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# The bilingual effect on cognitive development: not an executive function advantage, but a differentiation of mental abilities

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## ABSTRACT

Adopting a different theoretical framework from the one dominating the field, this study explored bilingualism influences on the development and differentiation of mental abilities. Albanian-Turkish bilingual ( $N = 122$ ) and Albanian-speaking monolingual ( $N = 129$ ) children, adolescents, and adults were assessed on monitoring, inhibitory control, processing efficiency, fluid reasoning, and vocabulary, and were asked to specify their own language efficiency (a cognizance index). Analyses showed a bilingual advantage in monitoring—adjusting for any fluid reasoning effects—which was larger in children. Moreover, a more pronounced bilingual benefit was observed for the incongruent condition RT of the attention task. Structural equation modelling showed though that the difference between language groups does not lie within the executive function domain (inhibitory control); it rather regards processing efficiency. Analyses also revealed increased differentiation of mental abilities in bilinguals, reflecting enhanced cognitive flexibility. Implications for cognitive developmental and individual differences theories are discussed.

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Bilingualism; cognitive development; abilities differentiation; processing efficiency; monitoring; fluid reasoning

## Introduction

In recent years, studies questioned the robustness and generality of the *bilingual cognitive advantage* (see Lehtonen et al., 2018; Paap, 2015), postulating that managing two co-activated language systems results in positive effects in cognitive performance other than language (Blumenfeld & Marian, 2013). Research so far looked for possible advantage in several cognitive processes, including monitoring (indexed by global response times), inhibitory control of attention (particularly, resistance to interference), and shifting (i.e. switching between stimuli or representations according to goals). However, mental processes do not work in isolation; thus, focusing on specific functions may mask the possible effects of bilingualism on overall mental structure.

Therefore, the present study explored the source of the bilingual advantage, as a function of age (Demetriou et al., 2017, 2019), in the organisation of cognitive processes. Specifically, we examined if

bilingualism enables refinement and differentiation of cognitive processes so that they may be more accurately activated and implemented according to mental goals. According to Spearman's (1927; see also Jensen, 1998) law of diminishing returns (SLODR), increasing cognitive ability causes differentiation between mental processes, both because of within age individual differences and within individual cognitive development with age. With differentiation, cognitive processes may be independently activated and flexibly applied, according to the demands of the task at hand (Demetriou et al., 2017, in press). We also explored self-awareness about language efficiency, an index of *cognizance* (see Demetriou et al., 2018a). *Cognizance* is the aspect of consciousness involving monitoring and awareness of mental states and processes, self-evaluation, and self-concepts about one's own and others' ability in using different mental processes (Kazi et al., 2019). Metacognition, knowing about

knowing (Efklides, 2008; Flavell, 1979), and Theory of Mind, awareness of mental states (Wellman, 2014), are components of cognizance. To our knowledge, this is the first study shifting emphasis in the study of bilingualism from executive functions to inter-relations between mental processes and self-awareness.

In the psychology of individual differences, there is wide agreement that general intelligence, *g*, relies at the apex of all cognitive processes (Spearman, 1904; see also Carroll, 1993; Jensen, 1998). Current research suggests that *g* is strongly associated with executive functions, (i.e. inhibitory control and working memory; Blair, 2016; Kyllonen & Christal, 1990), fluid reasoning (inductive, analogical, and deductive reasoning; Gustafsson & Undheim, 1996), and cognizance (Demetriou et al., 2018a). Research showed that these processes altogether account for 98% of variance in *g* (Demetriou et al., 2018b; Makris et al., 2017). However, the relative contribution of each process to the functioning of *g* varies with development, depending on the developmental priorities of each phase (Demetriou et al., 2017, 2018a; Makris et al., 2017). According to the Model of Developmental Priorities (MoDePrior; Demetriou et al., 2017, 2019) different mental processes dominate in successive developmental cycles, depending upon the functional needs of understanding in each phase. Inhibitory control and perceptual processes awareness dominate in preschool years (3–6 years). Inductive inference, working memory, awareness of inferential processes dominate in middle childhood (7–11 years). Deductive reasoning, awareness of logical constraints, and cognitive self-evaluation dominate in adolescence (12–17 years).

Changes in developmental priorities reflect two important aspects of intellectual development. First, the priorities of each phase provide a specific range of adaptive possibilities: self-directed behaviour, prediction and systematic interpretation of event sequences, and critical evaluation of truth and validity of relations between events, for the aforementioned major priorities, respectively. Second, with development, the relations between representations become increasingly complex, being differentiated but hierarchically organised. These changes enable individuals to deal with increasingly complex concepts and problems. Cognizance is critical in this respect, because awareness of mental processes and process-objects-activity relations allows re-processing and re-describing

them (Karmiloff-Smith, 1991) into new representations and rules, rendering their application more efficient in the future (Demetriou et al., 2018a; Demetriou et al., in press). The developmental priority model assumes that cognitive development may be accelerated if developmental priorities in each phase are properly targeted and met.

In the present context, it is assumed that learning new representations for the same objects and relations and switching between languages in bilingualism enhances inhibitory control and representational awareness, both dominating in early childhood, as well as fluid (inductive) reasoning, dominating in the middle childhood years; in principle, this would have to be beneficial for overall cognitive attainment. This may appear in both, superior cognitive performance relative to monolinguals and increased differentiation between processes as suggested by SLODR (see also Demetriou et al., 2017).

Research so far provided conflicting evidence about the effects of bilingualism on cognition. Several studies reported better performance of bilinguals relative to monolinguals in tasks addressing inhibitory control (Bialystok & DePape, 2009; Costa et al., 2008; Zied et al., 2004), cognitive flexibility (Prior & Gollan, 2011; Prior & MacWhinney, 2010; Soveri et al., 2011), working memory (Bialystok et al., 2008), and monitoring (Kapa & Colombo, 2013), especially in early childhood (Hansen et al., 2016; see Woumans et al., 2016 for longitudinal evidence regarding intellectual development). Yet, other studies have failed to replicate the suggested advantage (e.g. Ladas et al., 2015; Laketa et al., 2021; Paap et al., 2015, 2016; Studenica et al., 2021; see also Lehtonen et al., 2018; and Sanchez-Azanza et al., 2017), showed small effects (e.g. Donnelly, 2016), or provided mixed evidence (Chrysochoou et al., 2020), with the observed patterns depending on participants' age (e.g. Gathercole et al., 2014; Vivas et al., 2020).

Woumans and Duyck (2015) seem right in arguing that a polarised “yes or no” answer may not be useful in understanding the cognitive implications of bilingualism. In agreement with this argument, we believe that the potential influence of bilingualism on cognition merits further investigation using more comprehensive assessments of bilingual experiences (see de Bruin, 2019). In the present study, assuming the operation of multiple processes, we explore how the relations between inhibitory control (Carlson & Meltzoff, 2008), fluid

reasoning, verbal ability, and cognizance are affected by bilingualism. It has long been assumed that bilingualism may affect “the very structure of the intellect” (Peal & Lambert, 1962, p. 6).

Cummins (1981) suggested feeding cognitive functioning by two language channels challenges linguistic input processing, lexical retrieval, and also general representational capacity. There is evidence that, on the one hand, bilinguals are slower than monolinguals in accessing and retrieving items from mental lexicon (see Bialystok, 2009). However, on the other hand, having two different words for most concepts fosters understanding of the arbitrary symbolic nature of word-referents relations, enabling bilinguals to grasp the abstract and symbolic nature of representations (see Adesope et al., 2010). Peal and Lambert (1962) found that bilingual children outperformed monolingual peers on most non-verbal fluid intelligence measures obtained and argued that bilingualism is the cause of the difference.

The model of developmental priorities outlined above suggests that such beneficial effects would be expected more pronounced in childhood, when inhibitory control, representational awareness, and inferential—inductive reasoning processes dominate as priorities and may thus be boosted by the experience of learning two languages (see Demetriou et al., 2017, in press). In line with this assumption, it has been proposed that bilingualism effects on cognitive functioning may be found more pronounced in children (Donnelly, 2016—study 1; Grundy & Timmer, 2017; Yang & Yang, 2016), whereas several studies failed to replicate the advantage in young adulthood (e.g. Bialystok et al., 2005, 2014; Donnelly, 2016, study 1; Vivas et al., 2017).

Therefore, the present study aimed to explore how bilingualism influences the development of the following processes: monitoring (as reflected in participants’ overall response time in the attention task used), processing efficiency, and inhibitory control (as tapped by the congruent and incongruent conditions of the attention task, respectively), fluid reasoning (as reflected in performance on the Raven test). Moreover, we investigated the role of bilingualism on the relations among these processes and also verbal ability (vocabulary), and cognizance, as tapped by perceived language efficiency. The present study adds to the field by investigating an understudied bilingual population

namely, a relatively homogenous non-immigrant sample of Turkish-Albanian children, adolescents, and adults, who are simultaneous—early bilinguals and live in Kosovo where both languages are of high status. The monolingual sample consisted of Albanian-speaking peers of similar SES, living in the same country and cultural context.

Based on the literature above, the following predictions are tested.

- (1) Bilingualism positively influences inhibitory control, processing efficiency, monitoring, and fluid reasoning, more in early than in later age.
- (2) Better cognitive functioning among bilinguals coexists with greater differentiation of mental abilities to reflect enhanced cognitive flexibility (see Demetriou et al., 2017; Jensen, 1998; Tucker-Drob & Bates, 2016).
- (3) Positive relations are expected between the cognitive measures and perceived language efficiency—a cognizance index—within the bilingual group.

## Methods

### Participants

A total of 122 Albanian-Turkish bilingual and 129 Albanian-speaking monolingual participants were examined. These were about equally drawn among 7–12-year-old children, 13–17-year old adolescents, and 18–49-year-old adults, living in Kosovo (see Table 1 for details). Age ranges in the two younger groups aligns with participants’ separation into primary (the first group) and secondary school students (the second group).

The bilingual sample was relatively homogeneous, involving mostly *simultaneous—early* bilinguals (see Grosjean, 1989), exposed to both Albanian (the official language of the republic) and Turkish (a heritage language) within (a) the first three years of development (72.1% of participants), or (b) until age five for the younger groups (four children and two adolescents had such an age of onset, frequently using two languages for 4–6 and 10–11 years, respectively), or age seven for the adult group. Bilingual status was also confirmed by individual (for all participants) and parental reports (for children) on competence to use both languages daily and on a regular basis (see Bialystok, 2009; Grosjean, 2013). Performance

**Table 1.** Demographics and language background per age and language group.

Children	Monolinguals		Bilinguals	
	N = 40		N = 39	
	M (SD)	Range	M (SD)	Range
Age	10.05 (1.48)	7–12	9.92 (1.35)	8–12
Bilingualism onset			2.67 (1.22)	1–5
Albanian vocabulary	48.82 (5.37)	44–60	56.85 (2.76)	46–60
Turkish vocabulary	–	–	55.72 (2.29)	52–60
Gender	50% (male), 50% (female)		48.7% (male), 51.3% (female)	
SES level	67.5% (low), 32.5% (middle)		66.7% (low), 33.3% (middle)	
Adolescents	N = 52		N = 43	
	M (SD)	Range	M (SD)	Range
Age	14.88 (1.44)	13–17	15.40 (1.37)	13–17
Bilingualism onset			2.56 (1.01)	1–5
Albanian vocabulary	57.27 (3.50)	44–64	61.91 (2.75)	54–66
Turkish vocabulary	–	–	58.72 (3.72)	44–64
Gender	50% (male), 50% (female)		48.8% (male), 51.2% (female)	
SES level	69.2% (low), 30.8% (middle)		58.1% (low), 41.9% (middle)	
Adults	N = 37		N = 40	
	M (SD)	Range	M (SD)	Range
Age	30.78 (9.43)	18–49	27.20 (8.64)	18–47
Bilingualism onset			3.42 (1.34)	1–7
Albanian vocabulary	60.24 (4.07)	47–66	58.48 (4.46)	47–66
Turkish vocabulary	–	–	55.03 (4.82)	43–66
Gender	32.4% (male), 67.6% (female)		32.5% (male), 67.5% (female)	
SES level	67.6% (low), 29.7% (middle), 2.7% (high)		62.5% (low), 35% (middle), 2.5% (high)	

on vocabulary tests (see Table 1 and description of tasks in the next section) confirmed very good proficiency in each language spoken as a function of age group.

Bilinguals were recruited from the city of Prizren in Kosovo, where the Albanian-Turkish population is dominant. After the collapse of the Ottoman Empire, many Turkish citizens remained in Kosovo, establishing this bilingual community. The Turkish language is still attributed a prominent role in social life, spoken in the city even by non-ethnic Turks. Thus, the bilingual sample was of non-immigrant status, with its members holding an Albanian nationality. Bilingual children and adolescents were currently attending, and bilingual adults had all attended, Albanian-speaking schools, whereas they reported having received none (74.6% of participants) or only few years of formal education in Turkish. Turkish was mainly spoken at home and for socialising, and Albanian at work or school. However, there were participants that reported sometimes socialising in Albanian, as well as participants who have worked or were currently working in settings where Turkish was frequently used.

Monolinguals ( $N = 129$ ) were recruited from Prishtina, Peja, and Fushë in Kosovo. Besides

Albanian, they had not used another language on a daily/regular basis in the past and as was the case for bilinguals, they had minimum exposure to foreign languages: mostly to English, either in the context of school classes for few hours per week (currently for children and adolescents, and in the past for adults) or through the media (TV, internet).

The bilingual and monolingual participants of each age group (see Table 1 for descriptive statistics and frequencies) were matched on (a) age in years [ $t(77) = .398$ ,  $p = .692$  for children,  $t(93) = -1.764$ ,  $p = .081$  for adolescents,  $t(75) = 1.741$ ,  $p = .086$  for adults], (b) gender [ $\chi^2(1) = .013$ ,  $p = .909$  for children,  $\chi^2(1) = .013$ ,  $p = .910$  for adolescents,  $\chi^2(1) = .000$ ,  $p = .995$  for adults], and (c) SES [ $\chi^2(1) = .006$ ,  $p = .937$  for children,  $\chi^2(1) = 1.260$ ,  $p = .262$  for adolescents,  $\chi^2(2) = .243$ ,  $p = .885$  for adults], based on individual (for adults) or parental (in the case of children and adolescents) reports regarding education (from 0–did not finish elementary school to 6–postgraduate higher education), type of occupation (0–unemployed, 1–blue collar, 2–white collar), and position in occupation (from 0–unemployed to 6–executive member/big business owner); specific cut-off scores were then applied for inclusion in low SES (up to

8 points), middle (9 to 12), and high SES (13 or greater) groups (see also Chrysochoou et al., 2020; Ladas et al., 2015; Laketa et al., 2021; Vivas et al., 2017, 2020).

The study was approved by the Ethics Committee of the University of Sheffield. Informed consent was obtained from adults and parents, in addition to informed assent, obtained from children and adolescents.

## Measures

**Vocabulary:** Proficiency in Albanian, and additionally in Turkish for bilinguals was measured with adapted versions (see Ladas, 2013; Ladas et al., 2015; Laketa et al., 2021; Vivas et al., 2017, 2020) of the Wechsler productive vocabulary test, requiring word definitions (WISC III, Wechsler, 1991 for children, and WAIS III, Wechsler, 1997 for adolescents and adults). Following the standard scoring procedure, a sum was computed for each participant, based on the 30 and 33 items included in the WISC and the WAIS vocabulary tests respectively, with each item scored on a 0–2 scale.

**Perceived language efficiency:** Bilingual participants of all ages were asked to report on a five-point likert scale how efficient they felt in speaking, understanding, reading, and writing each language (very poorly—very well) (see also Ladas, 2013). The average of these four measures reflected perceived efficiency in each language, tapping on cognizance. The reliability of the measure was high for both Albanian (Cronbach's  $\alpha = .73$ ) and Turkish (Cronbach's  $\alpha = .76$ ).

**Raven's Progressive Matrices:** The *Colored Progressive Matrices* (CPM-Raven et al., 1998) was addressed to children and the *Standard Progressive Matrices* (SPM-Raven, 1958) to adolescents and adults. Participants see matrices involving a figure in each cell but one, and they have to choose a figure among the options provided to fill in the empty cell. CPM include three sets (A, AB, B) and SPM include five sets (A, B, AB, C, D) of 12 items each. Items within a set become increasingly difficult, requiring greater capacity to encode and analyze information. Analyses relied on the standardised performance attained by participants on the matrices solved by each group (see Results). The reliability of this test was very high (Cronbach's  $\alpha$  was .87).

**Attentional Network Test (ANT):** We used the Fan et al.' (2002) version, though as adopted by Callejas

et al. (2004), using an auditory alerting cue and only valid spatial cues. Participants had to keep their eyes on the fixation cross (+) throughout the experiment. In each trial, a cue appeared for 100 ms. There were four different types of cues: the no cue and central cue were control conditions for the alerting cue (beep sound) and the spatial cue (an asterisk was always presented at the location of the upcoming target array—above or below fixation), respectively. After an interval of 400 ms, the target array was presented above or below the fixation point. The target was an arrow, pointing either left or right. It was always presented centrally, alone or flanked by four identical arrows, according to the condition: in congruent trials, arrows pointed towards the same direction as the target; in incongruent trials, they pointed towards the opposite direction. There were dashes (instead of arrows) on the left and right side of the target in the neutral condition. Participants were required to respond with a left or right mouse click, based on the direction of the central arrow (target) in the array, presented for 1700 ms or until response.

Thus, each trial was a combination of one of the four cueing conditions (central cue, spatial, alerting cue, no cue) with one of the three flanker conditions (congruent, incongruent, neutral), and was presented 24 times (8 times in each block). The experiment included 24 practice trials, and three experimental blocks with 96 trials (feedback was provided only for the practice trials). Experimental trials were presented in random order. Completion time was approximately 25 min.

Children were administered the child version of the ANT (see Rueda et al., 2004), which differs in the format of the stimuli used; instead of arrows as target and flankers, yellow fish were used. Children were told that sometimes a central fish would appear on its own, and sometimes it would appear with other fish; however, they had to “feed” only the fish at the centre of the row, by appropriately responding with the mouse (i.e. if the fish pointed to the right, they should feed it with a right mouse click). There were 12 conditions overall, created by fully combining flanker congruency (congruent, incongruent, neutral) and cue type (spatial, central, alerting, no cue). Number of practice and experimental trials and blocks were equal to the adolescents' and adults' version. It is noted that the cue appeared for 150 ms and after an interval of 450 ms, the target

**Table 2.** Mean response times as a function of language group, age group, flanker type, and cue type.

Flanker type	Language group	Age group	Cue type			
			No cue <i>M (SD)</i>	Alerting cue <i>M (SD)</i>	Central cue <i>M (SD)</i>	Spatial cue <i>M (SD)</i>
Congruent	Monolinguals	Children	805 (145)	720 (129)	742 (132)	724 (129)
		Adolescents	562 (84)	536 (80)	546 (82)	492 (78)
		Adults	588 (104)	573 (101)	588 (116)	551 (114)
	Bilinguals	Children	522 (100)	424 (68)	427 (60)	420 (062)
		Adolescents	452 (61)	437 (54)	452 (57)	404 (52)
		Adults	527 (98)	505 (94)	523 (95)	474 (94)
Incongruent	Monolinguals	Children	852 (157)	816 (143)	837 (155)	785 (145)
		Adolescents	688 (145)	661 (135)	663 (129)	606 (131)
		Adults	725 (148)	700 (140)	704 (150)	664 (159)
	Bilinguals	Children	540 (93)	444 (53)	460 (62)	441 (63)
		Adolescents	499 (93)	471 (88)	495 (101)	432 (89)
		Adults	606 (122)	575 (118)	598 (121)	545 (126)
Neutral	Monolinguals	Children	765 (152)	707 (132)	706 (145)	706 (114)
		Adolescents	552 (81)	534 (73)	537 (77)	490 (74)
		Adults	582 (103)	564 (107)	573 (109)	541 (101)
	Bilinguals	Children	532 (90)	415(49)	413 (52)	408 (39)
		Adolescents	444 (48)	424 (51)	440 (53)	395 (45)
		Adults	516 (84)	494 (81)	508 (82)	463 (84)

array was presented above or below the fixation point for 1700 ms or until response. The reliability of this attentional measure was very high (Cronbach's alpha was .98).

## Results

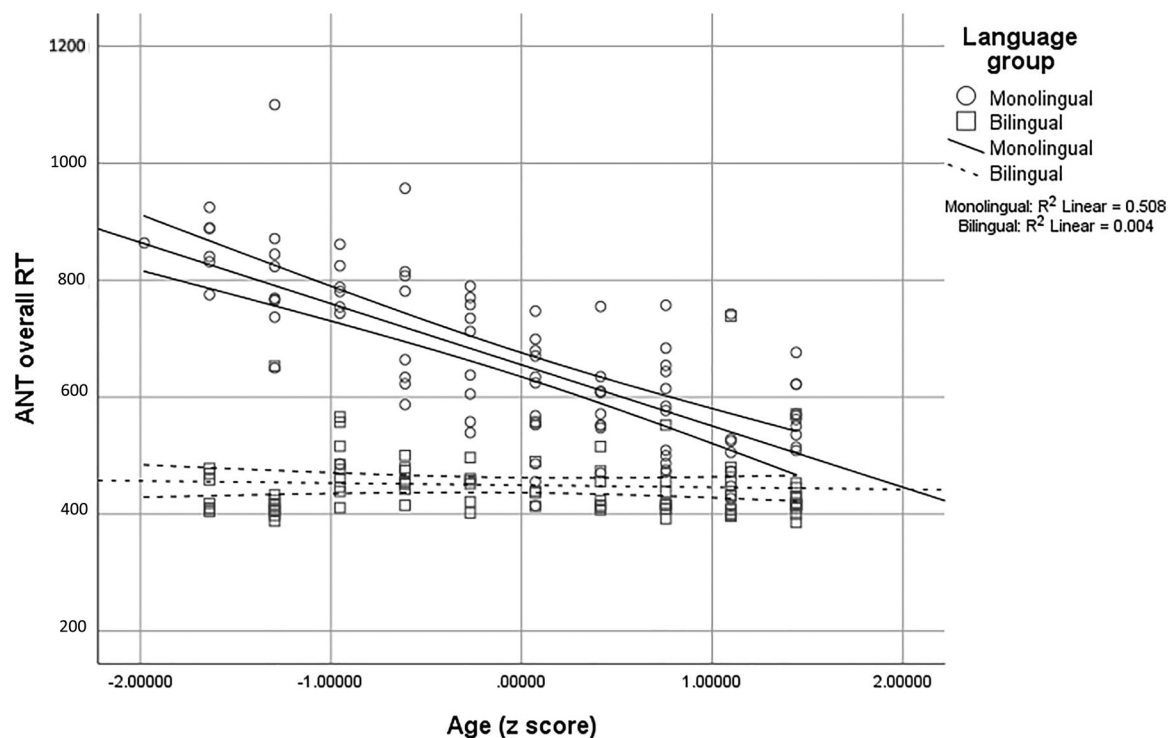
### Exploring attainment differences as a function of language and age group

A first set of analyses examined the interaction of the language and age group factors in determining performance on fluid reasoning (Raven's) and the ANT measures. This relates to our first prediction. With regard to fluid reasoning, to ensure comparability, performance on the Raven test was standardised based on the matrices solved by each group. A 3 (age group: children, adolescents, adults)  $\times$  2 (language group: bilingual vs. monolingual) ANOVA showed a non-significant effect of age group,  $F(2, 245) = .159, p = .853, \rho\eta^2 = .00$ , but a significant effect of language [ $F(1, 245) = 54.744, p < .001, \rho\eta^2 = .18$ ], indicating that bilinguals outperformed monolingual participants. The age  $\times$  language interaction was also significant [ $F(2, 245) = 6.036, p = .003, \rho\eta^2 = .05$ ], indicating that language group differences were smaller in children (mean of 97.97 for monolinguals vs. 102.09 for bilinguals) relative to adolescents (92.45 for monolinguals vs. 109.12 for bilinguals) or adults (91.28 for monolinguals vs. 108.06 for bilinguals).

Based on the differences above, performance on the Raven test was taken into account in the

analyses conducted to examine whether bilingual experience interacts with age to influence performance in the ANT task. Specifically, a 3 (age group: children, adolescents, adults)  $\times$  2 (language group: bilingual vs monolingual)  $\times$  4 (cue: central, spatial, alerting, no cue)  $\times$  3 (congruency: congruent, incongruent, neutral) ANCOVA, with repeated measures on the last two factors, and performance on the Raven test as a covariate, was conducted. This analysis showed significant main effects of age group [ $F(2, 243) = 25.804, p < .001, \rho\eta^2 = .175$ ] and language group [ $F(1, 243) = 165.381, p < .001, \rho\eta^2 = .41$ ]. Performance on the Raven test did not demonstrate a significant effect [ $F(1, 243) = 1.446, p = .230, \rho\eta^2 = .006$ ]. Notably, the age  $\times$  language group interaction was highly significant, [ $F(2,243) = 33.244, p < .001, \rho\eta^2 = .22$ ]. Specifically, bilingual participants had faster reactions overall, and in all ages (children:  $t(77) = 14.627, p < .001$ ; adolescents:  $t(93) = 7.836, p < .001$ ; adults:  $t(74) = 3.575, p < .001$ ). However, the advantage was larger in children (310 ms) relative to both adolescents (127 ms) and adults (87 ms), who did not significantly differ. Moreover, Bonferroni post-hoc comparisons showed that, although monolingual adolescents (572 ms) were significantly faster than children (764 ms,  $p < .001$ ), there was no difference in global RTs between children (454 ms) and adolescents (445 ms) in the bilingual sample. This pattern is further explored below, in the context of a moderated regression analysis.

Moreover, the main effect of cue was highly significant [Greenhouse—Geisser correction applied;  $F(2.399, 582.985) = 6.612, p = .001, \rho\eta^2 = .03$ ];



**Figure 1.** The moderating effect of bilingualism on age-related improvement in monitoring (ANT overall RT) among children and adolescents.

responses were slower overall in the no cue trials, and faster in the spatial condition trials, with responses in the other two conditions lying in between (see Table 2). Also, the effect of congruency was highly significant [ $F(1.277, 310.323) = 25.084, p < .001, \rho\eta^2 = .09$ ], with response times being significantly slower in the incongruent than the congruent and neutral conditions. The congruency by cue type interaction was not significant [ $F(5.513, 1339.67) = 1.110, p = .354, \rho\eta^2 = .005$ ]. There was a significant interaction between language group and congruency [ $F(1.277, 310.323) = 40.685, p < .001, \rho\eta^2 = .14$ ], which indicated that the bilingual benefit observed in the incongruent condition (212 ms) was significantly larger in magnitude than the comparable differences between the groups in the congruent (149 ms) or the neutral conditions (145 ms). These differences are tested further below, in the structural analyses. The congruency by age by language group interaction was not significant [ $F(2.554, 310.323) = 2.046, p = .117, \rho\eta^2 = .017$ ].

To better understand the pattern observed in the Bonferroni post-hoc comparisons mentioned above, we examined the possible moderating effect of bilingualism on the significant relationship

observed between age in years and monitoring (overall RT) in the children's and adolescents' sample ( $r = -.351, p < .001$ ). In the moderated regression analysis conducted (see Frazier et al., 2004), the cross product of bilingualism and age variables (interaction term) explained an additional 11.2% of variance in overall RT, over and above the 59.1% explained by the first order effects of the predictors (the standardised age values and the dummy coded bilingualism variable). Specifically, significant age-related changes in overall RT were only observed in the monolingual sample ( $r = -.713, p < .001$ ; vs.  $r = -.065, p = .563$  for the bilingual children and adolescents). Responses were already fast amongst younger bilinguals, in contrast to monolingual peers, for whom overall RT linearly decreased with increasing age (see simple regression slopes per language group in Figure 1).

#### **Structural equation modelling to further explore attainment differences and test structural relations as a function of language group**

Structural equation modelling was used to further explore the more pronounced bilingual benefit

observed for the incongruent condition RT of the ANT and test our second and third predictions, regarding structural relations and cognizance respectively. Specifically, two Structure Means Models were tested. The first involved two major factors: one for processing efficiency, related to all four congruent attention measures, and inhibitory control, related to all four incongruent condition measures of the attention task. There was a fluid reasoning factor which was related to the standardised performance attained by participants on the Raven test version addressed to them. Standardisation was computed within each age group. The relation of the fluid intelligence factor with this Raven z-score was fixed to 1 in both groups. There was also a dummy factor related to Albanian vocabulary in the monolinguals and two dummy factors, one for Albanian and one for Turkish vocabulary, in the bilinguals. The first version of the model was highly constrained. Specifically, all measure-factor and all factor-factor relations were constrained to be equal across the two groups. This manipulation assumes that the factors are identical in the two language groups and also that their relations are the same across the two groups. In the second version of the model, the equality constraints imposed on the measure-factor relations were preserved but the relations between factors were left free to vary between groups. A better fit of this model relative to the first would imply that the various factors may relate differently in the two groups.

To capture possible differences in performance, each measure was related to an intercept construct to specify the mean performance attained by each group on each measure involved in the model. The processing efficiency, the inhibitory control, the fluid reasoning, and the language-specific factors were also related to the intercept. In the fashion above, all measure-intercept relations were constrained to be equal across the two groups. However, the factor-intercept relations were fixed to 0 (zero) in the monolingual group and were left free to be estimated in the bilingual group. This manipulation assumes that the groups start the same in performance across measures but they may differ in the underlying latent factors involved.

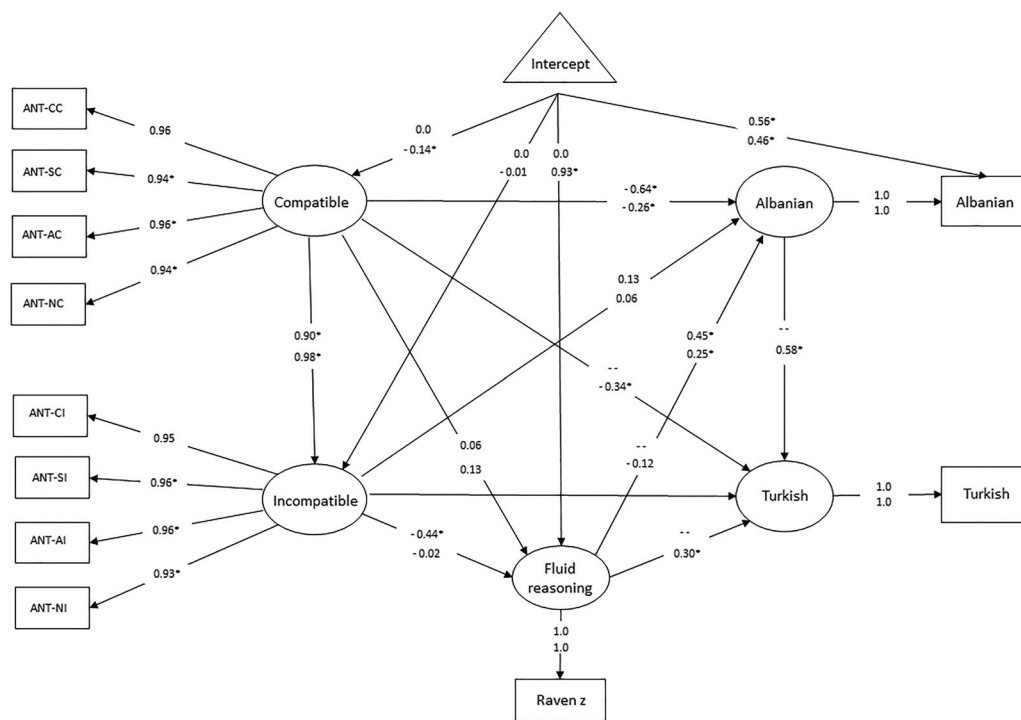
To estimate the minimum sample size required to obtain sufficient statistical accuracy for detecting effects of interest in the population a priori power analysis was conducted. Following the MacCallum et al. (1996, 2010) method, which is based on

discrepancies between null and alternative RMSEA values, we applied a test of close fit associated with RMSEA values less than or equal to .08. The significance level was  $\alpha = 0.05$ . The test of close fit indicated that the power of analysis for the total sample ( $N = 251$ ) and the degrees of freedom for the best models involving all relations of interest ( $df = 69$ ) was 1. Also, the power for the two language groups, involving the monolingual ( $N = 129$ ) and bilingual participants ( $N = 122$ ), was also very high (.98 and .97, respectively). Therefore, for approximate power of >80%, null RMSEA = 0, alternative RMSEA = 0.08, and  $\alpha = 5\%$ , both the total sample and the two language-specific samples would suffice.

Notably, the fit of the fully constrained model was not acceptable by most of the fit indices, Sattora-Bentler  $\chi^2$  (75) based on covariance matrix only = 167.758,  $p < .001$ , CFI, 1.00, RMSEA = .099 (.077–.120), AIC = 17.758; indices based on covariance matrix and the means: McDonalds FI = .829, RMSEA = .100 (.080–.120). However, the fit of the second model, where the equality constraints of the factor-factor relations were released, was very good and significantly better than the fully constrained model: Sattora-Bentler  $\chi^2$  (69) based on covariance matrix only = 91.398,  $p > .03$ , CFI, 1.00, RMSEA = .049 (.00–.077), AIC = 55.754;  $\Delta\chi^2$  (6) = 76.360,  $p < .001$ ; indices based on covariance matrix and the means: McDonalds FI = .956, RMSEA = .051 (.014–.078). This is the model shown in Figure 2.

Inspection of these results suggests the following conclusions. First, in terms of performance, the structured means differences between the two groups further clarified the differences found by the ANCOVA presented above. The present model suggests that the difference between the two groups does not lie within the domain of executive function (inhibitory control, that is, resistance to interference in the incongruent condition); rather, it seems to regard processing efficiency (congruent condition RTs). The bilingual group was significantly faster on the processing efficiency factor than the monolingual group (the factor intercept was significantly lower than 0 by  $-.14$  ms,  $z = -10.527$ ,  $p < .001$ ); however, there was no difference in inhibitory control (incongruent condition).

Moreover, in relation to our second aim, the covariance model suggested that some relations between the factors were similar and some were different between the two groups: the relation



**Figure 2.** The Structure Means Model comparing monolingual with bilingual participants. Notes: The first number in each pair indicates relations in the monolingual group and the second in the bilingual group, respectively. Only one measure-factor relation is shown because these relations were constrained to be equal across the two groups (the first is fixed to 1 for identification). Asterisks indicate significant relations or intercepts ( $p < .05$ ). Factor-factor relations were free to be estimated. The symbol--indicates that these relations did not exist in the monolingual group. ANT-CC/SC/AC/NC: ANT Central/Spatial/Alerting/No-Congruent; ANT-CI/SI/AI/NI: ANT Central/Spatial/Alerting/No-Incongruent.

between processing efficiency and inhibitory control was very high in both groups ( $\beta = .90$  and  $\beta = .98$  for the monolingual and the bilingual group, respectively). The relation between processing efficiency and fluid reasoning was very low and non-significant in both groups ( $\beta = .06$  and  $\beta = .13$  for the monolingual and the bilingual group, respectively). However, in line with our second prediction, assuming greater differentiation between mental abilities in bilinguals, the relation of inhibitory control with fluid reasoning was significant in the monolingual group, but lower and non-significant in the bilingual group ( $\beta = -.44$  and  $\beta = -.02$ ,  $z = 1.710$ ,  $p < .05$ ). Also, in line with the increased differentiation expected in bilinguals, the relation between Albanian vocabulary and processing efficiency was significant in both groups, yet higher in the monolingual group ( $\beta = -.64$ ) as compared to the bilingual group ( $\beta = -.26$ ,  $z = 3.163$ ,  $p < .01$ ). Along the same line, the relation of fluid reasoning with Albanian vocabulary was significant in both groups, yet significantly higher in the monolingual relative to the bilingual group ( $\beta = .45$  and  $\beta = .25$ , respectively,  $z = 2.350$ ,  $p < .01$ ). The

relation between Albanian vocabulary and the inhibitory control measure was insignificant in both groups ( $\beta = .13$  and  $.06$ ), as was the relation between Turkish vocabulary and inhibitory control in the bilingual group ( $\beta = -.12$ ). For bilinguals, there were significant relations between Turkish vocabulary and both processing efficiency ( $\beta = -.34$ ), as well as fluid reasoning ( $\beta = .30$ ). Finally, the relation between performance in the two vocabulary tests in the bilingual group was high and significant ( $\beta = .58$ ).

Finally, one might ask how cognizance relates with the factors above. To test our third prediction, expecting significant positive relations, the model above was tested on the bilingual group only, creating a factor for perceived efficiency in Turkish (the heritage language). This factor was associated with the cognizance measures described in method. The fit of this model was good, Sattora-Bentler  $\chi^2(89) = 145.715$ ,  $p < .001$ , CFI, 1.00, RMSEA = .073 (.051-.094), AIC = -32.285. Perceived efficiency in Turkish was moderately and significantly related with processing efficiency ( $\beta = .24$ ) and negatively

with fluid reasoning ( $\beta = -.22$ ). This pattern of relations suggests, contrary to our last prediction, that slower processing efficiency and lower performance on the Raven matrices was associated with higher perceived efficiency in mastering the heritage language. This pattern will be discussed below in the general discussion.

## Discussion

The present study acknowledged both calls for more detailed descriptions of bilingual experiences (see de Bruin, 2019), as well as the need for research regarding bilingual cognition to move forward (see Goldsmith & Morton, 2018; Paap, 2015; Poarch & Krott, 2019). We focused on individual differences in cognitive processes related to *g* which are sensitive to environmental modulation in childhood (i.e. inhibitory control—specifically, resistance to interference—, monitoring, processing efficiency, and fluid reasoning), based on current developmental models of intelligence and cognitive development (Demetriou & Spanoudis, 2018; Demetriou et al., 2017, 2018a, 2019; see also Best & Miller, 2010). We also tested a bilingual population that has not been studied so far; that is a sample of non-immigrant, simultaneous or early Turkish-Albanian bilinguals (children to middle-aged adults), living in Kosovo. We explored whether growing up bilingual and living in a bilingual community is associated not only with better cognitive functioning, but with increased differentiation of mental abilities (in line with Spearman's relevant hypothesis), as the latter would be indicated by weaker relations among the relevant measures obtained. The findings are discussed below, stressing the need to move beyond the suggested executive bilingual advantage, to a thorough investigation of cognitive development and abilities' differentiation as a function of well-described bilingual experiences.

Specifically, adjusting for any fluid reasoning effects (performance on the Raven test), bilingual participants were found faster overall (monitoring index), and demonstrated a more pronounced benefit in the incongruent ANT task trials (inhibitory control). In line with our first prediction, the difference between groups in overall RT was greater in the children's group. Further exploration of this pattern amongst the children's and adolescents' sample, via a moderated regression analysis, showed that responses were already fast amongst younger bilinguals, in contrast to monolingual

peers, for whom overall RT linearly decreased with increasing age (see Figure 1). This pattern is in agreement with the findings of Yang and Yang (2016), who observed bilingualism effects in all global measures of attention obtained, but at markedly larger magnitude for children than adults. These findings are also aligned with the more pronounced bilingual benefit observed among the youngest bilingual participants in the Hansen et al. (2016) study with school-age children. Even if assessments regarded working memory and proactive control, the researchers attributed this age-related pattern to the significant attentional demands assumed to be placed on young bilingual children, when challenged to manage two concurrently activated languages in daily life. Our findings also align with studies showing that the effect of bilingualism on cognition depends on the developmental phase studied, as more pronounced effects have been demonstrated in samples of children (or older adults), rather than in young adults (Bialystok et al., 2014; Donnelly, 2016; Grundy & Timmer, 2017; Vivas et al., 2020).

Structural equation modelling was employed to further explore the bilingual benefits observed in the attention task. This method allows calculating unbiased estimates of group mean differences on latent variables, via modelling measurement error. The results did not point to an executive function bilingual advantage: group differences regarded processing efficiency, rather than inhibitory control (as reflected in mean RTs in the congruent and incongruent ANT task conditions, respectively). This approach, being novel to the bilingual advantage literature, may be useful for clarifying the source of any language group differences. Notably, lack of a bilingual advantage on inhibitory control is consistent with recent evidence, questioning the generality and robustness of the suggested advantage (Chrysochoou et al., 2020; Ladas et al., 2015; Laketa et al., 2021; Lehtonen et al., 2018; Vivas et al., 2017, 2020; see also Antón et al., 2016; Duñabeitia et al., 2014). In line though with evidence suggesting better general monitoring skills in bilinguals (as indexed by overall RTs; see Costa et al., 2008; Lehtonen et al., 2018), our analyses showed faster RTs in bilinguals overall, as well as for the congruent condition (processing efficiency index) of the attention task. Better monitoring capacity in bilingual participants would result from the need to continuously monitor the surrounding context, so as to select the appropriate language (Costa et al., 2008).

With regard to fluid reasoning, the magnitude of the difference observed in favour of bilinguals was greater in the adolescents' and adults' groups, relative to the children's group. This could be seen as an outcome of prioritisation of reasoning (inductive) development in the middle childhood years (see MoDePrior; Demetriou et al., 2017, 2019), allowing for the demonstration of significant modulating effects of bilingualism in the period that directly follows (adolescence). It is additionally noted that performance on the Raven test (the fluid reasoning index) did not assert a significant covariate effect in the ANCOVA conducted for the ANT task measures. These patterns align with suggestions that being able to think in, communicate via, as well as reflect on different languages, may lead bilinguals to approach language as just one among several conceptual systems; each involving phenomena, rules, and principles that can be organised in broader, interconnected categories. Developing this special, objective awareness of language (see *objectification hypothesis* in Hakuta et al., 1987) might assert independent influences on bilinguals' fluid reasoning (see also earlier studies by Darcy, 1953; Peal & Lambert, 1962).

This interpretation is also in agreement with recent longitudinal findings for positive bilingualism effects on intellectual development (see Woumans et al., 2016 for findings in the early years), that extend to the silver years and are independent of childhood intelligence (see Bak et al., 2014). Such evidence does not support the alternative explanation; namely that individuals with better fluid reasoning would be more likely to develop an additional language and become bilingual. Further to this conclusion, in the present study, where a bilingual benefit in fluid reasoning was also observed, bilingual status reflected the socio-cultural context since birth or within the very first years of development. Our participants grew up and live in a bilingual community, thus speaking both the official language of the context and a heritage language, rather than learning an additional language and becoming bilingual in a formal, educational or professional context. Obviously, naturally-occurring group methodology is an inherent limitation of the studies published so far on the effects of bilingualism on cognition. However, we propose here that if fluid reasoning and inference (related to fluid intelligence) are pieces of the mental structure "puzzle", and if interdependence of mental abilities is influenced by life experiences,

then these abilities are also worth being examined in studies on bilingualism (see Bak et al., 2014; Woumans et al., 2016).

In doing so, a series of structural equation models explored two novel research questions for the bilingualism field. That is, the differentiation of the mental abilities tested as a function of bilingual experience, as well as the relations between these abilities and perceived language efficiency—a cognizance index that is relevant to bilingualism. As noted in the introduction, core mental abilities, including inhibitory control of attention and reasoning, along with cognizance account for significant proportions of *g*-related variance (e.g. Makris et al., 2017). Specifically, our findings confirmed our second prediction, in line with Spearman's SLODR (see also Blum & Holling, 2017) and other suggestions for increased flexibility in shifting between systems or processes as a function of enhanced mental efficiency (see Demetriou et al., 2017; Jensen, 1998; Tucker-Drob & Bates, 2016). In summary, Albanian vocabulary (context language) was less dependent on fluid reasoning and processing efficiency in the bilingual group relative to the monolingual group, suggesting more flexibility in its use. Also, the relation of inhibitory control with fluid reasoning was significant in the monolingual group, but lower and non-significant in the bilingual group. This suggests that reasoning and inference may run in autonomy from control processes in bilinguals.

In explaining these findings, one might refer to links drawn between bilingual cognitive and linguistic development, from the first decades of relevant exploration. As Peal and Lambert (1962) noted, developing two verbal expressions for each notion from the first sensitive years of development may result to concept formation relying more heavily on the general properties of environmental events, rather than on concretes. Thus, the enriched linguistic environment that is offered to bilingual speakers, especially if that occurs early on in development, could support greater differentiation of language and mental representations, thus, facilitating more fine-grained and flexible recruitment of information processing resources by bilinguals.

In conclusion, in the present study, bilingual participants showed superior processing efficiency and more autonomous mental abilities, relative to monolingual peers, confirming the importance of the former for integrating information across the cognitive system. Future research could explore whether

bilingualism acts not only as a buffer against *g* saturation and cognitive decline (in line with Alladi et al., 2013 suggestions), but also helps to retain a diverse pool of autonomous specialised resources across the lifespan, to support behaviour. In their meta-analysis, Blum and Holling (2017) did report greater ability differentiation with increasing age; yet, information was not provided about the linguistic profiles of participants in the specific study.

Finally, results came contrary to our third prediction. On the one hand, the relations between bilingual participants' cognizance index (perceived efficiency in Turkish) and either processing efficiency or fluid reasoning were weak. On the other hand, they were negative, paradoxically suggesting that slower processing efficiency and poorer fluid reasoning is associated with higher perceived efficiency in mastering an additional (other than the context) language among some individuals (~5% of variance). Puzzling as it might seem, this finding is quite common in self-concept and self-evaluation research. It derives from a personality mechanism that has a strong developmental dimension. This is social desirability, driving individuals to represent or evaluate themselves as being better than their actual achievement justifies. This trend diminishes with development and increasing ability. In fact, these relations dropped to non-significant when children were excluded from the model (see also Demetriou et al., 2019).

Summing up, in the present study we investigated a relatively large sample ( $N=251$ ) of Albanian-Turkish bilingual non-immigrants, growing up in a bilingual community, and Albanian monolingual individuals—children, adolescents, adults—of similar SES and socio-cultural background, all living in the same geographical region. Approaching the investigation of possible cognitive correlates of bilingualism from a different perspective, we studied whether any positive effects of bilingualism on cognitive functioning translate into increased differentiation of mental abilities as well. We found a bilingual benefit in monitoring, which was more pronounced among children. It is noted that group differences were independent of fluid reasoning, also found enhanced among bilinguals. Yet, our findings did not point to a bilingual advantage in inhibitory control, in line with recent findings questioning benefits in the executive domain. We found, however, enhanced processing efficiency, along with smaller interdependency of mental abilities in the bilingual sample. The latter aligns with

Spearman's SLODR, as well as recent suggestions for more flexible application of mental processes in the light of enhanced mental efficiency (see Demetriou et al., 2017; Jensen, 1998; Tucker-Drob & Bates, 2016).

We propose that future research must enhance its focus, from bilingualism effects on specific executive functions to more systematic investigations of cognitive developmental trajectories and differentiation of mental abilities, as a function of bilingual experience. In doing so, researchers could aim for even more comprehensive assessments, including, for example, measures of working memory, set-shifting, or planning, along with assessments of awareness of a wider set of cognitive capacities (rather than of language efficiency solely). Emphasis on cognizance, this critical driving force of cognitive development (see Demetriou et al., 2018a), is deemed necessary, if the field is to move forward, towards theoretically framed investigations of bilingual cognitive development. Future studies should also consider developmental prioritisation of *g*-related processes (see MoDePrior; Demetriou et al., 2017, 2019), focusing on successive phases, from early childhood to adulthood. The present investigation did involve different age groups (attempted in few studies so far), yet in the context of a cross-sectional design, which did not cover the whole lifespan. For example, our oldest participants were middle-aged adults, despite evidence suggesting more pronounced positive effects of bilingualism in the silver years. Future, longitudinal investigations might also involve different bilingual populations (e.g. non-migrant versus migrant bilingual populations, speaking different language pairs etc.), as well as describe bilingual profiles in greater detail, involving measures of acculturation, motivation and attitudes to learn and use two languages, language switching in daily life contexts, or support of bilingualism in the school setting or by teachers (see recent relevant studies by Laketa et al., 2021; Studenica et al., 2021). This line of research will help disentangle bilingual and monolingual cognitive developmental trajectories as a function of a life experience that offers naturally occurring training of mental abilities, and becomes more and more common in today's world of migration and mobility. Moreover, we suggest that viewing bilingual cognitive development via the lens of individual differences is more likely to capture the complex interaction between environment and the human mind.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Data availability statement

Data associated to this publication can be found at <https://data.world/vivas/cognitionbilingualsturkishalbanian/settings?tab=access>.

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