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ORIGINAL ARTICLE

Two is better than one: bilingual education promotes the flexible mind

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Abstract The interest in the influence of bilingualism on our daily life is constantly growing. Speaking two languages (or more) requires people to develop a flexible mindset to rapidly switch back and forth between languages. This study investigated whether and to what extent attending bilingual education benefits cognitive control. We tested two groups of Dutch high-school students who either followed regular classes in Dutch or were taught in both English and Dutch. They performed on a global–local switching paradigm that provides well-established measures of cognitive flexibility and attentional processing style. As predicted, the bilingually educated group showed smaller switching costs (i.e., greater cognitive flexibility) and a decreased global precedence effect than the regular group. Our findings support the idea that bilingual education promotes cognitive flexibility and a bias towards a more focused "scope" of attention.

Introduction

Due to sociolinguistic background and foreign language education, many people have learned to speak more than one language. For example, about 56 % of all Europeans consider themselves a functional bilingual or multilingual (Special Eurobarometer 2006). Many bilinguals acquired their languages relatively late and do not have equal proficiency over their first (L1) and second (L2) languages (Christoffels, de Groot, & Kroll, 2006; Grosjean, 2010). Nevertheless, bilinguals are able to switch between languages when they choose to do so. Accumulating research on bilingualism shows that, even when only one language is used, the irrelevant language is also constantly activated (e.g., Thierry & Wu, 2007; De Groot & Christoffels, 2006; Kroll, Bobb, & Wodniecka, 2006). Therefore, bilinguals need to continuously control and negotiate two (or even more) languages, and are thought to continuously exert general cognitive control abilities when they use more than one language systematically (e.g., Bialystok, Craik, & Ryan, 2006; Colzato et al., 2008; De Groot & Christoffels, 2006; Green, 1998). In the present study, we address the possible beneficial role of daily mixed language use on the expression of these cognitive control processes in late learners of the L2.

A growing number of studies report that life-long bilinguals outperform monolinguals on a number of nonlinguistic tests of cognitive control. Advantages have been reported for tasks that involve response conflict (inhibition), such as the Simon task (e.g., Bialystok, 2006; Bialystok, Craik, & Luk, 2008; Bialystok, Craik, Klein, & Viswanathan, 2004) and the flanker task (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Tao, Marzecová, Taft, Asanowicz, & Wodniecka, 2011). This bilingual advantage on general cognitive abilities is shown in different age groups, from infancy (Kovács & Mehler, 2009), through childhood (Poarch & van Hell, 2012), adulthood (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2008), into senescence (Bialystok et al., 2004).

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Note however, that there is controversy on the nature and even the existence of this advantage. In a review, Hilchey & Klein (2011) addressed the possible bilingual advantage on inhibitory processing. The authors conclude that there seems to be a general cognitive advantage, in that bilinguals generally perform faster, not that bilinguals outperform monolinguals in response conflict tasks per se. In addition, Costa et al. (2009) explored bilingual advantages in response conflict and concluded that bilinguals outperform monolinguals in overall reaction times, but only when the task recruits a good deal of monitoring resources; they did not find better conflict resolution.

Another hallmark of cognitive control is mental flexibility. General domain switching (sometimes called 'shifting'; Miyake et al., 2000) between tasks was shown to be related to bilingual language control in a number of studies (Garbin et al., 2010; Prior & Gollan, 2011; Prior & MacWhinney, 2010). During task switching, bilinguals were found to recruit more brain areas related to language control than monolinguals, which implicates that the neural circuitry involving control differs for monolinguals and bilinguals (Rodríguez-Pujadas et al., 2013). Moreover, life-long bilingualism was found to be associated to a general improvement in selecting goal-relevant information from competing, goal-irrelevant information (Colzato et al., 2008; Hommel, Colzato, Fischer, & Christoffels, 2011; Khare, Verma, Kar, Srinivasan, & Brysbaert, 2013). Again, these overall encouraging findings are complicated by some failures to replicate a bilingual advantage on task switching (Paap & Greenberg, 2013).

Clearly, currently not all variables are known that determine when beneficial consequences of bilingualism arise. One likely variable is the actual daily mixed language use. According to the adaptive control hypothesis (Green & Abutalebi, 2013), language control processes adapt to demands placed on them by different linguistic backgrounds. This predicts considerable differences between individuals depending on how often they use and switch between their languages on a daily basis.

In the previous research, participants are typically only selected if they are fluent in both languages and acquired those languages early or even from birth (e.g., Bialystok, 2006; Colzato et al., 2008; Costa et al., 2008; Prior & Gollan, 2011; but see Tao et al., 2011). To expand on this research, in the present study we aimed to investigate whether advantages are also found for bilinguals that learned their second language later in life in a school setting. Is a bilingual upbringing essential to develop cognitive control advantages? Or, is daily mixed language use an important variable determining cognitive consequences of bilingualism?

If it is not essential to be a life-long bilingual, then also bilinguals who learned their L2 later in life (at school) may benefit from being bilingual. In particular, the bilingual language context, i.e., how frequent and under what circumstances different languages are used, may be of large influence on the cognitive consequences of bilingualism. This would mean that only bilinguals who switch frequently between their languages may train the neural circuitry that involves language control (Green, 2011), and, as a consequence, show enhanced general cognitive control abilities. We hypothesized that a day-to-day bilingual context may influence cognitive processing and enhance cognitive control. In the present study, we compare, for the first time, two groups of late bilinguals from a very similar background that differ on how much demand is placed on their language management at school.

In our study, we focused on mental flexibility because this aspect of cognitive control seems to be most related to what may be trained by daily language switching. We tested mental flexibility by assessing switch costs in a combined global–local switching task, which has been used in other domains to measure cognitive flexibility (e.g., Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010; Huizinga, Dolan, & van der Molen, 2006). The global–local switching task requires switching between tasks and ignoring irrelevant information, because participants switch between attending global and local dimension in a compound visual stimulus. In addition, the global–local task can be used to measure attentional processing style (Navon, 1977) because it indicates dominance of attending to global information rather than compositional detail. Participants are typically shown a global stimulus (e.g., the letter 'H') which is composed of smaller letters. These letters can be congruent ('H') or incongruent ('S') to the global letter. The usual finding in a global–local task is that information at the global level is processed faster and more accurately than information at the local level. This effect, the "global precedence effect", may differ for different groups of participants. The difference in global preference is taken to indicate a qualitatively different attentional processing style: a smaller global preference is taken to indicate a more focused 'spotlight of attention'.

It was shown that individual differences in lifestyle may bias attentional processing style. For example, in relation to religious upbringing, it was found that Dutch Calvinists showed a less pronounced global precedence effect than atheists, indicating that practicing this religion might lead one to attend to more local aspects (Colzato, van den Wildenberg, & Hommel, 2008). That bilingualism may influence cognitive processing style in a similar way is suggested by the findings of Hommel et al., (2011). They found qualitative differences in creative thinking, with better convergent thinking, but worse divergent thinking for the bilinguals than the monolinguals. Indeed, the constant need to keep two or more highly active languages separate may also foster the kind of executive control processing required for focused attention. This would be indicated by a smaller global precedence effect.

Interestingly, a version of the global–local task task has been used once in a bilingual context before (Bialystok, 2010). Children of around 6 years old were compared on a letter task (H consisting of small H or S) and a shape task (squares consisting of circles or squares). Monolinguals and life-long bilinguals were compared who performed similarly on measures of language and cognitive ability. The bilingual children were consistently faster than monolinguals across all the different trials, even though the groups were comparable on other measures of processing speed. However, the global precedence effect was not affected by the language group. It should be noted that also the standard global precedence effect was not clearly demonstrated in this study, which is likely due to the young age of the participants (Bialystok, 2010). A difference between monolinguals and bilinguals on global precedence is therefore also less likely detected.

In the current study, we compared a group of Dutch high-school students studying in a bilingual language environment (following a bilingual track) in an otherwise Dutch-speaking school with a group of students from the same school who attended the standard monolingual track. The bilingual track results in a mixed language context because at least half of the classes are taught in English in a Dutch-speaking school, which means that they have to switch between Dutch and English many times a day between breaks and classes.

We expected that such a mixed language context might enhance general cognitive flexibility in late bilinguals as compared to bilinguals in a monolingual context. Therefore, we hypothesized that students following the bilingual track would show smaller switch costs in a global–local task switching paradigm. Furthermore, cognitive processing style might be influenced. We predicted that the mixed language environment induced by a bilingual track may therefore also lead to a more focused processing style, as indicated by a smaller global precedence effect.

Methods

Participants

Fifty-nine young healthy high-school students served as participants, consisting of one group of late bilingual students ($n = 29$) receiving education in Dutch and another group of late bilinguals receiving education in both English and Dutch ($n = 31$, see Table 1 for demographic characteristics, Digit span, and English proficiency scores). Note that, to detect main and interaction effects with a medium effect size ($f = 0.25$) for our design with a power of 0.95 the required sample consists of at least 54 participants (calculated with G-Power; Faul, Erdfelder, Lang, & Buchner, 2007). Participants were recruited from the same school in Zoetermeer that provides both bilingual and monolingual education at pre-university level ("VWO"), and were requested to participate via their teachers.

All participants were high-school students (mean age = 17.3, SD = 0.84), with corrected or corrected-to-normal vision. As part of the Dutch educational system, all students have learned English at school, on average starting at the age of 10. However, the bilingual participants had followed at least three full years of bilingual education, with at least 50 % of all their classes taught in English. Two of the 31 potential participants of the bilingual group were excluded (3.28 %), as one student ran out of time before completing the global–local switching task, and another showed extremely poor performance (an average switch cost of more than three times interquartile range (IQR) from the rest of the reaction times in that group). Informed consent was obtained from the participants after the nature of the study was explained to them. The protocol and the remuneration arrangements of 5 € were approved by the institutional ethical review board (Leiden University, Institute for Psychological Research).

Participant characteristics are reported in Table 1. Statistical tests revealed no significant differences between the monolingual group and bilingual group for gender (χ^2) = 0.83, $p = .36$), age ($W = 776$, $p = .06$), and age of acquisition [$t(57) = 0.86$, $p = .39$]. No significant difference between the groups was found either for the Digit

Table 1 Means (SD) for demographic characteristics, digit span scores, and English proficiency scores for monolingually and bilingually educated students

Sample	Monolingual education	Bilingual education
Number of participants (M:F)	29 (15:14)	30 (17:13)
Age (in years)	17.5 (0.9)	17.0 (0.7)
Age of acquisition	10.5 (0.1)	10.2 (1.2)
Digit span score	14 (3.0)	15 (3.1)
Forward	6.9 (1.6)	7.5 (1.7)
Backward	6.9 (2.1)	7.5 (1.9)
English proficiency		
Lextale*	67 (10.7)	79 (8.3)
Self-rated proficiency (mean)*	7.1 (1.4)	8.4 (0.8)
Speaking*	7.1 (1.7)	8.3 (0.9)
Writing*	6.8 (1.5)	8.2 (1.0)
Comprehending*	7.4 (1.5)	8.7 (1.2)
Reading*	7.5 (1.2)	8.5 (1.0)
Switching between languages*	2.5 (0.9)	3.4 (1.0)

* $p < .05$ (significant group difference)

Span Score [$t(57) = -1.47$, $p = .15$], or separately for the forward [$t(57) = -1.60$, $p = .12$] or backward span [$t(57) = -0.80$, $p = .42$]. As expected, significant differences between the two groups were found on all proficiency measures, i.e., the LexTALE vocabulary knowledge test [$t(57) = -4.61$, $p < .0001$], self-estimated proficiency overall [$t(57) = -4.48$, $p < .0001$], as well as in self-estimated proficiency for speaking [$t(57) = -3.43$, $p < .01$], writing [$t(57) = -4.45$, $p < .0001$], listening [$t(57) = -3.65$, $p < .01$], and reading [$t(57) = -3.41$, $p < .01$] separately. A significant difference was also found for the self-reported amount of switching between languages (question 3 of the BSWQ; five-point scale); $t(57) = -3.73$, $p < .001$).

Procedure and design

All participants were tested individually in separate classroom in their school. After signing the informed consent form, they completed a series of tasks. There were two experimental tasks: the global–local switching task and a bilingual verbal stop task (not reported in the present study). Further, we administered LexTALE (Lemhöfer & Broersma, 2012) to assess English vocabulary knowledge, and an adaptation of the Digit span (a subtest of the Wechsler Adult Intelligence Scale—Revised; Wechsler, 1987). Finally, a language background questionnaire was administered, which included a translation of questions from the Bilingual Language Switching Questionnaire (BSWQ; Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman, & Münte, 2011) to assess self-reported switching. Task order was counterbalanced between the Digit span, stop task, and global–local switching task. The questionnaires were always filled in at the start, and LexTALE at the end of the experiment. After completing these measurements, the experimental session ended and all participants were paid and debriefed.

Global–local switching task

Participants responded to randomly presented rectangles or squares by pressing a left or right response button, respectively. The target stimuli were adopted from Colzato et al., (2010), and consisted of geometric figures. Rectangles and squares consisted of smaller rectangles or squares (which made four possibilities). That is, the global stimuli (i.e., squares or rectangles; 93 × 93 pixels or 93 × 189 pixels, respectively) were composed of many smaller "local" stimuli (i.e., squares or rectangles; 21 × 21 pixels or 8 × 46 pixels, respectively). The space between the local elements of a stimulus was three pixels. A global square consisted of 16 small squares or 8 small rectangles; a global rectangle consisted of 32 small squares or 16 small rectangles. The "local" and "global" cues were the same size as the global and local stimuli and were presented at 189 pixels from the center of the computer screen.

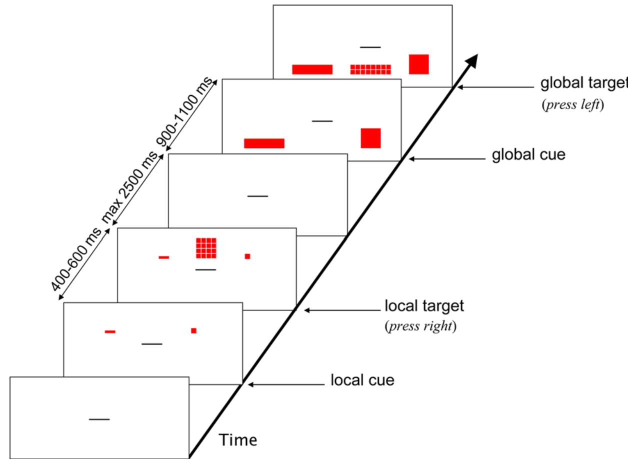

Fig. 1 Sequence of events in a trial of the switch blocks

Participants were presented with one of the four possible stimuli: a rectangle consisting of smaller rectangles or squares, or a square consisting of smaller rectangles or squares. A cue (a rectangle and square, congruous in location with the associated response button) appeared 400–600 ms before the stimulus (located at the center of the screen, between the two cues). The cue was either small or large, and indicated to which level (global/local) the participants should attend in the upcoming stimulus (see Fig. 1). The rectangle or square was associated with a spatially assigned response button that was pressed with either the left or right index finger (which stimulus corresponded to which button was counterbalanced across participants).

The four possible stimuli made it so that trials could either be congruent or incongruent. A congruent trial was a bigger shape built up out of similar smaller shapes (e.g., a large square consisting of smaller squares), an incongruent trial a bigger shape built up out of different smaller shapes (e.g., a large square consisting of smaller rectangles). Both the color of cues and the color of the target stimulus were red, and both remained on the screen until a response was given or 2,500 ms had passed. The interval between response and presentation of the next cue was 900–1,100 ms (See Fig. 1).

In total, three blocks of trials were administered. The first two blocks consisted of 50 trials each, and were training blocks in which the dimension to be attended (global or local) was constant across all trials within that block. Training block order was counterbalanced between participants, meaning that half of the participants started with the "local block", the other half with the "global block”. In the third experimental block of 160 trials, participants had to switch between attending to the global or local dimension every four trials. Using this task, trials could simultaneously be, for example, global, incongruent, and repetition trials. Because of this, participants performed on a total of 80 congruent trials, 80 incongruent trials, 80 global trials and 80 local trials, 39 switch trials, and 120 repetition trials (excluding the very first trial, as it is not a repetition, nor a switch trial).

LexTALE

LexTALE is a vocabulary knowledge test for medium to highly proficient speakers of English as a second language (Lemhöfer & Broersma, 2012). It consists of an un-speeded lexical decision task, programmed in E-prime. In the task, sixty (non)words were presented on a computer screen. Participants were always presented with the words in the same order and instructed to decide whether or not the presented word was an existing English word (or not). By mouse button, they indicated their ‘yes’ or ‘no’ response. Furthermore, they were instructed that, if they were sure that the word existed, even though they did not know its exact meaning, they should respond “yes” but if they were not sure if it was an existing word, they should respond “no”. The task used British English rather than American English spelling (e.g., “realise” instead of “realize”; “colour” instead of “color”, and so on); participants were asked to not pay attention to this. Duration of the task was about 5 min; participants could take as much time as needed for each (non)word to make a decision. The first three items were practice items and discarded. Of the remaining 60 items (40 existing words, 20 non-words), a score was calculated that indicates the percentage of correct responses, corrected for the unequal proportions of words and non-words: [(number of words correct/40 × 100) + (number of non-words correct/20 × 100)]/2 (see Lemhöfer & Broersma, 2012).

Digit span

Five series of numbers of increasing length (from 4 to 8 in the forward condition, and 3 to 7 in the backward condition) were read to each participant at the rate of one digit per second. Participants had to repeat the numbers in the same order (forward span) or in reversed order (backward span). The task was prerecorded, and the experimenter initiated each trial and evaluated the response. Each set length was tested twice; the task was ended if the participant made an error in two consecutive digit sets. Forward and backward digit span were added together to form the ‘Digit span score’ (ranging from 0 to 24).

Statistical analysis

Independent *t* tests, Wilcoxon rank sum test and Chi-squared tests were performed to test differences between the two groups. Mean reaction times and proportions of errors were analyzed by means of ANOVAs using Target level (global vs. local), the Congruency between the stimuli on the two levels (congruent vs. incongruent), and Task switch (i.e., same vs. different target level as in previous trial: task repetition vs. alternation) as within- and Group (monolingually vs. bilingually educated) as between-participants factor. A significance level of $p < .05$ was adopted for all tests.

Results

Table 2 presents the average RT and percent error for each condition in the global–local task. Reaction times revealed three reliable main effects, but no main effect of Group, $F(1, 57) = 2.24$, $p = .14$, MSE = 28,519.04, $\eta^2p = 0.03$. First, the effect of Switch, $F(1, 57) = 104.49$, $p < .0001$, MSE = 3,480.57, $\eta^2p = 0.65$, was due to that repeating the task allowed for faster responding than switching between target levels (385 vs. 441 ms). Second, the effect of Target level, $F(1, 57) = 174.52$, $p < .0001$, MSE = 1,588.49, $\eta^2p = 0.75$, reflected the well-known global preference (Navon, 1977), that is, faster responses to globally than locally defined targets (389 vs. 437 ms). Third, the Congruency effect, $F(1, 57) = 47.24$, $p < .0001$, MSE = 2,411.66, $\eta^2p = 0.45$, indicated interference from the non-target level, that is, faster responses if the stimulus at the currently irrelevant level was congruent with the present target than if that stimulus was incongruent (397 vs. 428 ms).

Table 2 Means (SD) for reaction times (RT) and errors for each condition in the task

Condition	Monolingual education		Bilingual education	
	Mean RT (SD)	Mean error (SD)	Mean RT (SD)	Mean error (SD)
Switch	458 (82)	7.3 (1.0)	423 (62)	6.1 (1.0)
Repetition	391 (49)	5.6 (0.7)	379 (56)	5.8 (0.7)
Switch cost	67 (55)		44 (24)	
Local Target	453 (63)	7.8 (0.9)	422 (58)	6.3 (0.9)
Global Target	396 (64)	5.1 (0.8)	381 (61)	5.6 (0.8)
Global precedence	57 (33)		41 (22)	
Incongruent	441 (75)	10.8 (1.2)	416 (64)	9.9 (1.2)
Congruent	409 (54)	2.1 (0.4)	386 (54)	2.0 (0.4)
Congruency effect	32 (44)		30 (22)	

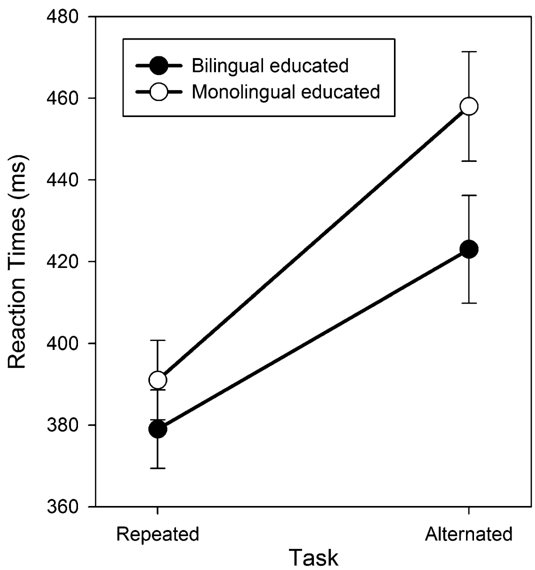

Fig. 2 Mean Reaction Times (ms) as a function of group (monolingual vs. bilingual education) and task switch (i.e., same vs. different target level as in previous trial: task repetition vs. alternation). *Error bars* represent standard errors

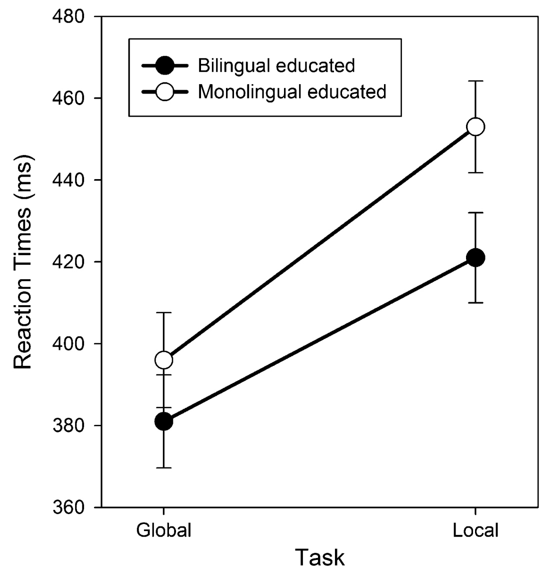

Fig. 3 Mean reaction times (ms) as a function of group (monolingual vs. bilingual education) and Target level (global vs. local). *Error bars* represent standard errors

More important for present purposes are the interactions with Group. The size of the Switch effect varied with Group, $F(1, 57) = 4.74$, $p < .05$, MSE = 3,480.57, $\eta^2 p = 0.08$. As suggested by Fig. 2, switching costs were reliable for both monolingually and bilingually educated participants, $F(1, 28) = 44.57$, $p < .0001$, MSE = 5,902.04, $\eta^2 p = 0.61$ and $F(1, 29) = 100.29$, $p < .0001$, MSE = 1,142.60, $\eta^2 p = 0.78$, respectively. However, as predicted, switch costs were reduced in the bilingually compared to the monolingually educated group (44 vs. 67 ms). This reduction was due to better performance on switch trials, suggesting that bilingualism selectively targeted the condition in which cognitive control was needed most.

As expected, the size of the global precedence effect varied as well between groups, $F(1, 57) = 4.72$, $p < .05$, MSE = 1,588.49, $\eta^2 p = 0.08$. As indicated by Fig. 3, the global precedence effect was statistically reliable for both monolingually and bilingually educated participants, $F(1, 28) = 83.66$, $p < .0{,}001$, MSE = 2,209.19, $\eta^2 p = 0.75$ and $F(1, 29) = 99.51$, $p < .0001$, MSE = 989.19, $\eta^2 p = 0.77$, respectively. However, the global precedence effect was decreased in the bilingually compared to the monolingually educated group (40 vs. 57 ms) as indication that the bilinguals were associated with a bias towards a more focused "scope" of attention. Higher order interactions were not significant.

Overall, participants made errors on 6.2 % (SD = 0.5) of the trials. Analyzing the error rates revealed two main effects. First, the effect of Congruency, $F(1, 58) = 99.41$, $p < .0001$, MSE = 81.48, $\eta^2 p = 0.64$, reflects the interference of the irrelevant target level, with a smaller proportion of errors on congruent as compared to incongruent trials (2.1 vs. 10.3 %). Second, the effect of Target level, $F(1,58) = 6.41$, $p < .05$, MSE = 51.33, $\eta^2 p = 0.10$, suggested fewer errors to globally than locally defined targets (5.4 vs. 7.0 %). There were no significant group differences in error rates (see also Table 2). Therefore, it is unlikely that the found reaction time effects were due to speed–accuracy trade-offs.

Although group differences on digit span were not significant, there was a numerical difference between groups. To assess the role of group differences in memory, we reanalyzed the data using digit span as covariate. There was no change to the pattern of results [i.e., smaller switch cost for the bilingually educated group ($F(1, 56) = 6.97$, $p < .05$, MSE = 3,486.66, $\eta^2 p = 0.09$) and a smaller global precedence effect ($F(1, 56) = 5.36$, $p < .05$, MSE = 1,481.57, $\eta^2 p = 0.11$)].

Discussion

The present study indicates that an intensive bilingual language context is associated with a flexible mind and a relative focused 'scope' of attention. We compared two groups of late bilingual Dutch high-school students from the same school. The main difference between the groups was that one group followed a bilingual education track (where at least 50 % of the classes are taught in L2), whereas the other group attended the regular monolingual track.

Bilingually educated participants showed smaller switching costs and reduced global precedence effects than participants who followed regular education. This suggests that bilingual education is associated with better cognitive control skills and a bias toward a more focused 'spotlight of attention'. There were no significant group differences found for average reaction time on the task, gender, working memory, age of acquisition of L2, which makes an account of our results in terms of pre-existing group differences unlikely.

First, we observed that bilingual education is associated with smaller switch costs, a relatively well-established index of cognitive flexibility (Miyake et al., 2000; Monsell, 2003). There is a growing controversy in the literature on whether or not bilingualism may induce general cognitive advances (e.g., Paap & Greenberg, 2013). The current results may offer some support for the idea that bilingualism promotes cognitive flexibility in general.

Switching costs in tasks as used in the present study are thought to consist of two major components: the preparatory component and the residual component (e.g., Meiran, Chorev, & Sapir, 2000). Because participants know to what information they should attend in the upcoming trial (global vs. local) as trial sequences were predictable and the inter-trial and the cue–target interval were quite long (on average 1,000 and 500 ms, respectively), the preparatory component is nearly eliminated (Meiran, 1996). What remains is the residual component, as this component is resistant to preparation. The residual component reflects mental processes that must occur after target onset on switch trials, regardless of the amount of preparation time (e.g., Monsell, 2003). Residual costs result from the involuntary, presumably stimulus-triggered activation of the previous task set. As we mainly measured the residual switch costs in the present study, we infer that bilingual education affects, or is associated with, reduction of these type of costs.

Second, the bilingually educated group showed a smaller global precedence effect than the control group. Given that global precedence is taken to reflect a bias towards a large "scope" of attention, a small global precedence effect would imply a more analytical/focused attentional scope. We speculate that bilingual education may induce particular cognitive control strategies that generalize to situations that have no bearing on bilingual skills. For instance, learning to keep two or more languages separate and manage them in a mixed language context might induce a chronic attentional-control bias towards local, and away from global features of people's behavior, events, and objects.

Given that both mental flexibility and the focus of attention are modulated by bilingual education, one might pose the question if the two are related. One could argue that a more focused attention would make it harder to shift between tasks. Instead, we found that bilingual education was not only related to a more focused attentional scope but also to reduced switching costs. In terms of processing, one might not expect that mental flexibility has much in common with the 'spotlight of attention'. Indeed, there was no correlation between switching costs and global precedence effect ($r = -.09$, $p = .50$). This suggests that—although both may be modulated by regularly switching languages—one does not influence the other. Further evidence that these effects may be dissociated is provided by a recent study in which people who frequently play video games showed decreased switch costs, but no difference in global precedence between frequent and infrequent gamers (Colzato et al., 2010).

Future studies need to investigate how long-lasting the effect of bilingual education is on the visual processing of global and local features, by comparing bilingually educated people who are still immersed in a bilingual context to those who are not. If bilingual education would really induce a chronic attentional bias, one would expect at least some after-effect of such practice in people who do not live in a bilingual environment anymore. Furthermore, it would be interesting to investigate whether other aspects of cognitive control, such as conflict resolution, are also influenced by bilingual education. Finally, as our results are based upon a group comparison, it is important to confirm our findings in the form of a longitudinal study in which students are measured before and after following bilingual education.

Our results are consistent with the idea that attending school in a context that taxes language management demands leads to a general improvement in selecting goal-relevant information from competing, goal-irrelevant information. Indeed, Colzato et al., (2008) found that bilinguals are not more efficient in inhibiting unwanted motor responses than monolinguals, but are less efficient than monolinguals in distributing attentional resources over multiple visual target events. This suggests that using multiple languages leads to a stronger, more selective focusing of cognitive control (Colzato et al., 2008). It should be noted that language immergence programs may not have the same results, as they do not require the students to frequently switch between languages.

In sum, we found smaller switching costs and a smaller global precedence effect for high-school students who attended a bilingual track compared to students who attended the monolingual track. Clearly, life-long bilingualism is not a prerequisite, also late bilingualism may benefit mental flexibility, and daily mixed language use may impact on general cognitive processing. To conclude, our results indicate that bilingual education may promote cognitive flexibility and a bias towards a more focused "scope" of attention.

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