Chapter 3

Musical and multilingual experience are related to healthy aging: better some than none but even better together

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ABSTRACT

Life experiences that are complex, sustained, and intense, such as active participation in music and speaking multiple languages, have been suggested to contribute to maintaining or improving cognitive performance and mental health. The current study focuses on whether lifetime musical and multilingual experiences differentially relate to cognition and well-being in older adults, and tests whether there is a cumulative effect of both experiences. 11,335 older adults from the population-based Lifelines Cohort Study completed a musical and multilingual background and experience questionnaire. Latent Class Analysis was used to categorize individuals into subgroups according to their various musical and multilingual experiences resulting in a (1) non-musical, low-multilingual group; (2) non-musical, high-multilingual group; (3) musical, low-multilingual group; and (4) musical high-multilingual group. To determine whether the groups differed in terms of cognition or emotional affect, differences in Ruff Figural Fluency Test (RFFT) and Positive and Negative Affect Schedule (PANAS) scores were investigated by means of multinomial logistic regression analysis. Having high-multilingual, and not musical, experience, was related to better RFFT performance compared to no experience, but not to more positive affect. Having both musical and high-multilingual experiences is related to better RFFT performance and more positive affect in advanced age compared to having only one experience or none. Importantly, these results were found independently of age, level of education and socio-economic status. Musical and multilingual experiences relate to healthy aging, especially when combined, which supports the suggestion that a broader spectrum of lifetime experiences relates to cognitive reserve.

3.1 INTRODUCTION

Worldwide, the proportion of older adults is greatly increasing, attributable to the rapidly increasing human life expectancy (European Commission, 2020). However, a longer life does not necessarily entail a longer healthy life. Research targeting the promotion of healthy aging to preserve physical and mental health is more topical than ever before.

The older adult life stage is characterized by substantial individual variation in the extent to which older adults experience age-associated ailments. For instance, the degree of cognitive decline vastly differs, possibly due to differences in resilience and cognitive reserve, built through a lifetime of experiences related to, among many other things, education, mental stimulation, and traits such as intelligence (Song et al., 2022; Stern et al., 2019). Being mentally and physically active and socially integrated in life has been associated with preservation of cognitive and mental health and may act as a protective mechanism against dementia (Dause & Kirby, 2019; Fratiglioni et al., 2004), contribute to (self-perceived) quality of life (Machón et al., 2017), and in turn emotional well-being (Scheibe & Carstensen, 2010).

Cognitive maintenance in older adulthood is partly experienced-based and has been most notably linked to cognitively complex, sustained, and intense life experiences (reviewed in e.g., Kramer et al., 2004; Song et al., 2022). Two particularly prominent activities in this respect, which are commonly practised and experienced by many people across the lifespan, are active participation in music (i.e., playing a musical instrument or singing in a choir) and speaking multiple languages.

Playing a musical instrument or engaging with music through singing (in a choir) is related to cognitive ability and healthy aging (reviewed in Román-Caballero et al., 2018; Schneider et al., 2019). It is a complex and sustained activity that requires a broad range of cognitive processes and has been shown to induce neuroplastic changes in brain networks underlying these processes (reviewed in Moreno & Bidelman, 2014; Olszewska et al., 2021). It has been related to improved cognition and the preservation of cognitive functioning in adulthood (Hanna-Pladdy & MacKay, 2011; Mansky et al., 2020). Furthermore, short-term musical training in older adulthood can improve cognition (Alain et al., 2019; Bugos et al., 2007), and well-being (Seinfeld et al., 2013) in healthy older adults, as well as in older adults with mild cognitive impairment (MCI) (Dorris et al., 2021).

Speaking multiple languages is another intense and complex activity that is typically sustained through life and that has been related to improved cognition (Bialystok, 2017). Similar to playing a musical instrument, speaking multiple languages requires several cognitive

processes, including monitoring, inhibition of- and switching between languages. These cognitive processes are needed to resolve the constant conflict alleged to occur by juggling multiple languages (Kroll & Bialystok, 2013). Speaking multiple languages has furthermore been linked to neuroplastic changes across the lifespan (reviewed in Li et al., 2014), in turn contributing to improved cognitive functioning (Bak et al., 2014; Bialystok, 2017; Bialystok et al., 2012). Neuroplastic changes resulting from multilingual experiences potentially protect against age-related cognitive decline (Van den Noort, Vermeire, et al., 2019; Watson et al., 2016; Woumans et al., 2017). Also, language training in older adulthood has been related to improved well-being and cognition (Bubbico et al., 2019; Pfenninger & Polz, 2018). It should be noted, however, that multilingual practices as cognitive enhancement is sometimes disputed (reviewed in Mukadam et al., 2017; van den Noort et al., 2019). Behavioral consequences have repeatedly shown not to be present, even in the case of neural consequences of multilingual practices (DeLuca, Rothman, et al., 2020; Kousaie & Phillips, 2017; McLaughlin et al., 2004).

While there are many similarities, important differences in how music and language experiences affect cognition and mental health across the lifespan also exist (Moreno & Bidelman, 2014). There is some evidence for unique effects on cognition as well as shared effects for musical and multilingual experiences in young adults (Bialystok & DePape, 2009; D'Souza et al., 2018), but to date none of this work concerned older adults. Yet, this age group is of particular interest because it is at the older adult life stage that cognitive reserve becomes more pertinent, as cognitive and mental resources are compromised. Although it is impossible to control for all experiences and traits that individuals have and that might be related to mentally healthy aging, it is important to study the interactions of variables and experiences that may drive even marginal cognitive advantages (Leivada et al., 2020; Valian, 2015). Crucially, as it suggested that the wider the spectrum of lifetime experiences, the more cognitive reserve is likely to be enhanced (Krivanek et al., 2021; Stern, 2012, 2021), potential cumulative effects of musical and multilingual experiences need to be examined more closely in a senior population.

The current study aims to investigate whether musical and multilingual experiences, are related to cognitive performance and subjective well-being in older adults. It examines whether there are differences between these experiences and, crucially, assesses their cumulative effects. We expect that better executive functioning, measured using the Ruff Figural Fluency Test (RFFT), and emotional well-being, measured using the Positive and Negative Affect Schedule (PANAS), are related to at least one such an experience compared to no such life experience. We assume that engaging in multiple complex life experiences is more challenging and stimulating than a single experience. It is therefore hypothesized

that experiences combined have a stronger relationship with cognitive and mental health. Studying unique, shared, and cumulative effects of lifelong engagement to complex skill learning in the domain of music and multilingualism will provide insights into healthy aging and how complex life experiences relate to more healthy life years.

3.2 METHODS

3.2.1 Study sample

This study used data from the *Lifelines Cohort Study,* a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviors of 167,729 persons living in the North of The Netherlands (described in Scholtens et al., 2015). It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioral, physical and psychological factors which contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. Recruitment and baseline measurements of the *Lifelines* study started in 2006 and ended in 2013. Written informed consent was obtained from all participants. The *Lifelines Cohort Study* is conducted according to the principles of the Declaration of Helsinki and approved by the ethics committee of the University Medical Center Groningen, the Netherlands.

3.2.2 Language and music background questionnaire

Lifelines participants aged 65 years or older in December 2019 (approximately 20,500 participants) were approached via email through the *Lifelines* infrastructure and asked to complete a questionnaire tapping their musical and multilingual backgrounds and experiences. A total of 11,335 participants responded and completed the questionnaire between December 2019 and April 2020.

The musical background and experience questionnaire was based on the questionnaire used in Gooding et al. (2014). Seven questions prompted information pertaining to (1) musical (including singing) experiences at any life stage [yes/no], (2) musical engagement experiences as part of a group or solitary activity [yes/no], (3) with or without instruction [yes/no], (4) age of onset playing a musical instrument or singing, (5) life years during which musical activities were most actively practised [<18, 18 – 30, 31 – 60, >60 years old], (6) the intensity [>1, 1, <1 hour a week], and duration of musical engagement during the most active period [5-point Likert scale ranging from every day to more than once a month], and (7) current activities playing an instrument or singing [yes/no].

The multilingual background and experiences questionnaire contained 16 questions and was based on the questionnaire used in Pot et al. (2018). It tapped information including (1) mastered/learned languages and dialects (dialects are treated as languages), (2) self-reported receptive and productive proficiency in these languages [scale 1 – 10], (3) the age of, and (4) contexts in which these languages were learned [with/without schooling], (5) self-perceived multilingual status [multilingual yes/no], (6) current multilingual language use in daily life [yes/no], (7) frequency of current or past multilingual language use [5-point Likert scale ranging from every day to more than once a month], (8) multilingual switching behavior [3-point Likert scale ranging from no switching to switching often], and (9) social networks and settings in which multiple languages are used [at home, at work, at society/club, business, other].

3.2.3 Cognitive and mental health variables

The Ruff Figural Fluency Test (RFFT) (Ruff et al., 1987) was included as a measure of cognitive health, and the Dutch version of the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) as a measure of emotional well-being. The RFFT and the PANAS were administered during the baseline measurement (between 2006 and 2013). Of all Lifelines measures, these two were selected as measures of cognitive and mental health because they were administered at the same time, while this was not the case for other measures included in the Lifelines database. Although there was a lag of several years between administration of the RFFT and PANAS and the time when the musical and multilingual backgrounds and experience questionnaire were sent out, we believe that this is justified because exposure to musical and/or multilingual experiences is assumed to be relatively stable over this timespan. Only 1% of the participants started playing a musical instrument and 4% stopped using multiple languages between the moment of assessment of the RFFT/PANAS and the musical and multilingual questionnaire.

The RFFT was used as a broad measure of executive functioning as it relies on many different cognitive processes, among which initiation, planning (strategies), cognitive flexibility, and divergent reasoning (Gardner et al., 2013; Kuiper et al., 2017). The RFFT is a paper and pencil test where participants – within the time span of 60 seconds – draw as many unique designs as possible on a sheet of paper with 35 dots arranged in seven rows and five columns, by connecting the dots in different patterns. This is repeated five times, each time using a sheet with a different stimulus pattern. Performance on the RFFT is expressed by the total number of unique designs (i.e., the sum of all five parts), with scores ranging between 0 and 175. The RFFT is sensitive to small differences in cognitive performance of older adults, has shown

good test-retest reliability (Foster et al., 2005; Ruff et al., 1987) and can discriminate between different educational levels and ages (Izaks et al., 2011; van Eersel et al., 2015).

The PANAS is a questionnaire that consists of 10 items (phrased as adjectives) to measure positive affect (PA; e.g., enthusiastic, inspired) and 10 items measuring negative affect (NA; e.g., distressed, irritable). In the *Lifelines* study, affect was measured using the PANAS over the past four weeks (i.e., how participants felt over the past four weeks). Participants responded to the items on a 5-points Likert scale ranging from 1 (not at all) to 5 (very much). The total score for each subscale was computed by summing the items from each subscale, resulting in scores ranging from 10 to 50 for each subscale. Higher scores on the positive and negative scales indicated higher positive and negative affect, respectively.

3.2.4 Statistical analyses

Participants who completed the musical and multilingual experience and background questionnaire (N=10,691; see Figure 3.1) were categorized into subgroups according to their various musical and multilingual experiences using Latent Class Analysis (LCA). The exact description on how this was performed can be found in the supplementary materials (supplement 3.A). Descriptive statistics were calculated on the basis of the emergent subgroups with respect to demographics (age, level of education, and income level) and musical and multilingual background and experiences.

Lifelines data on the RFFT and PANAS were complete for 5,807 out of the total number of participants (N=10,691) categorized using LCA (see Figure 3.1). LCA was not performed over this smaller sample, but over the larger sample to include more individuals and therefore more experiences, independently of any potential bias that may have resulted from not having completed the RFFT or PANAS. Descriptive statistics were also performed on the final sample of 5,807 participants for age (at baseline and at time of administration of the musical and multilingual experience questionnaire), sex, level of education, and monthly net household income level (all at baseline). Inferential statistics were used to describe subgroup comparability.

Educational level was categorized as low (primary education, and lower vocational or junior secondary education), middle (secondary vocational and senior secondary education) or high (higher vocational education and university education). Net income level was categorized as low (<2000 euros/month), middle (2000 – 3000 euros/month) or high (>3000 euros/month).

As a next step, data (N=5,807) were subjected to a multinomial logistic regression analysis. Group, as determined using LCA, served as the dependent categorical variable. The number of unique designs on the RFFT, positive affect, and negative affect served as independent variables to predict group. Age at baseline, level of education, and income level (as indicators of socioeconomic status [SES]) were added as covariates to the multinomial logistic regression model. Multinomial logistic regression was performed using the 'multinom' function from the nnet package in R (Venables & Ripley, 2002). The regression coefficients from the model were converted into odds ratios by exponentiating them. The odds ratios are an unstandardized effect size statistic: the larger the odds ratio, the larger the effect. As the R package does not include *p*-value calculation for the regression coefficients, *p*-values were calculated using Wald tests (following Liang et al., 2020).

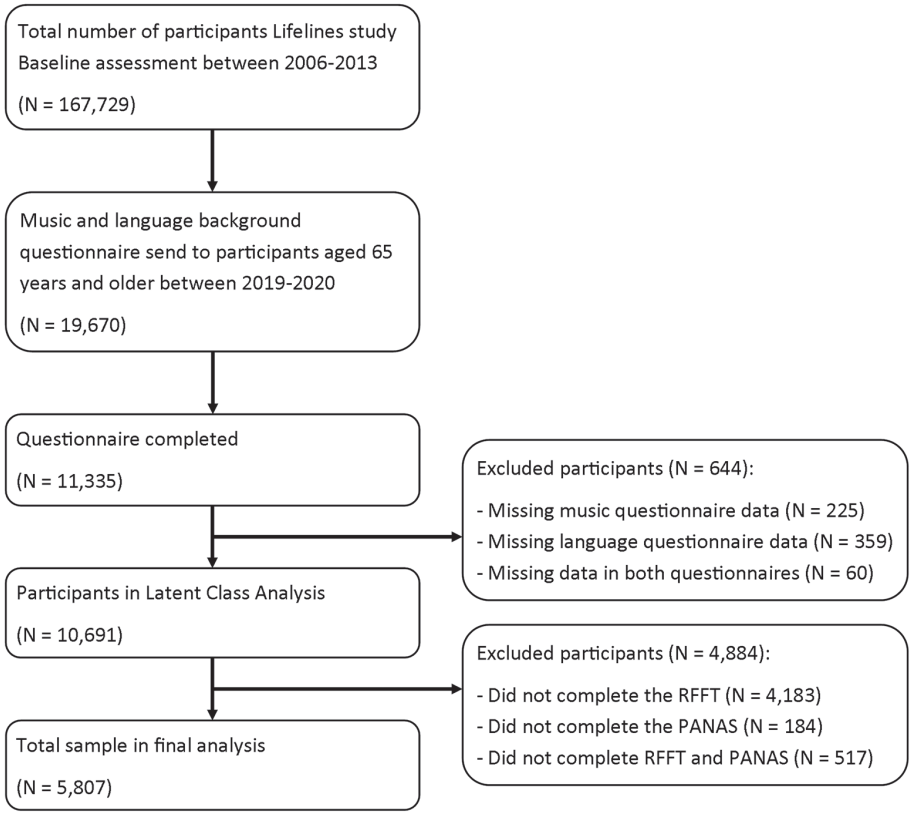

Figure 3.1 Flow-chart of data collection

3.3 RESULTS

3.3.1 Latent classes (subgroups)

Four latent classes formed the optimal solution (see supplement 3.A) to describe the total sample (N=10,691). Classes were clearly defined into groups with and without musical experience (Table 3.1). Multilingualism was considered as a scale ranging from low to high multilingual load based on an individual combination of the number of learned languages, current multilingual language use, and frequency of multilingual language use. The different classes could then be characterized as (1) no musical experience and low multilingualism (*non-musical, low-multilingual [nMlM]*, N=1,441, 13%); (2) no musical experience but high multilingual (*non-musical, high multilingual [nMhM]*, N=3,148, 29%); (3) musical experience but low multilingualism (*musical, non-multilingual [MlM]*, N=1,430, 13%); and (4) musical experience and high multilingualism (*musical, high multilingual [MhM]*, N=4,672, 44%). A description of the different classes and their musical and multilingual experience can be found in the supplementary materials (supplement 3.A).

3.3.2 Sample characteristics

The sample for which PANAS and RFFT data was available (N=5,807) is approximately 54% of the total sample used in LCA (N=10,691) to create the subgroups. This percentage is reflected within the four subgroups, except for subgroup 3 (1, *nMlM:* N=713 [49%]; 2, *nMhM:* N=1749 [55%]; 3, *MlM:* N=765 [12%]; 4, *MhM:* N=2580 [55%]).

Of the final sample of 5,807 participants, 53% was female (N=3075) and the average age of the sample was 71.40 (*SD*=4.55, range 65.0 to 93.8) years at the time of administration of the musical and multilingual background and experience questionnaire (administered between December 2019 and April 2020), and 62.59 (*SD*=4.65, range 52.3 to 86.3) years at the time of administering the RFFT and PANAS (baseline measurement; administered between 2006 and 2013). An ANOVA test of variance showed that the subgroups differed significantly from each other in age at baseline ($F(3,5770)=9.24$, $p<0.001$), and age at the moment of completing the music and language questionnaire ($F(3,5803)=9.16$, $p<0.001$). Subgroup 3 (*MlM*) was the oldest at both assessment waves, whereas subgroup 2 (*nMhM*) was the youngest. Furthermore, Kruskal-Wallis tests determine that the subgroups also differed in baseline level of education ($H(3)=233.8$, $p<0.001$) and baseline income level ($H(3)=52.8$, $p<0.001$). Subgroup 4 (*MhM*) was more highly educated and had a higher income level than the other subgroups, whereas subgroup 1 (*nMlM*) showed a comparatively lower level of education and lower income level.

Table 3.1 Descriptive statistics on demographics and musical and language experiences per subgroup

				Subgroup			
				1 – nMlM nonmusical non multilingual	2 – nMhM nonmusical multilingual	3 – MlM musical non multilingual	4 – MhM musical multilingual
Total per subgroup	N (%)			1441 (14%)	3148 (29%)	1430 (13%)	4672 (44%)
Age at baseline	Mean (SD)			63.05 (4.71)	62.22 (4.65)	63.12 (4.65)	62.56 (4.63)
Age at questionnaire	Mean (SD)			71.85 (4.62)	71.04 (4.54)	71.90 (4.56)	71.37 (4.55)
Income level	N (%)	1	low	222 (31%)	444 (25%)	223 (29%)	578 (22%)
		2	middle	220 (31%)	573 (33%)	221 (29%)	883 (34%)
		3	high	130 (18%)	485 (28%)	185 (24%)	770 (30%)
Educational attainment	N (%)	1	low	443 (62%)	784 (45%)	357 (47%)	919 (36%)
		2	middle	158 (22%)	513 (39%)	187 (24%)	630 (24%)
		3	high	95 (13%)	405 (23%)	195 (25%)	968 (38%)
Ever played	Median			No	No	Yes	Yes
musical instrument	N (%)		Yes	0	0	1430 (100%)	4672 (100%)
or singing			No	1441 (100%)	3148 (100%)	0	0
Current play	Median			NA	NA	No	No
musical instrument	N (%)		Yes	0	0	409 (29%)	1715 (37%)
or singing			No	0	0	1021 (71%)	2957 (63%)
Frequency playing	Median			NA	NA	3	2
musical instrument	N (%)	1	every day	0	0	179 (13%)	730 (16%)
or singing		2	more than once a week	0	0	534 (37%)	2120 (45%)
		3	3 – 5 times a month	0	0	657 (46%)	1659 (35%)
		4	1 – 2 times a month	0	0	48 (3%)	119 (3%)

				Subgroup			
				1 – nMlM nonmusical non multilingual	2 – nMhM nonmusical multilingual	3 – MlM musical non multilingual	4 – MhM musical multilingual
		5	less than once a month	0	0	12 (1%)	44 (1%)
Number of learned languages	Median			2	4	3	5
	N (%)		1	471 (33%)	68 (2%)	278 (19%)	66 (1%)
			2	302 (21%)	598 (19%)	242 (17%)	626 (13%)
			3	203 (14%)	595 (19%)	212 (15%)	662 (14%)
			4	285 (20%)	665 (21%)	379 (27%)	918 (20%)
			5	156 (11%)	873 (28%)	247 (17%)	1530 (33%)
			6	<25 (2%)	256 (8%)	54 (4%)	595 (13%)
			7	<10 (1%)	93 (3%)	18 (1%)	275 (6%)
Current multilingual language use	Median			no	yes	no	yes
	N (%)		yes	24 (2%)	2917 (93%)	14 (1%)	4407 (94%)
			no	1417 (98%)	231 (5%)	1416 (99%)	265 (6%)
Frequency of multilingual language use	Median			5	2	5	2
	N (%)	1	every day	<25 (2%)	1066 (34%)	<10 (1%)	1616 (35%)
		2	more than once a week	<10 (1%)	893 (28%)	<25 (2%)	1392 (30%)
		3	once a week	44 (3%)	407 (13%)	71 (5%)	543 (12%)
		4	once a month	114 (8%)	294 (9%)	146 (10%)	449 (10%)
		5	less than once a month	1258 (87%)	488 (16%)	1187 (83%)	672 (14%)

Note: Percentages present the percentage of participants per subgroup. Numbers and percentages do not always add up to the total numbers of participants (100%) in the subgroups for the variables age, income level and educational attainment due to missing data. Percentages may not always add up to 100% due to rounding. To avoid identifying individuals and numbers under 10, in case of a N of 10 or less for a specific response category, the specific N is not mentioned for that response category and the closest-consecutive response category.

Table 3.2 Descriptive statistics on RFFT and PANAS scores

Variables		1 – nMlM nonmusical non multilingual (N=713)	2 – nMhM nonmusical multilingual (N=1749)	3 – MlM musical non multilingual (N=765)	4 – MhM musical multilingual (N=2580)
RRFT	Mean (SD)	64.30 (18.79)	69.58 (20.14)	69.10 (20.47)	73.48 (21.40)
unique designs	Range	1 – 130	1 – 132	10 – 133	1 – 149
PANAS	Mean (SD)	34.92 (3.87)	35.21 (3.91)	34.97 (3.98)	35.66 (3.80)
Positive Affect	Range	18 – 48	19 – 48	15 – 48	17 – 49
PANAS	Mean (SD)	20.25 (4.88)	19.79 (4.88)	20.53 (4.96)	20.31 (4.97)
Negative Affect	Range	10 – 37	10 – 42	10 – 37	10 – 43

3.3.3 Cognitive and mental health

Mean RFFT and PANAS scores are listed in Table 3.2 for all subgroups. Multinomial logistic regression was performed three times, once with subgroup 1 (*nMlM*), once with subgroup 4 (*MhM*) and once with subgroup 2 (*nMhM*) as the reference category. All other groups are compared against the reference group, allowing a direct comparison between two groups. Which subgroup is taken as reference is important regarding the comparisons that can be made between the groups, but makes no difference for the calculated coefficients, probabilities or significances (Kwak & Clayton-Matthews, 2002). The regression analyses were tested against a conservative Bonferroni-adjusted Alpha level of 0.0167 (=0.05/3). Results of these analyses are presented in Table 3.3. All models were controlled for age, level of education and income level.

The multinomial logistic regression with subgroup 1 (*nMlM*) as the reference category allowed assessment of the effect of having a musical and/or multilingual compared to no or little experience. The analysis showed that compared to subgroup 1 (*nMlM*) the high-multilingual experience subgroups (subgroup 2 [*nMhM*], and 4 [*MhM*]) were significantly more likely to show better executive functioning (Model 1, Table 3.3), while controlling for age, level of education and income level. The largest odds ratio, and thus the largest difference, was found between subgroup 1 and subgroup 4. Executive functioning uniquely related to group membership, in addition to the significant relation between level of education and group membership. The same analysis was performed with subgroup 4 (*MM*) as the reference category to test the effect of having both musical and high-multilingual life experiences compared to only one experience. Results of Model 2 (Table 3.3) showed that individuals with better RFFT performance were significantly more likely to fall into the reference group (subgroup 4 [*MhM*]) as compared to subgroups 2 (*nMhM*) and 3 (*MlM*).

Additionally, repeating the analysis with subgroup 2 (*nMM*) as the reference category allowed assessment of differences between having only musical experience compared to having only multilingual experience. No significant difference between subgroups 2 and 3 was found on the RFFT score (Model 3; Table 3.3).

Table 3.3 Results of the multinomial logistic regression analyses

		Reference	Subgroup	Odds Ratio	p	95% CI
RFFT unique designs	Model 1	1 (nMlM)	2 (nMhM)	1.006	0.014*	1.00 – 1.01
		1 (nMlM)	3 (MlM)	1.007	0.033	1.00 – 1.01
		1 (nMlM)	4 (MhM)	1.014	<0.001**	1.01 – 1.02
	Model 2	4 (MhM)	1 (nMlM)	0.986	<0.001**	0.98 – 0.99
		4 (MhM)	2 (nMhM)	0.992	<0.001**	0.99 – 1.00
		4 (MhM)	3 (MlM)	0.992	0.001*	0.99 – 1.00
	Model 3	2 (nMhM)	3 (MlM)	1.000	0.965	1.00 – 1.01
Positive Affect	Model 1	1 (nMlM)	2 (nMhM)	1.012	0.372	0.99 – 1.04
		1 (nMlM)	3 (MlM)	1.004	0.805	0.97 – 1.03
		1 (nMlM)	4 (MhM)	1.049	<0.001**	1.02 – 1.08
	Model 2	4 (MhM)	1 (nMlM)	0.953	<0.001**	0.93 – 0.98
		4 (MhM)	2 (nMhM)	0.963	<0.001**	0.95 – 0.98
		4 (MhM)	3 (MlM)	0.956	<0.001**	0.93 – 0.98
	Model 3	2 (nMhM)	3 (MlM)	0.992	0.532	0.97 – 1.02
Negative Affect	Model 1	1 (nMlM)	2 (nMhM)	0.987	0.210	0.97 – 1.01
		1 (nMlM)	3 (MlM)	1.018	0.135	0.99 – 1.04
		1 (nMlM)	4 (MhM)	1.029	0.004*	1.01 – 1.05
	Model 2	4 (MhM)	1 (nMlM)	0.971	0.004*	0.95 – 0.99
		4 (MhM)	2 (nMhM)	0.959	<0.001**	0.94 – 0.97
		4 (MhM)	3 (MlM)	0.989	0.249	0.97 – 1.01
	Model 3	2 (nMhM)	3 (MlM)	1.032	<0.001**	1.01 – 1.05
Age	Model 1	1 (nMlM)	2 (nMhM)	0.968	0.003	0.95 – 0.99
		1 (nMlM)	3 (MlM)	1.010	0.430	0.99 – 1.04
		1 (nMlM)	4 (MhM)	0.988	0.231	0.97 – 1.01
	Model 2	4 (MhM)	1 (nMlM)	1.013	0.231	0.99 – 1.03
		4 (MhM)	2 (nMhM)	0.981	0.012*	0.97 – 1.00
		4 (MhM)	3 (MlM)	1.023	0.024	1.00 – 1.04
	Model 3	2 (nMhM)	3 (MlM)	1.043	<0.001**	1.02 – 1.06

		Reference	Subgroup	Odds Ratio	p	95% CI
Education	Model 1	1 (nMlM)	2 (nMhM)	2.032	<0.001**	1.51 – 2.73
high		1 (nMlM)	3 (MlM)	2.473	<0.001**	1.77 – 3.45
		1 (nMlM)	4 (MhM)	3.965	<0.001**	2.99 – 5.25
	Model 2	4 (MhM)	1 (nMlM)	0.252	<0.001**	0.19 – 0.33
		4 (MhM)	2 (nMhM)	0.512	<0.001**	0.43 – 0.61
		4 (MhM)	3 (MlM)	0.624	<0.001**	0.49 – 0.79
	Model 3	2 (nMhM)	3 (MlM)	1.217	0.127	0.95 – 1.57
Education	Model 1	1 (nMlM)	2 (nMhM)	1.692	<0.001**	1.33 – 2.15
Middle		1 (nMlM)	3 (MlM)	1.457	<0.010*	1.09 – 1.94
		1 (nMlM)	4 (MhM)	1.649	<0.001**	1.30 – 2.09
	Model 2	4 (MhM)	1 (nMlM)	0.607	<0.001**	0.48 – 0.77
		4 (MhM)	2 (nMhM)	1.026	0.760	0.87 – 1.21
		4 (MhM)	3 (MlM)	0.884	0.293	0.70 – 1.11
	Model 3	2 (nMhM)	3 (MlM)	0.861	0.212	0.68 – 1.09
Income	Model 1	1 (nMlM)	2 (nMhM)	1.166	0.193	0.93 – 1.47
middle		1 (nMlM)	3 (MlM)	0.899	0.443	0.69 – 1.18
		1 (nMlM)	4 (MhM)	1.300	0.022	1.04 – 1.63
	Model 2	4 (MhM)	1 (nMlM)	0.769	0.022	0.61 – 0.96
		4 (MhM)	2 (nMhM)	0.897	0.205	0.76 – 1.06
		4 (MhM)	3 (MlM)	0.692	<0.001**	0.55 – 0.86
	Model 3	2 (nMhM)	3 (MlM)	0.771	0.027	0.61 – 0.97
Income	Model 1	1 (nMlM)	2 (nMhM)	1.333	0.039	1.01 – 1.75
high		1 (nMlM)	3 (MlM)	0.998	0.991	0.73 – 1.37
		1 (nMlM)	4 (MhM)	1.232	0.125	0.94 – 1.61
	Model 2	4 (MhM)	1 (nMlM)	0.812	0.125	0.62 – 1.06
		4 (MhM)	2 (nMhM)	1.082	0.405	0.90 – 1.30
		4 (MhM)	3 (MlM)	0.810	0.095	0.63 – 1.04
	Model 3	2 (nMhM)	3 (MlM)	0.749	0.028	0.58 – 0.97

Note: Multinomial logistic regression analysis was performed three times. First with subgroup 1 (nMlM) as reference group, next with subgroup 4 (MhM) as reference group, and with subgroup 2 (nMhM) as reference group. Regression models were corrected for age, level of education, and income level. nMlM = nonmusical low multilingual; nMhM = nonmusical high multilingual; MlM = musical low multilingual; MhM = musical high multilingual

*significant at the level of 0.0167, corrected for multiple testing using Bonferonni.

**significant at the level of 0.001

3.3.2 Sample characteristics

The sample for which PANAS and RFFT data was available (N=5,807) is approximately 54% of the total sample used in LCA (N=10,691) to create the subgroups. This percentage is reflected within the four subgroups, except for subgroup 3 (1, *nMlM:* N=713 [49%]; 2, *nMhM:* N=1749 [55%]; 3, *MlM:* N=765 [12%]; 4, *MhM:* N=2580 [55%]).

Of the final sample of 5,807 participants, 53% was female (N=3075) and the average age of the sample was 71.40 (*SD*=4.55, range 65.0 to 93.8) years at the time of administration of the musical and multilingual background and experience questionnaire (administered between December 2019 and April 2020), and 62.59 (*SD*=4.65, range 52.3 to 86.3) years at the time of administering the RFFT and PANAS (baseline measurement; administered between 2006 and 2013). An ANOVA test of variance showed that the subgroups differed significantly from each other in age at baseline ($F(3,5770)=9.24$, $p<0.001$), and age at the moment of completing the music and language questionnaire ($F(3,5803)=9.16$, $p<0.001$). Subgroup 3 (*MlM*) was the oldest at both assessment waves, whereas subgroup 2 (*nMhM*) was the youngest. Furthermore, Kruskal-Wallis tests determine that the subgroups also differed in baseline level of education ($H(3)=233.8$, $p<0.001$) and baseline income level ($H(3)=52.8$, $p<0.001$). Subgroup 4 (*MhM*) was more highly educated and had a higher income level than the other subgroups, whereas subgroup 1 (*nMlM*) showed a comparatively lower level of education and lower income level.

3.4 DISCUSSION

This study examined whether musical and multilingual life experiences are related to cognition and emotional well-being and whether there are cumulative effects of both experiences in a large population-based sample of older adults in the Northern Netherlands.

The single experience groups (subgroups 2 and 3) demonstrated similar levels of executive functioning and positive affect. Therefore, in contrast to previous work in young adults (Alain et al., 2018; Bialystok & DePape, 2009; D'Souza et al., 2018; Moradzadeh et al., 2015), we did not find support for a difference in cognitive performance between musical and multilingual experiences which is consistent with other work (Bialystok & DePape, 2009; Moreno et al., 2014; Schroeder et al., 2016). Results did indicate a difference between the group without musical and with low-multilingual experience (i.e., no experience, subgroup 1) and having multilingual experience: the high-multilingual group (subgroup 4) was more likely show better executive functioning.

Crucially, as complex as musical and multilingual life experiences are in and by themselves, in individuals with both life experiences, we see the highest cognitive performance scores: the group with both musical and high-multilingual experience showed the highest RFFT scores. The idea that accumulated complex life experiences contribute more strongly than a single experience is underlined by the results of this study on positive affect as a measure of subjective well-being: the group with both experiences demonstrated more positive feelings compared to the group with only one or no experience.

Interestingly, the group with both experiences also demonstrated more negative feelings: the group with both musical and high-multilingual experience or with only musical experience were more likely to show higher levels of negative affect than the other groups. While this may seem contradictory, it is possible that having multiple life experiences, and thus a more varied palette of activities, leads to a more varied emotional palette as well. More activities may relate to more life engagement, which may relate to greater enjoyment, but also greater risk for involvement in disappointments (Isaacowitz & Smith, 2003). Alternatively, people with higher levels of negative affect may engage in activities to reduce negative affectivity. This could explain the relation between high negative affect and practicing music as music experience has been found to reduce negative affect (Groarke & Hogan, 2019; Seinfeld et al., 2013).

Cognitive performance and complex experiences thus seem to be related, but our study design does not permit for causal inference. Speculating on the direction of causation, individuals with higher levels of cognitive functioning and emotional well-being might be more likely to engage in and sustain in practicing music and multilingualism. However, one usually does not speak multiple languages due to a certain talent or interest, but this is often simply a function of circumstances or one's living situation (Bialystok et al., 2012). Alternatively, cognitive performance may emerge from complex life experiences. Musical and multilingual experiences both constitute complex and sustained life experiences that rely on several cognitive functions and multiple underlying brain networks. It could therefore be argued that the complex process of (lifelong) adapting to a new environment that could contribute to cognition and well-being in older adults. This conclusion is in line with others suggesting that complex experiences (Park, 2019; Valenzuela & Sachdev, 2006) and a broad spectrum of experiences (Krivanek et al., 2021; Stern, 2012, 2021) may contribute to cognitive performance in later life where cognitive reserve effects emerge. However, this is the first study to relate the combination of musical and multilingual experiences to cognitive performance in older adults specifically.

Different complex, sustained, and intense life experiences may involve different brain networks, in turn leading to general improvements across cognitive tasks but may also be more pronounced for some tasks than for others, depending on the type of practice (music versus language). Indeed, some studies have found no differences between people with musical or multilingual experiences at the behavioral level but did find differences in brain networks involved (Alain et al., 2018; Moreno & Bidelman, 2014). Although there is overlap and transfer between the two experiences (Asaridou & McQueen, 2013), musical and multilingual experiences stimulate and shape the brain in different ways (Alain et al., 2018; Moreno & Bidelman, 2014). For example, musical training has been shown to be positively associated with inferior frontal cortex and parahippocampal volumes, in addition to posterior cingulate cortex volume, insula and medial orbitofrontal cortex, areas important for memory, emotion-regulation and motivation (Chaddock-Heyman et al., 2021). Multilingualism, on the other hand, has been associated with increased gray matter density in regions implicated in executive control, including the dorsolateral prefrontal cortex, caudate nucleus and anterior cingulate cortex (Hayakawa & Marian, 2019). Future research would do well to not only explore how multiple complex life experiences relate to task performance but to add an examination of underlying brain networks in addition to behavioral paradigms.

The (combined) effect of musical and multilingual experiences may uniquely apply to later phases of life which could explain earlier null findings. Compared to young adults (aged 30 years or younger), life experiences in older adults (55 years and older) have built up over more years. Factors such as the duration and intensity of the experience may therefore be of great importance. The call for a focus on the intensity of a life experience is in line with current views on the effects of multilingualism (Gullifer & Titone, 2020; Marian & Hayakawa, 2021; Pot et al., 2018). Although we did not further investigate the link between experience intensity and cognition and mental health, future research would do well to tackle this. We furthermore recommend performing a similar study to ours in an older population or a population of older adults with clinical levels of cognitive decline. Life experiences that aid in preserving cognitive functioning and well-being could be even stronger in these populations.

Importantly, we established the relation between life experiences and cognition and affect on the basis of a large population-based sample. Moreover, all results were controlled for age, level of education, and income level (as indicator for SES), while all other variables varied freely within the groups, decreasing the risk of biases. Better executive functioning appears to significantly relate to having multiple complex life experience in addition to the significant relation between life experiences and level of education. This further demonstrates, and reinforces our suggestion, that it is precisely the multiplicity of experiences that likely builds

cognitive reserve. Furthermore, while the effect sizes are small, the narrow confidence intervals indicate precise population estimates and therefore reliable evidence. Perhaps the fact that the effects are small explains why findings from earlier studies with smaller samples have produced mixed results.

A number of limitations underlie the current study. First, other experiences or individual traits (which were not measured in the current study) may also play a role. Someone who has multiple complex life experiences may be characterized by certain traits that in fact drive healthy aging (Valian, 2015). It is complex, virtually impossible, to truly isolate experiences that attribute an effect on cognitive reserve to any single experience. It has shown to be already quite complex to characterize the multilingual experience itself which relates to another limitation. The questions from the questionnaire and the way in which they were asked and could be answered are allowed for inconsistent answers about someone's multilingualism. Additionally, and relatedly, a problem in the existing literature is that different cognitive tasks and language measures are used making it difficult to compare studies and formulate clear predictions. A third important limitation related to the measures of cognition and effect is that these were only momentary assessments and were administered at a different time than the experience questionnaires. Although no major changes are to be expected given the age of the participants, cognition may have changed since the RFFT administration. It was not possible to assess changes in cognition and affect over time and how this change relates to complex life experiences, which would be an interesting direction for future research. It would be interesting for future work to compare how these two life experiences interact with changes in cognition and well-being over time. A final limitation is the limited cognitive characterization of the sample. Factors such as medication use, depression, and mild cognitive impairment (MCI) were not considered while these factors may have influenced the results. On the other hand, despite the fact that these and other factors varied within the population may lead to substantial inter-individual variation, the current study still found a relation between complex life experiences and cognition and emotional well-being.

In conclusion, high executive functioning, positive and negative affect were all related to having complex life experiences. The current study suggests that musical and multilingual experiences are related to healthy aging, especially when combined. The study is based on a large representative population-based sample of older adults in the Netherlands allowing for a largely unbiased evaluation of results. This is underscored by the Latent Class Analysis used to classify individuals into groups, rather than splitting the data into groups based on predetermined criteria.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUPPLEMENTARY MATERIALS TO CHAPTER 3

Supplement 3.A: Latent Class Analysis (LCA)

INTRODUCTION

A prominent and topical issue in multilingualism research that researchers are increasingly recognizing is that multilingualism is a continuous experience rather than constituting a categorical variable. This can be extended to musical experiences. Comparing groups of individuals with or without given life experiences masks the variability within the groups. In addition, to create groups, an arbitrary boundary must often be imposed resulting in different criteria for each study. Latent Class Analysis (LCA) overcomes these issues: rather than splitting the data into groups based on – somewhat arbitrarily – predetermined criteria, groups were made according to the patterns of individual answers to the musical and multilingual background and experience questionnaire.

METHOD

Based on an exploratory LCA, data of three questions on musical experience and three questions on multilingual experience and background served as input for the LCA: (1) musical (including singing) experience at any life stage [yes/no], (2) frequency of musical engagement during the most active period [5-point Likert scale ranging from every day to more than once a month], (3) current activities playing an instrument or singing [yes/no], (4) the number of mastered/learned languages and dialects [1 – 7], (5) current multilingual language use in daily life [yes/no], (6) frequency of current or past multilingual language use [5-point Likert scale ranging from every day to more than once a month]. There is one score for each of these questions for each participant and these data served as the input for the LCA. Participants with incomplete data on these six questions were removed prior to the LCA. This was the case for 644 subjects, leaving 10,691 subjects as input for the LCA (see Figure 3.1).

To find the best fitting model, following guidelines by Weller et al. (2020), the LCA model was built multiple times with a varying number of classes, ranging from two to eight classes. Model selection was based on the value of Bayesian Information Criterion (BIC) and sample-size adjusted BIC (aBIC), where a lower value suggests a better fit (Muthen & Muthen, 2000). All models were re-estimated 10 times to find the optimal maximum likelihood solution (Linzer & Lewis, 2011). The model that best fit the data was selected and subsequently used to assign all 10,691 participants to their predicted subgroup for further analysis. The final model was furthermore described in terms of entropy as an estimate of how accurately the model defines classes (Linzer & Lewis, 2011). Although no consensus for cutoff value exists

for the evaluation of entropy, values closer to 1.0 indicate better classification quality and values greater than 0.80 are indicative of adequate classification quality (Brose et al., 2014; Jung & Wickrama, 2008).

RESULTS

To decide on the number of classes, LCA was performed multiple times on all available data (comprising 10,691 participants). A careful examination of the models led to a selection of a four-class model solution as the best fit for the data, as evidenced by the BIC, and aBIC values (see Table 3.A.1). This four-class model had an entropy value of 0.90, reflecting a clear delineation of classes.

Table 3.A.1 Fit of Latent Class Analysis models

Latent class numbers	Likelihood ratio G^2	BIC	aBIC
2	5746.7	119558.5	119434.6
3	3270.2	117264.5	117077.0
4	899.0	115078.7	114827.6
5	824.6	115189.7	117150.0
6	728.6	115361.5	114900.9
7	654.0	115444.3	114948.2
8	624.9	115546.9	115040.9

Note. BIC = Bayesian Information Criterion, aBIC = sample-size adjusted BIC. N=10,691

Latent classes (subgroups)

Musical experience

Participants in the two musical subgroups (subgroups 3 [MlM], and 4 [MhM]) all had a musical experience (among which singing) at some point in their lives, but at the time of testing most did not actively pursue musical activities (see Table 3.1). People had started playing an instrument or singing at the mean age of 19.0 years in subgroup 3 (*SD*=15.7), and at the mean age of 17.5 years in subgroup 4 (*SD*=14.7). The mean age is probably a rather skewed representation given that most participants actively played a musical instrument before the age of 18 (57.2% and 57.8% for subgroup 3 and 4, respectively). A substantial percentage also actively played a musical instrument or sang after the age of 60 (24.6% and 28.0% for subgroup 3 and 4, respectively). Most participants who learned to play a musical instrument did so under the guidance of a music teacher in a one-to-one instructional setting (66.6% in subgroup 3, 71.6% in subgroup 4) and only 26.7% and 33.0% for subgroup 3 and 4, respectively, played an instrument as part of a group or band. In the case of singing, on the other hand, most participants did so as part of a group activity (57.6% in subgroup 3,

60.0% in subgroup 4). The subgroups differed in frequency of playing/singing (see Table 3.1), while in both subgroups participants were most likely to have played/sung more than one hour a week (62.6% in subgroup 3, 71.2% in subgroup 4).

Multilingual experiences

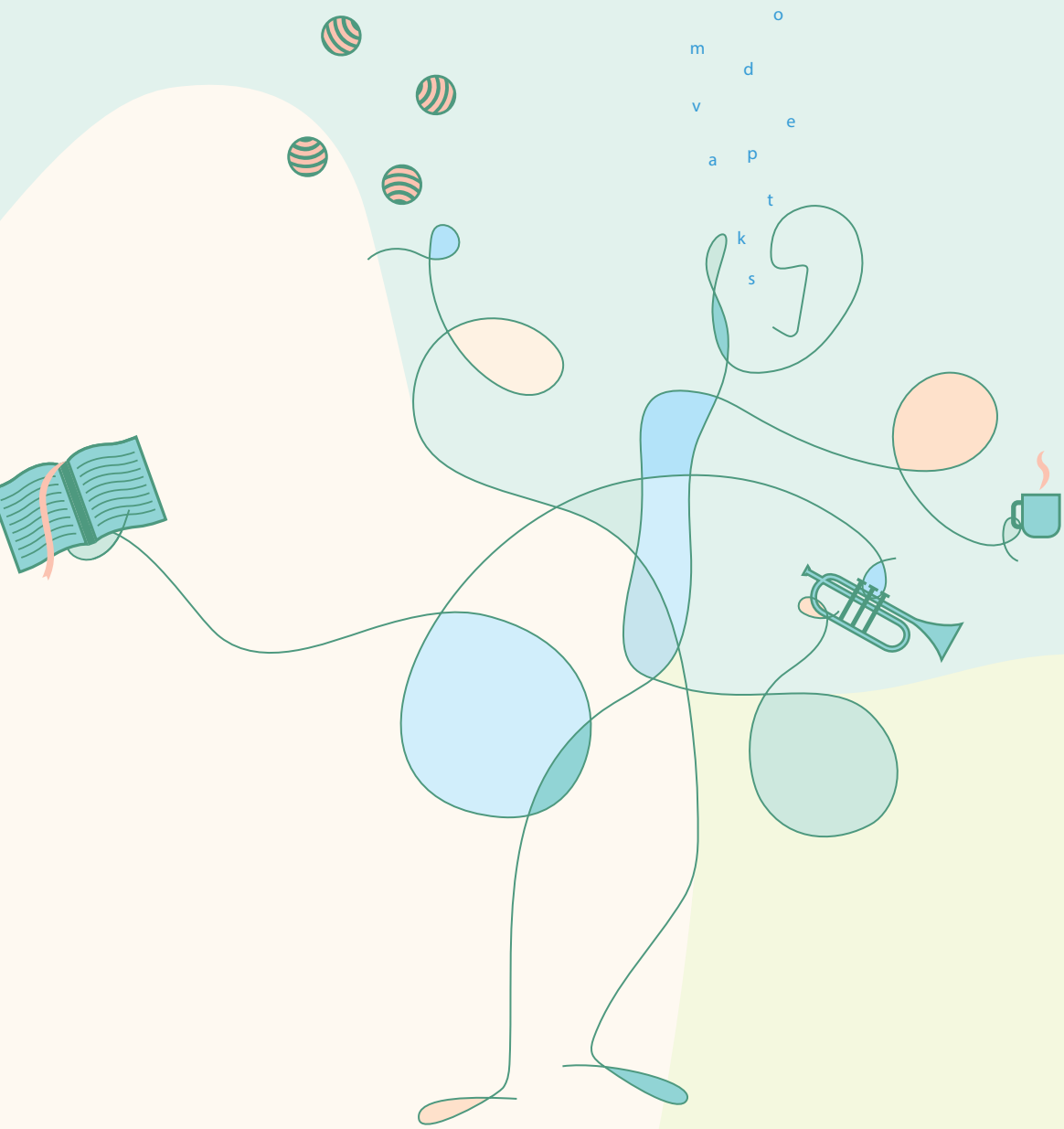
The number of spoken languages varied in all subgroups, from one to seven. Table 3.A.2 presents which languages were mainly spoken and by what percentage of participants in each group. In the two low-multilingual subgroups (subgroups 1 and 3), more than 70% of the participants reported Dutch as their L1, in contrast to approximately 50% of the participants in the two high-multilingual subgroups (subgroups 2 and 4). Indeed, Frisian was reported more often as participants' L1 in subgroups 2 and 4 (23.0% and 23.2%, respectively) compared to approximately 5% in subgroups 1 and 3, and Dutch as L2. Apart from Dutch, in all subgroups the Lower Saxon dialect was also often reported as L1 (subgroup 1: 17.8%, subgroup 2: 21.5%; subgroup 3: 13.8%; subgroup 4: 19.6%). English, German, and French (in this order) were most frequently reported as additional languages in all subgroups. These languages are taught at Dutch (secondary) schools and are spoken in neighboring countries.

Table 3.A.2 The most reported spoken languages per subgroup and the number (and percentage) of participants per subgroup that reported to speak these languages

Reported language N (%)	1 – nMlM nonmusical non multilingual (N=1441)	2 – nMhM nonmusical multilingual (N=3148)	3 – MlM musical non multilingual (N=1430)	4 – MhM musical multilingual (N=4672)
Dutch	1217 (88%)	2966 (94%)	1299 (91%)	4371 (94%)
English	697 (48%)	2079 (66%)	917 (64%)	3504 (75%)
German	496 (34%)	1871 (59%)	731 (51%)	3229 (69%)
French	348 (24%)	1349 (43%)	601 (42%)	2656 (56%)
Lower Saxon	379 (26%)	1338 (43%)	351 (25%)	1946 (42%)
Frisian	154 (11%)	1250 (40%)	213 (15%)	1949 (42%)

Within the two high-multilingual subgroups (subgroups 2 [nMhM] and 4 [MhM]), and as opposed to the musical groups, by far most participants reported to still use multiple languages in daily life (see Table 3.1). Most often, participants reported not to switch between their spoken languages within one situation or setting (49.1% subgroup 2, 46.7% subgroup 4). Instead, different languages were reportedly used in different settings with different interlocutors. Frequent switches between languages within settings was only reported by 6% and 7% of the sample in subgroups 2 and 4, respectively. Most participants in subgroups

2 and 4 reported to use multiple languages with relatives (57.5% and 57.7%, respectively) and friends (55.6% and 60.0%, respectively), primarily in the home setting (50.0% and 49.5%, respectively). Participants in both subgroups had most commonly learned their first language (L1) without (formal) education, in contrast to additional languages, which were most often reported to have been learned through (formal) education. Apart from the L1, participants generally indicated to be better at understanding a language than speaking it. Participants were best able to speak and understand their L2 (understand: *M*=8.61, *SD*=1.57 subgroup 2; *M*=8.70, *SD*=1.51 subgroup 4; speak: *M*=8.17, *SD*=1.79 subgroup 2; *M*=8.25, *SD*=1.78 subgroup 4). Not all participants within the high-multilingual subgroups perceived themselves as multilingual, although the majority did: in subgroup 2, 71.3% and in subgroup 4, 77.3% of the participants self-categorized as multilingual.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