
% Date: 26 February 2015


1. Contact details
============================================================

1a. Main researcher
------------------------------------------------------------
- name: Nele Verreyt and Evy Woumans
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- e-mail: evy.woumans@ugent.be

1b. Responsible Staff Member (ZAP)
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- name: Wouter Duyck
- address: Henri Dunantlaan 2, 9000 Gent
- e-mail: wouter.duyck@ugent.be

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9000 Ghent, Belgium.


2. Information about the datasets to which this sheet applies
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* Reference of the publication in which the datasets are reported:
Verreyt, N., Woumans, E., Vandelanotte, D., Szmalec, A., & Duyck, W.
(2015). The influency of language switching experience on the
bilingual executive control advantage. Bilingualism: Language and
Cognition. doi: 10.1017/S1366728914000352

* Which datasets in that publication does this sheet apply to?: The
sheet applies to all data reported in the study



3. Information about the files that have been stored
============================================================


3a. Raw data
------------------------------------------------------------

* Have the raw data been stored by the main researcher? [x] YES /
[ ] NO
If NO, please justify:

* On which platform are the raw data stored?
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```
% Data Storage Fact Sheet

% Name/identifier study: Verbal and non-verbal cognitive control in
bilinguals and interpreters
% Author: Evy Woumans
% Date: 26 February 2015


1. Contact details
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1a. Main researcher
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- name: Evy Woumans
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* Have the raw data been stored by the main researcher? [x] YES /
[ ] NO
If NO, please justify:

* On which platform are the raw data stored?
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```
% Data Storage Fact Sheet

% Name/identifier study: Bilingualism delays clinical manifestation
of Alzheimer's disease
% Author: Evy Woumans
% Date: 26 February 2015


1. Contact details
===========================================================

1a. Main researcher
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2. Information about the datasets to which this sheet applies
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* Reference of the publication in which the datasets are reported:
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Alzheimer's disease. Bilingualism: Language and Cognition. doi:
10.1017/S136672891400087X

* Which datasets in that publication does this sheet apply to?: The
sheet applies to all data reported in the study



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3a. Raw data
-----------------------------------------------------------

* Have the raw data been stored by the main researcher? [x] YES /
[ ] NO
If NO, please justify:

* On which platform are the raw data stored?
```

```
% Data Storage Fact Sheet

% Name/identifier study: Can faces prime a language?
% Author: Evy Woumans
% Date: 26 February 2015


1. Contact details
===========================================================

1a. Main researcher
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  - [x] researcher PC
  - [ ] research group file server
  - [x] other (specify): part of the data are also stored on a hard
drive in another lab in Barcelona
```