Aging in multilingual Netherlands

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CHAPTER 3

Multilingual social relationships

Abstract | This chapter builds on the research on multilingualism and cognitive aging reported on in the previous chapter by investigating more specifically the settings under which positive cognitive effects of bilingualism emerge. The study reported on here assesses under which circumstances language use and linguistic diversity of social relations contributes to enhanced cognitive performance, and how this is connected to cognitive reserve. This is done by assessing demographics, health, quality of life, personality characteristics, language knowledge and use, and details on social relations in a subset of the diverse group of multilingual older adults (n=244) in the Netherlands reported on in chapter 2. A partial least squares regression analysis is employed to help determine more precisely why some individuals do show enhanced cognitive performance and others do not, despite all being multilingual.[1]

[1]This chapter has been slightly adapted for this dissertation and has been accepted pending major/minor revisions in: Pot, A., Keijzer, M.C.J. and de Bot, K. (submitted). The contribution of multilingual close social relationships to cognitive reserve. *Bilingualism: Language and Cognition*.

3.1 Introduction

As people age, cognitive performance gradually declines. Not all individuals show decline at the same rate, however, and certain life experiences such as musical training and engaging in physical exercise can significantly improve cognitive performance. Multilingualism has been positively (but controversially) put forward as one such cognitively enriching life experience, due to the cognitively complex skill of managing two languages in one mind (Bialystok, 2017; Prior and MacWhinney, 2010; Valian, 2015).

Recently, the field of bilingualism and cognition has directed its attention to the circumstances and settings under which positive cognitive effects of bilingualism emerge (Bialystok and Sullivan, 2017). Marked differences are, for example, observed regarding cognitive control mechanisms for different bilingual populations and for a variety of interactional contexts (Ooi et al., 2018; Timmer et al., 2018). These differences relate to variation in the environment of multilinguals, calling for the importance to situate and investigate language use in a broader context of life-experiences (Pot et al., 2018c).

Executive control performance is at its peak in young adulthood, where bilingual effects are rarely observed. In children and older adults, however, there is greater variability in executive functions, making differences in cognitive performance easier to detect in very young or older populations (Park et al., 2002). Most notably in relation to older age, this diversification in executive functions is generally attributed to individual rates of gradual cognitive decline, affecting the capacity to speedily process information. An alternative view on aging, however, argues that aging is not a process of decline over time but rather an accumulation of relevant experiences. Slower processing is explained as heavier memory search demands, as individuals need to filter through more knowledge and experiences than younger adults (Ramscar et al., 2014). Perhaps multilingualism may in this sense contribute to greater mental flexibility, through which the memory search process is optimised.

A recent analysis on the operationalization of bilingualism in different studies attested that information on the sociolinguistic context of bilingual populations is only taken into account in 30% of the studies investigating bilingual advantages (Surrain and Luk, 2017). Moreover, forms of (bilingual) language use,

such as dialect usage, are hardly ever mentioned in studies and language questionnaires. The current study addresses precisely these issues by being one of the first to investigate how a large set of individual variables, of which language use is one, may together explain enhanced cognitive performance. As part of this aim, special attention is paid to the close social relationships of a diverse group of older multilinguals, as we assess whether and how social relationships (i.e., the interactional context of language) modify a bilingual cognitive effect.

A socially engaged lifestyle as well as multilingualism have separately been associated with the build-up of a cognitive reserve in old age (a reserve capacity that allows the brain to better adapt to cognitive changes as a result of aging, brain damage or disease) (Chauvin et al., 2017; Scarmeas and Stern, 2003). When we consider how the diversity of social relationships modulates multilingualism in older individuals, this may shed additional light on how and when multilingualism can be an asset in building cognitive reserve.

3.2 Background

3.2.1 Cognitive reserve

Cognitive reserve becomes visible when two individuals with similar levels and types of brain pathology/ atrophy perform differently on effortful cognitive tasks. In the literature on reserve a distinction is generally made between cognitive reserve and brain reserve. Yet it is still unclear how these two forms of reserve interact (Stern, 2012). Brain reserve is generally regarded as brain 'hardware', relating to actual anatomic differences between individuals. This is manifested as more synapses or denser neuronal networks and can be regarded as a passive form of reserve (Satz, 1993).

Cognitive reserve, on the other hand, can be regarded as brain 'software' with which the brain can efficiently execute tasks. Specifically pertaining to cognitive reserve, a further distinction is made between either more efficient processing of information or compensation (i.e., the recruitment of neural pathways not normally employed in the execution of a given task). The latter in turn is said to be induced by brain damage and nudges the brain to call upon alternate brain areas (Stern, 2002). These definitions also reveal the connectedness of brain versus

cognitive reserve, as calling upon alternate brain areas likely induces a form of structural changes in the brain (brain reserve).

Environmental enrichment, such as education and mental stimulation, but also life experiences like musical training or navigation skills may induce structural but not necessarily permanent brain changes (Herholz and Zatorre, 2012; Maguire et al., 2000). Barulli and Stern (2013) note that cognitive training activities or interventions, as well as long-term cognitive stimulation promote brain plasticity. These structural brain changes in turn enhance mental flexibility, either in the sense of more efficient processing of information along existing neural pathways, or through a flexibility to recruit additional pathways to perform a cognitive task.

3.2.2 Bilingualism and cognitive reserve

Bilingualism is an all-encompassing life-experience that engages a large brain network. Neuroanatomical research has observed that the brain regions recruited for executive functions partly overlap with brain regions handling language control (Abutalebi and Green, 2016). Therefore, speaking multiple languages relies on executive control and attention, it is argued, through which these brain systems are better developed, ultimately resulting in greater grey and white matter density that buffers the early onset of dementia (Perani and Abutalebi, 2015). Studies have demonstrated that some bilinguals with high brain atrophy perform behaviourally on a par with monolinguals with better-intact brains, suggesting an increased ability of bilinguals to recruit alternate brain networks when regular pathways are obstructed (Kowoll et al., 2016).

As such, bilingualism may induce cognitive reserve either by increasing grey matter density (brain reserve) and/or by enhancing global mental flexibility, a combination of the two, or in interaction with related variables such as education or SES (Chauvin et al., 2017). However, as bilingual experiences differ, it is difficult to attribute bilingual cognitive advantages to one isolated mechanism of control, such as inhibition (Bialystok, 2017). Rather, it is argued that individual bilinguals exercise a multitude of strategies to regulate processing of different languages. Which strategies individuals employ and to what extent depends on (interactions between) e.g. working memory, speed of processing, inhibitory

functioning and language experience. The inter-individual language processing variation suggests a plastic view on bilingual language processing (Fricke et al., 2018).

Although brain data provide compelling evidence of cognitive differences between bilinguals and monolinguals, in isolation this cannot lead to insights as to what those differences mean or how they come about. In a reply to commentaries on a recent review of neuroanatomical data in relation to bilingual cognition, García-Pentón et al. (2016), argue that without context (behavioural data), it is impossible to determine the cause for observed brain differences. In other words, although brain data may be a compelling argument for demonstrating cognitive effects for bilingualism, only when paired with behavioural data can such an effect be demonstrated (cf. de Bot, 2008).

3.2.3 How does bilingualism modulate cognitive control?

Pairing neuroanatomical data from bilingual speakers to their behavioural data itself is highly problematic: there is substantial uncertainty over the mechanisms by which bilingualism influences cognitive control. There is a lack of clear theoretical models that outline how bilingualism functions in relation to cognition and how it can modulate it; which factors play a role and to what extent (see Hartsuiker, 2015; Marzecová et al., 2013). As a response to a paper by Valian (2015), who reviews the inconsistent results reported regarding a bilingual cognitive advantage, Luk (2015) advocates a more fine-grained look at 'bilingualism'. This call is underscored by a recent analysis on the operationalisations of bilingualism across the literature by Surrain and Luk (2017), which demonstrated the variability in sampling bilinguals. Differences in intensity, balance or the duration of bilingualism (i.e., age of acquisition) between and within groups may obscure null-results when these groups are subsequently compared.

Even in studies where the label bilingualism is more carefully treated, mixed results are obtained. Yow and Li (2015), for example, assessed language balance in young English-Mandarin adults as a composite measure of language proficiency, frequency of use of two languages and age of acquisition. They found that only highly proficient balanced bilinguals (in proficiency and frequency of use of both languages) performed better on measures of controlling attention. The number

of languages spoken by a bilingual has also been linked to the magnitude of a cognitive effect, although this factor, too, seems to be integrated in and related to other factors rather than being able to explain cognitive outcomes by itself. Ihle et al. (2016), for instance, conclude that in old age, having a command of multiple languages may contribute to cognitive reserve, yet not in all participants and dependent on other cognitively stimulating activities the participants engaged in and their verbal abilities and basic cognitive processing speed.

There thus seems to be no systematic/consistent difference between bilingual and monolingual groups, especially not among young adults and in small samples (these studies typically have small ns), as Paap et al. (2014) empirically assessed. Differences in self-ratings of bilingual proficiency lead to unstable outcomes for different bilingual populations, underscoring the difficulty of comparing bilingual groups with different language combinations (Tomoschuk et al., 2018). Moreover, Bak (2016a) argues that advantages may only show up under specific circumstances, in specific groups, and crucially depending on the interactional context (see also Ooi et al., 2018).

The effect of the interactional context on language use is at the core of the Adaptive Control Hypothesis (Green and Abutalebi, 2013), which postulates that bilinguals situated in interactional contexts in which language switching intensity is high show less of a cognitive control advantage than bilinguals who mostly reside in strictly separate language contexts (e.g., at work and at home they use different languages). This is because precisely this latter group has to continuously suppress the activation of one of their languages depending on the context, thus needing a greater degree of mental flexibility. Notably, it is not switching itself that would account for enhanced cognitive control, but the requirement of particular interactional contexts (or perhaps social domains) to keep two (or more) languages apart. This culminates in enhanced attention control, as especially in this dual-language context individuals need to continuously monitor the environment for language cues to adapt to the linguistic context. In other words, through the adaptive control hypothesis, we can perhaps better get at the mechanisms that underlie the cognitive flexibility effect in bilingualism and with that perhaps also the nature of cognitive reserve.

Indeed, when looking more closely at the control mechanisms involved in a typical measure of executive control – a Flanker task – Ong et al. (2017) demon-

strated that bilingual elderly were better able to filter out the distracting flankers, and that this reflects an enhanced attention-control mechanism. With a sophisticated statistical technique, the researchers calculated the non-decision time for mono- and bilingual elders on response to congruent items (whereby the flanking arrows correspond to the direction of the middle arrow) and incongruent items (whereby the flanking arrows are in the opposite direction of the middle arrow). Bilingual elderly already focus their attention and ignore the distracting flankers, before inhibiting a response. This suggests not only that the Flanker task provides information of attention-control processes, rather than tapping inhibitory control which it is often claimed to do, but also that it reflects advantages in precisely the attention aspect of cognition.

A recent study by Pot et al. (2018c), too, demonstrated that some multilinguals show enhanced attention control on a Flanker task. Most notably, however, they found that it is the usage of multiple languages, rather than 'being' multilingual which demonstrates enhanced attention effects, and it is only in interaction with other factors such as education, personality and quality of life that the influence of bilingualism emerges. This echoes the position of Baum and Titone (2014), who point out that a particular factor such as musical training or bilingualism will not have an equally large impact for people who may or may not already benefit from other sources of enrichment, such as the advantages that come with a high socioeconomic status (2014, p. 877).

3.2.4 The social context

As becomes evident from the studies above, much more than a factor in isolation, multilingualism is a complex, social variable. Language usage changes depending on the social domain in which it is used, and is influenced by the degree of switching between languages, or the monolingual or bilingual social context the individual is in (Grosjean, 1998). Therefore, knowledge in relation to the language environment in which individuals use their language(s), and how this may interact with other lifestyle factors (in other words, awareness of a bilingual's needs, as Grosjean argues) is equally important when studying multilingualism in relation to cognitive control or the building up of cognitive reserve.

In an overview of the impact of lifestyle on cognitive reserve, Scarmeas and

Stern (2003) postulate that a socially engaged lifestyle – in a broad sense engaging in social contact, not being isolated and a socially enriched environment – may contribute to the build-up of cognitive reserve. It is said to increase the synaptic density in the neocortical association cortex, through which more unaffected neurons can compensate for loss of brain functions. Alternatively, subjects may develop more efficient circuits of synaptic connectivity when engaging in leisure activities or having an active lifestyle. A third possibility is that lifelong experience with a certain lifestyle variable (for example multilingualism) and the continued practice of this may lead to more flexibility in recruiting alternate brain networks. Modifications to one's environment and lifestyle changes could thus influence the rate of cognitive decline. This has been demonstrated before for sustained physical exercise (Blankevoort et al., 2013), playing a musical instrument (Hanna-Pladdy and Gajewski, 2012) and engaging in social relationships (Engelhardt et al., 2010).

A comprehensive review in *The Lancet* (Fratiglioni et al., 2004) assessed the results of studies looking into the effects of an active and/or socially integrated lifestyle on cognitive health in later life. They found that, across the different domains of aging (social, psychological and biological), maintaining activity (e.g., engaging in sports activities or clubs, musical activity, or other engaging hobbies) and having a large and diverse social network was positively associated with better cognitive functioning. Similar findings are reported in Crooks et al. (2008), who assessed the cognitive capacities of a group of elderly women and mapped the size of their social network. They demonstrated in a four-year longitudinal follow-up that a larger social network and daily social contact was positively associated with cognitive performance and fewer indices of dementia in their participant sample.

Especially in older adulthood, the size and function of one's social network changes (e.g., Caplan, 1974; Tilburg and Groenou, 2002). A meta-study towards the relation between social relationships and cognitive decline in older adults revealed that having poor social relationships (in terms of size and function) is related to cognitive decline, although the robustness of this finding is likely mediated by other lifestyle factors, such as diet or exercise, that are not always taken into account (Kuiper et al., 2016).

Especially the diversity, rather than the size of a social network is associated with cognitive health, as demonstrated in a six-year longitudinal study incorpo-

rating 2959 Dutch older adults by Ellwardt et al. (2015). They conclude that although complexity of one's social network is related to cognitive performance, this is neither directly explained by the number nor specific types of relationships (relations in different social domains: family, neighbourhood, clubs) in one's individual network. Rather, diversified social relationships contribute to enriched environments, which require more intense switching between context and in this way facilitate brain training. Similarly, in a study towards the interaction between language, cognitive skills and social networks in two residential communities of the 'oldest-old' (classified here as individuals aged 85 or older), Keller-Cohen et al. (2006) observed that a high degree of interaction with friends and diverse relationships in an individual's social network was related to better performance on a lexical decision task.

The social aspect in the study towards cognitive effects for multilingualism has up until now received relatively little attention, even though language is inherently a social phenomenon and it is hence likely that the social environment in which individuals reside has an impact on the language that they use. In the domain of language shift or maintenance studies have indeed exemplified that the presence or absence of social L1 or L2 networks play an integral part in the study of language change (De Bot and Stoessel, 2002).

The relevance of the social context in bilingualism studies has recently taken a turn to investigating the social flexibility rather than mental flexibility of bilinguals versus monolinguals. A recent study towards bilingual and monolingual's social skills argued that bilinguals have greater social flexibility (Ikizer and Ramírez-Esparza, 2017). The authors claim that because bilinguals alternate between two languages, they may also alternate with more ease between different social environments. However, as Vives et al. (2018) point out in a commentary, the foundations for this claim are somewhat shaky, especially because the bilingual group was half the size of the monolingual group and included bicultural participants (from a wide variety of backgrounds), which were absent from the monolingual group. Vives et al. (2018) propose that using different languages may broaden the interactional horizon through which individuals can look at the world in different ways. Then perhaps the increase in variability in social experiences may foster cognitive flexibility, although this remains up until now speculative.

3.2.5 This study

The current study focusses on on the concerns that have been raised in relation to the issues regarding multilingualism research, and its associated cognitive reserve and lifestyle variables. It is embedded within current approaches that detail the precise circumstances under which a multilingual effect emerges. Most specifically, it looks at the role of bilingualism within social networks as this appears to be most neglected so far and most in need of exploration.

Our research question is whether and how having more linguistically diverse social relationships contributes to cognitive performance in a diverse group of multilingual older adults. Isolating factors when searching for a cognitive reserve is virtually impossible, and attempts to do so may partly account for the mixed findings in life-experiences that are said to enhance cognitive performance.

Rather than dismissing the search for cognitive advantages altogether on the basis of the complexity of interacting variables, it makes it all the more intriguing and necessary to investigate whether we can pinpoint certain life-experiences to play a role in cognitive performance, and under which precise circumstances these 'advantages' may take effect. This helps us to situate the role of language as a social phenomenon in cognitive control in a more detailed context and aids in uncovering more about how language control influences cognition.

We hypothesise that, in light of enhanced mental flexibility, having linguistically diverse social networks co-varies with the usage of different languages across social domains and as such contributes to cognitive control. Individual language usage patterns and social relationships may elucidate the role of speaking different languages in cognitive performance. Moreover, as we approach multilingualism as something that is connected to other lifestyle factors, we believe that also social diversity co-varies with other dimensions of aging, such as health factors, quality of life or personality.

Departing again from the objective that multilingualism is a contextually situated variable, we do not distinguish groups of participants, but consider a diverse group of multilinguals, thereby paying more attention to individual differences within this group. Moreover, this also means that we do not consider confounding factors as 'masking' the effect of multilingualism on cognitive performance, but as an asset in helping to determine under which circumstances multilingualism

may be beneficial to cognitive health.

Answering the question of how diverse social relations relate to other language measures and cognitive performance in a model with a wide variety of individual background variables requires an alternative, individual approach to data analysis. This is why we propose the use of a multivariate statistic in the form of partial least squares regression.

3.3 Method

3.3.1 Participants

To study the effect of social relationships on language use and cognitive performance, we used the data on social relationships from a total of 244 older adults (65-95 years old, mean age 71.5, 119 males) living in the northern part of the Netherlands. These seniors completed an extensive background questionnaire tapping demographic, health, personality and language information (in which we also regarded dialect as a language) and performed three cognitive tasks measuring inhibition/attention, set-shifting and working memory. Crucially, a number of items on the questionnaire tapped social networks of the speakers, whereby participants listed details on their 5 closest social relations.

Participants were generally well-educated (mean of 5 on a scale of 1-6), and felt they had a high quality of life (mean of 8 out of 10). The majority was physically active (67%) and almost half of the sample played or had played a musical instrument (48%). On average, the sample reported to speak four languages, with a high level of proficiency in at least their first two languages, which were mostly Dutch, Frisian, a local dialect (Gronings or Drents) or German (mean L1 = 4.9, mean L2 = 4.6 and mean L3 = 3.9 on a scale of 1-5). The majority acquired their first two languages before the age of 12 (64%) although the age range increased for the L2 and L3 (standard deviation L2 = 9.3 and L3 = 10.4). All participants in general had a positive attitude towards their first three languages but used their first, second and third listed languages to varying degrees across different social domains. In other words, this presented a relatively homogeneous subset of speakers in terms of SES but at the same tine they were quite varied in their reported multilingual use.

3.3.2 Materials

We asked participants to complete a comprehensive background questionnaire which elicited information on demographics, health status, quality of life, the 'big five' personality domains (Gosling et al., 2003), language proficiency, age of onset of acquisition, language use in different social settings, amount of switching between languages (never to always on a five-point scale), attitude towards the first three languages and the five persons with which participants were in frequent contact (type of relationship and in which language). For the operationalization of language, we also included dialect usage. A full summary of the background questionnaire is provided in Table 2.3 in chapter 2. Here, we report on the type of social relationships the participants listed.

Participants could list a maximum of five close social relations, of which summary statistics are presented in Table 3.3.2 below. Participants provided information on the type of relationship (in the first column: mostly family members and friends), the languages in which they interact (in the second column: mostly Dutch and Frisian) and the contact frequency with their relations (the final column: weekly contact is most frequent).

Table 3.1: *Frequency of occurrence of 5 closest social relationships (n = 244)*

Relationships	Languages	Contact frequency
Family 538	Dutch 545	Weekly 508
Friend 207	Frisian 300	Daily 284
Partner 164	Dialect Gronings 73	3-5xpw 142
Neighbour 107	Dialect Drents 55	Monthly 114
Hobby/sport 85	Dutch-Frisian 43	Often 78
Work 82	English 31	Biweekly 75
Other 37	Other 173	Other 19

In addition, Table 3.3.2 shows the statistics on social language usage, listing the degree of use of the first, second and third language across the social domains of family, friends, neighbours and acquaintances on a scale of 1 (never) to 5 (always), the degree of switching according to a specific context (again on a 5-point

scale), as well as the mean diversity in types of social relationships and languages for the participant sample.

Table 3.2: *Social variables of participant sample*

Variable	N	Mean	St.d	Min	Max
Contextual switching	240	2.45	0.77	1	4.67
Across-domain use of L1	244	4.15	0.80	1.50	5
Across-domain use of L2	241	3.17	0.96	1	5
Across-domain use of L3	222	1.91	0.73	0.25	4.50
Number of different languages in network	244	2.14	0.85	1	4
Number of different relations	244	3.11	0.94	1	5

In addition to the background questionnaire, participants completed three cognitive tasks. A Flanker task, whereby participants need to react as fast as possible to the direction of the middle arrow, flanked by arrows pointing in the same or the opposite direction – measuring inhibition/attention regulation. A Wisconsin Card Sorting Task, whereby participants sort cards according to a changing rule to which they need to adapt, and not persist using the old rule – measuring shifting between mental sets. And lastly a non-verbal working memory assessment using a Corsi Blocks Tapping Task, whereby participants tap an increasing sequence of blocks in a particular order. We calculated a Flanker effect score, which reflects the difference between the reaction times on incongruent items versus congruent items. A smaller Flanker effect score suggests overall faster performance. The WCST error score reflects the number of persistent errors participants make when they have to sort the cards based on a new rule (and they instead persist sorting according to the old rule). The Corsi span score reflects the maximum number of items in a sequence that participants can successfully recall. Summary statistics are provided in Table 3.3.2 below.

Some individuals obtained a negative flanker effect score, suggesting faster performance on the incongruent items than on the congruent (also see the previous chapter). A negative effect score might be a reflection of hyper-focus on the task, and we have thus decided to retain these negative scores in the calculations as they may reflect enhanced attention processes.

Table 3.3: *Descriptive statistics for the three cognitive tests*

Cognitive test	N	Mean	St.d	Min	Max
Flanker effect score	187	89.56	167.41	−362.80	895.85
WCST error score	174	12.49	4.84	4	28
Corsi span	116	4.66	0.95	2	7

3.3.3 Procedure

In order to see whether a more diverse use of different languages (having multilingual contacts) or more different types of relationships co-varies with the degree of multilingual language usage in explaining cognitive performance we fitted a partial least squares (PLS) regression model to the data. In contrast to linear regression models, PLS regression does not require variables to be uncorrelated with each other and rather calculates whether certain variables may cluster together and in such compounds may be responsible for explaining part of the variance in a regression model.

Also, variables do not need to be selected beforehand for inclusion, thereby limiting the risk of cherry-picking in the data an building a model based on only those variables that show a significant contribution to the total explained variance, as may happen in explorative linear regression modelling. Using the 'pls' package in R (Mevik and Wehrens, 2007), we built two models, one with the Flanker effect score as dependent variable, and the other with the WCST error score. The working memory score obtained with the Corsi task was added as a factor to both models.

Beside the scores on either the Flanker or WCST task as dependent variables, we included the following factors in the models. For demographics and health status we tapped age, gender, education, income, the province of residence, self-reported health status, quality of life, being physically active and whether individuals play(ed) a musical instrument. In terms of language use we included the number of languages, proficiency and age of onset of acquisition in L1, L2 and L3, across-domain usage of L1/2/3, attitude towards L1/2/3, early versus late acquisition and degree of contextual switching. For the social relationship measures

we included the diversity of languages in social relations and the number of diverse relationships. Personality was measured with the 'big five': extraversion, agreeableness, conscientiousness, emotional stability and openness to new experiences.

To determine which variables in both PLS models contribute to the percentage of explained variance we calculated each variable's importance in prediction (VIP, cf. Mehmood et al., 2012). The weight of each variable is a measure of its contribution to the model according to the total variance explained by each component of the PLS regression. A threshold of 'importance' of > 0.83 thereby yields the most relevant variables, which is what we therefore used in the study.

We calculated the mean VIP score for each variable by aggregating each variable's scores per component and calculating the range (lowest and highest VIP scores). Through examining the mean, standard deviation and minimum and maximum scores we could decide which variables are overall important in prediction. The output of the VIP analysis was subsequently presented in a VIP plot.

3.4 Results

The first PLS regression model was fitted to the Flanker effect scores of the participants. The output yielded a 10-component solution, explained overall 24.6% of the variance of the Flanker effect score. We aggregated the VIP scores of each variable for each component into a mean score for each variable (VIP scores generally show low standard deviations across components. The full results are presented in appendix A. Here, in Table 3.4, we present only the contributing variables with mean (or max) VIP scores above 0.89.

Table 3.4: *Contributing mean and max VIP scores (above 0.89) of PLS regression on Flanker data*

Variable	Components	Mean	St.d	Min	Max
Age	10	**1.586**	0.899	0.224	2.353
AoA L1	10	**1.709**	0.147	1.349	1.918
AoA L2	10	**1.585**	0.391	2.233	3.434
AoA L3	10	**2.601**	0.613	2.055	3.971
Extravert	10	**1.011**	0.364	0.516	1.420
Conscientiousness	10	**0.904**	0.145	0.601	1.107
Emotional stability	10	**1.454**	0.171	1.22	1.846
Open to experiences	10	**1.613**	0.124	1.359	1.851
Language combinations	10	**1.196**	0.148	0.92	1.393
Across-domain L1	10	0.447	0.332	0.121	**0.927**
Across-domain L2	10	**1.260**	0.17	0.84	1.462
Across-domain L3	10	**0.964**	0.094	0.873	1.181
Number unique Ls	10	0.817	0.072	0.748	**0.970**

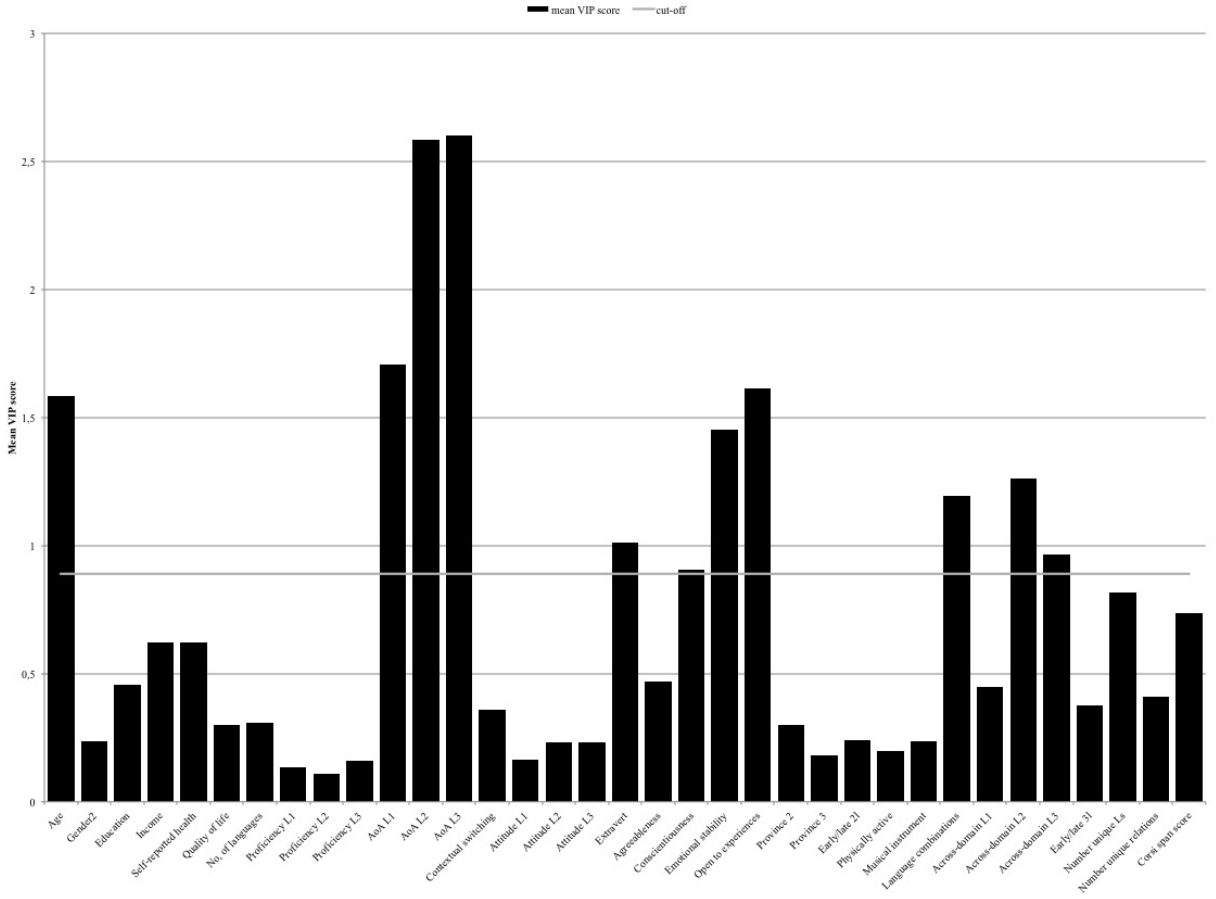

Figure 3.1: *VIP plot of mean VIP scores Flanker PLS model.*

The variables that make a relevant contribution to the explained variance in the PLS Flanker effect score model are combinations of different variable categories: the demographic variable age co-varies with age of language acquisition and language use patterns (across-domain use of mainly the L2 and L3) and the personality traits of being extravert, conscientious, emotionally stable and open to new experiences. When considering the maximum VIP scores in the final column of Table 3.4, we can also add across-domain use of the L1 and having more diverse languages with close social relations. In other words, it is through a combination of different categories that enhanced Flanker performance can be observed, uniquely revealed through the PLS analysis.

The PLS model built for the WCST error scores yielded a 5-component solution with an overall explained variance of 37.2%. Table 3.4 below lists again the mean VIP scores above 0.89, and the full table can be found in appendix B. We see again that different variable categories together explain part of the model variation. More specifically, education, age of onset of acquisition of the L2 and L3 and extroversion contribute to the model. When considering the maximum VIP scores, we can also include income, age of onset of acquisition of the L1, conscientiousness and being open to new experiences. Strikingly, no other language measures contribute to the explained variance.

Table 3.5: *Contributing mean and max VIP scores (above 0.83) of PLS regression on WCST data*

Variables	Components	Mean	St.d	Min	Max
Age	5	**3.266**	0.33	2.769	3.569
Education	5	**0.894**	0.17	0.631	1.052
Income	5	0.734	0.113	0.592	**0.881**
AoA L1	5	0.568	0.39	0.334	**1.261**
AoA L2	5	**3.341**	0.299	2.878	3.67
AoAL3	5	**2.369**	0.215	2.196	2.724
Extravert	5	**1.321**	0.255	1.087	1.74
Conscientiousness	5	0.8	0.223	0.603	**1.182**
Open to experiences	5	0.783	0.237	0.626	**1.2**

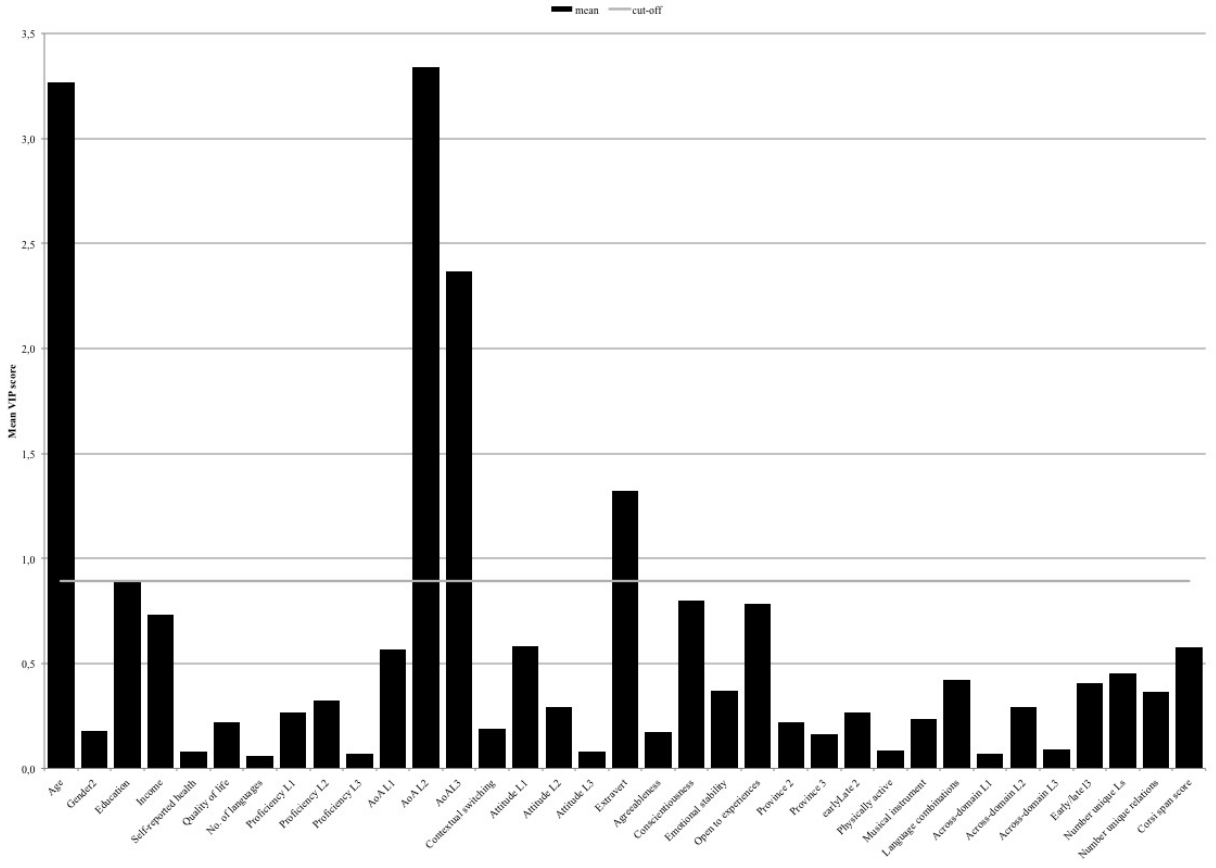

Figure 3.2: *VIP plot of mean scores WCST PLS model.*

3.5 Discussion

The present study aimed to shed more light on the closest social relationships of multilingual older adults, to see whether the type of relationship or degree of differential language use is connected to the use of languages in different social domains, and in this way mediates cognitive performance. And if so, what this could tell us about the role of multilingualism in modulating cognitive reserve. To assess linguistic and relational diversity in close social relationships, we asked participants to list five people with whom they are in frequent contact, thereby providing information on the relationship as well as the language in which this contact takes place. A statistical technique that has to our knowledge until now never been used in this setting was applied (a partial least squares regression model (PLS), that uniquely allowed us to view how different variables cluster together. We therefore fitted two PLS regression models to the data on the two cognitive tests, thereby including the factors listed in the background questionnaire as well as information on the diversity of languages and relationships in those five contacts listed. The results demonstrate two structurally different models, whereby some predictors of cognitive effects overlap, such as age and education, but where language knowledge and social language usage predictors show up differentially.

Both models feature age as a robust predictor, as well as educational level. For the 24.6% explained variance in Flanker effect scores, the age of onset of acquisition of all three languages are robust predictors, as well as the use of especially the L2 and L3 across different social domains. For the 37.2% explained variance in the WCST error scores, only age of acquisition of the L2 and L3 as language measures are predictors. Personality scores reflecting openness to new experiences and being conscientious make a significant contribution to the explained variance in both models.

To first of all answer the research question on what the close social relationships of individuals tell us about cognitive performance, we note that only the number of different languages in one's closest social relationships contributes just above the threshold of 0.83 to the Flanker model. For the degree of WCST errors neither a more diverse network in terms of relationships, nor in terms of languages makes a significant contribution to the model, and here degree of L1/2/3

usage across different social domains does not contribute to the explained variance either. These results demonstrate the intricacies of the circumstances under which cognitive effects are observed, and underscore the need for studies looking into how and why certain variables cluster together. In interaction with demographic and personality variables, language use and social relationships do present a significant contribution to enhanced cognitive performance. When interpreting how this contribution may come about, it is worthwhile to consider what the two cognitive tasks measure.

As argued in the previous chapter and studied using sophisticated statistical analyses in Ong et al. (2017), the Flanker task likely measures in a large part an attention-orienting process, rather than inhibitory control. Individuals who perform faster on the incongruent flanker items exercise enhanced attention control. When we consider the use of different languages in different social domains, it makes sense to argue that individuals who need to continuously monitor their environment for language cues and regularly switch from one language to the other depending on the social context, exercise enhanced attentional control.

This may, however, also be present in individuals speaking one language, who switch between registers and stylistically adapt their language according to the context. A more fine-grained analysis of individuals' language usage patterns, thereby also taking note of stylistic variation, should explore whether register switching also significantly requires enhanced attention control. If an enhanced effect for multilinguals then still shows up, it could speculatively be because a multilingual individual has to engage in 'double attention': gauging the language as well as the stylistic context. Alternatively, enhanced attention control has to do with being sensitive to variations in the linguistic context (hence the interaction of language use with conscientiousness and emotional stability). This would make only those multilinguals (or monolinguals) with these personality characteristics more attentive to change.

Whether this makes bilinguals more socially flexible, as Ikizer and Ramírez-Esparza (2017) argue, however, would still be a step too far. We see that language use is positively related to cognitive performance, and usage relates to having more diverse languages in close relations, but based on our data it is too big a step to conclude that having multiple languages at your disposal makes you by nature more socially flexible. One explanation for the diversity of languages in

relation to cognitive performance is that those individuals with linguistically diverse social relations are more attuned to language cues than people with less linguistic network diversity, when using different languages with their close social relations. However, as shown in the VIP plots, other factors influence this relationship, most notably personality. Individuals with higher scores on extraversion, for example, may be quicker or more flexible in forging social relationships, which underscores the relevance of models that can take a wide variety of individual variables into account in uncovering the specifics of how language modulates cognitive flexibility.

The interaction of language diversity with the age of onset of acquisition of all three languages, which explains a large portion of the Flanker's model, is interesting. It could be that a network is more linguistically diverse when older adults use different languages with different connections they formed over the lifespan. Earlier acquisition of an additional language means extra years of opportunities to forge network connections in that language, and perhaps also having more domains to use that language in.

The WCST error score is said to provide an indication of the ability to switch between mental sets, and thereby inhibiting an old rule in favour of a new rule. Considering the absence of any language measures beyond age of onset of acquisition in this model, it can be argued that multilingualism, as the use of different languages in context, does not necessarily train inhibitory control and the ability to shift and suppress old information. This is in line with what Kroll and Bialystok (2013) postulate: bilingualism likely trains a more global construct of mental flexibility, rather than inhibitory control. This mental flexibility could come better to the fore in attention selection processes, something that the WCST (allegedly, given the results) does not measure. Only the age of onset of acquisition of the first three languages contributes to the explained variance in terms of multilingualism. The relatively high contribution of these variables, observed in the Flanker model as well, might to some extent tie in with the social relationships of the study's subjects.

The more we know about the environment and language history of participants, the better we are able to investigate how factors work together and why one factor may be stronger in one population than in another, as Baum and Titone (2014) rightly point out. The complex interaction of variables, whereby the num-

ber of different languages used trumps the relational diversity of contacts, is in line with findings by Ellwardt et al. (2015). It strengthens the arguments to approach multilingualism as a multidimensional and dynamic variable, for which in experiments knowledge on the language environment of the participants is of pivotal importance when assessing certain 'consequences' of multilingualism for the mind.

This ties into the argument proposed by Fricke et al. (2018), who note that also in monolingual language use, multiple studies have investigated how individual language processing skills lead to fundamental variation in language processing, showing its malleability. It is unthinkable that this inter-individual variation should not also exist in bilingual language processing, and that investigations between and within bilinguals may unmask some of the differences found between studies on bilingualism and cognitive performance. This can be applied more broadly to research investigating differences in native and non-native speakers, or early and late L2 learners that shows that even among native speakers (or L1ers) there is considerable individual variation (cf. Hulstijn, 2019).

Therefore, referring back to the research on bilingualism and cognitive reserve, it becomes more and more evident that the build-up of a reserve varies per individual. Brain imaging studies are a promising means to pinpoint which individuals show instances of cognitive reserve, either by recruiting alternate brain networks or by more efficiently using existing pathways. However, even though we can compare brain density or functioning among different groups, we know nothing about what might cause certain brain differences unless we also obtain behavioural and background information of participants (cf. García-Pentón et al., 2016).

Alternatively, it can be asked whether the construct of cognitive reserve actually exists within the brain, ready to be used, or whether it arises from an interplay between a number of factors in a given context at a given time within an individual. In that case, is what we are observing in brains and behaviours among individuals a reflection of an independent work force that can be called upon by any brain area when needed, or a localised additional capacity of the language production and perception system. In that sense, CR perhaps only persists when it is continuously practised through cognitive stimulation. Given the interplay of different variables, which is unique for every individual, it makes sense to ar-

gue that cognitive benefits are individually distinct outcomes of a unique and time/context-bound interaction between variables. This study, using a cluster-based analysis, provides a promising first step into the co-occurrence of different variables in uncovering when cognitive benefits in the context of bilingualism occur. Future studies should take this individual variability, and the importance of context into account more (cf. Surrain and Luk, 2017).

3.5.1 Limitations

Our conclusions are built on a large dataset that we obtained through asking participants to fill in a questionnaire and conduct experiments online. The size and multifaceted nature of the dataset strengthens the power of the results, and self-reports enabled us to obtain important information regarding individuals' social backgrounds. Having said that, it needs to be noted that the population was self-selected and that the language measures, too, relied on self-reports. Although we could have used a more objective measure of proficiency, the strength of self-reports is that it is quick to assess, enabling a larger sample size. Our aim is not to generalise our results to a wider multilingual population. On the contrary, our results indicate that certain multilingual factors that have a large impact on cognitive performance in one participant sample may be entirely absent in another and we advocate for studies that consider multilingualism in a wider social environment. Nonetheless, the ultimate participant sample may constitute a rather special group in the Netherlands, with a high education and SES, and who are proud to speak different languages and regional dialects. Perhaps those people who do not consider themselves 'multilingual enough' have refrained from participating in the first place.

Another limitation pertains to the method of data collection. To effectively measure an individual's language abilities, objective measures should be collected in addition to self-reports. Also, the measurement accuracies of the cognitive tasks are more difficult to control via an online environment as was used in our study. Our aim with this dataset however was to investigate inter-group differences in a diverse multilingual population, to illuminate the complex interactions of different aspects of language knowledge and use with health, personality and social data. Despite the lack of objective accounts of language ability and experi-

mental control, we managed to shed light on why some multilingual individuals show enhanced cognitive performance and others do not. This initial exploration opens up the field for studies investigating individual differences in multilingual language use with more rigour.

3.6 Conclusion

The results of this study show that multilingualism contributes to enhanced cognitive performance in some multilingual individuals but not in others. The presence of enhanced attention control depends on the use of the different languages across different social domains and the number of different languages used with close social relations, in combination with an early age of onset of acquisition of these languages, certain personality traits and a high level of education. Inhibition or set-shifting is less strongly associated with multilingualism and social relations, but more with age, level of education and the age of onset of acquisition of the second and third language.

By means of an analysis that clusters contributing variables, we were able to shed light on why some individuals do show enhanced cognitive performance and others do not, despite all being multilingual. We also argue that the mechanisms of cognitive reserve are still not clear, but that, given the individual interplay of variables, reserve is a phenomenon that emerges from this interactional context. Future studies should explore this claim in more detail. From this study it most of all becomes clear that enhanced cognitive performance emerges from an interplay of multilingual language use in a particular environment, and inter-individual differences relating to education and personality. We therefore advocate for a move away from dichotomous group studies and more focus on the complex interplay of factors within multilingual populations.

PART II

Language and aging as a migrant in the Netherlands