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Language switching and domain-general control in interpreters

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The purpose of this paper is to examine whether and how training and professional experience in interpreting affect task switching in this bilingual population. In the first experiment, we compared a group of interpreting students to a group of translation students using the bilingual categorization task to assess their domain-specific language switching before and after training. In the second experiment, we added a group of professional interpreters to the participants in experiment 1 to test prepotent response inhibition using the Simon task (domain-general). First, the results showed training-related improvement in the bilingual categorization task in both student groups, indicating a similar effect for translation and interpreting training. Second, both student groups showed better performance on the Simon task compared to professional interpreters, but only on response times and not on accuracy. The correlation analyses of the two tasks in student groups only showed significant correlations between the global RTs and supported the hypothesis that proactive language control may depend more on inhibition than on the switching-specific factor. Considering language background, the lower onset age of L2 acquisition (AOA2) in the interpreting students (compared to the translation students) was significantly correlated with the congruency effect in the Simon task, indicating an impact of language background on domain-general control. Results were discussed in light of the different engaging elements, including task specificity, training length, research method, and participants' linguistic profile.

KEYWORDS

language switching, Simon task, interpreting, bilingualism, cognitive control, bilingual advantage, executive functions, translation

1. Introduction

Executive functions (EFs) as mechanisms for controlling our thoughts and behaviors play an important role in our daily lives. They regulate switching between different tasks, inhibiting irrelevant information, focusing our attention on the task in hand, and to perform and finish our daily activities (Miyake et al., 2000). But which factors affect these mechanisms? Research shows that they are influenced by both genetic factors and environmental factors (Miyake and Friedman, 2012; Gustavson et al., 2018), which means both of them are important on the way they influence the productivity of our Executive Functions. Genetic factors have contributed to a better understanding of individual differences, and environmental factors have led us to a better understanding of how the lifestyle and different kinds of training may affect EFs in different populations (Gustavson et al., 2018). Bilinguals have been widely investigated so far (Grundy, 2020); the main idea is that bilinguals in addition to their daily activities should also use the EFs to control and manage their different languages (Bialystok, 2017). They should inhibit one of the languages when speaking (Misra et al., 2012), switch to another language when necessary (Prior and Gollan, 2011), and constantly monitor and control the language output to produce an acceptable content (Abutalebi et al., 2012). The question in bilingualism studies was if these additional language control task may affect (train) their EFs in general (Guo et al., 2011; Bialystok et al., 2012).

Two of the important general-purpose EF mechanisms which are tested widely in the bilinguals are task-switching and inhibition (e.g., Bialystok et al., 2008; Prior and Gollan, 2011; Green and Abutalebi, 2013). Task-switching or shifting is referred to as the ability of switching back and forth between mental sets or tasks at hand. The switch cost is measured by the calculation of the difference between response times on switch and repeat trials using different tasks such as the number-letter or the local-global task (Vandierendonck et al., 2010). Inhibition on the other hand, is the ability to inhibit the dominant, automatic, or prepotent responses and is measured by tasks such as STROOP and Stop-signal task (for review, see Miyake et al., 2000). These two EF mechanisms of Switching and Inhibition have shown different patterns in bilingualism research. Some research indicates a positive impact of bilingualism on these two EF mechanisms (Bialystok et al., 2004; Prior and Gollan, 2011; Stasenko et al., 2017) while others report no conclusive difference between bilinguals and monolinguals (Donnelly et al., 2015; Paap et al., 2019). It is suggested that the main reason for these kind of inconsistencies lies in the different characteristics which are involved in the research designs; including but not limited to the participants' sociolinguistics backgrounds, age, daily switching pattern, and the cognitive tasks which are used in different studies (Green and Abutalebi, 2013; Yang et al., 2016). Both task-switching and inhibition seem to play an important role in Bilingual Language Control (BLC), the ability which ensures proper production of a target language in bilinguals (Declerck et al., 2017).

Bilingualism is known to be a continuum which includes different populations with distinct language behaviors (Luk and Bialystok, 2013). The term covers both passive and active bilinguals with different onset ages of second language acquisition (AoA L2) namely the simultaneous or late bilinguals (for review, see Bonfieni, 2018). Each group of bilinguals has their own switching behavior and lives in different sociolinguistic contexts. Controlling for the background conditions of the participants can have a direct impact on the results of the research, the use of a homogeneous bilingual participants can help us to better understand the impact of bilingualism on Switching and Inhibition behaviors in bilinguals. Additionally, this will help us to know if the differences, if any, are due to individual factors (e.g., AoA L2), environmental factors, such as daily language switching patterns and the manner of language acquisition [e.g., implicit or explicit (classroom-based)].

One of the important groups within the bilingual populations which has always been in the center of the EFs research is interpreters (Liu et al., 2004; Chmiel, 2010). Research on the EF processes in the interpreters is important in several ways. Taking bilingualism as a continuum, interpreters are situated at the extreme end of this spectrum. They do not only master several languages, but also the way they use these languages almost simultaneously provides an ideal condition to better understand the impact of bilingualism on the EFs and BLC mechanisms. First, simultaneous interpreters listen to a source language and render the message into a target language, meaning that language comprehension and language production occurs approximately at the same time with little or no chance for correcting errors (Liu et al., 2004). This interpreting task needs a high amount of EF control while keeping two languages separated and monitoring to avoid possible mistakes and constantly changing the mental sets form one language into another one (Babcock and Vallesi, 2017). Second, if we consider bilingualism as a continuum, then interpreting group as a specific form of bilinguals could be better matched for their background factors in sense of the language-proficiency level, the language-switching patterns, and the level of language training or work experience (Tzou et al., 2012; Henrard and Van Daele, 2017).

1.1. Task-switching in interpreters

Task-switching as a core characteristic of interpreting activity has been the focus of many studies (Becker et al., 2016; Dong and Liu, 2016; Babcock and Vallesi, 2017). A successful interpreting performance depends on how well they switch between their source language (comprehension) and target language (production). Research on task-switching in this group is focused on two important questions; (a) how could interpreting training affect switching behavior in interpreters? and (b) do interpreters perform better in switching tasks compare to control groups? To answer these questions, an analysis of longitudinal studies on this interpreter training effect have shown an almost consistent pattern and has indicated a positive effect of interpreting training on switching ability in trainees (Macnamara and Conway, 2014, 2016; Dong and Liu, 2016). Two studies by Macnamara and Conway (2014, 2016) tested same interpreting students at different points of time during their interpreting studies to look at the training effect on switching, and the results showed faster switching costs for the students with the advance of their interpreting studies (e.g., first semester compared to the fourth semester). However, these studies lack the matched control groups and left the question unanswered whether this improvement is due to interpreting training or the test-retest effect (Macnamara and Conway, 2014, 2016). Later studies tackled this question by including two control groups: Dong and Liu (2016) and Babcock and Vallesi (2017) compared interpreting students to translation students and one additional control group at the beginning and the end of their studies. Both studies revealed a decrease in switch costs after training, however they found no significant group differences in the switch costs. The results proposed that these reductions in switch costs are due to the possible test-retest effect in longitudinal studies. However, Dong and Liu (2016) showed that even if there was no group difference between the three student groups in the color-shape task, only interpreting students faced significant progress in their switch costs from the pre-training to post-training session. In contrast to these two longitudinal studies, a new longitudinal study by Van de Putte et al. (2018) reported no decrease in switch costs for both interpreting and translation students after training using the same color-shape task. Considering that all three longitudinal studies used almost the same switching task to test the interpreting groups and reported different results, the authors suggested that the use of other EF tasks that tap into different types of control processes in interpreters may be beneficial (Van de Putte et al., 2018). Furthermore, it is clear that the current literature has mostly focused on the general switching ability in interpreters but not specific language switching mechanisms by using standard language switching tests to answer more precise questions, e.g., how could switching to L1 or L2 be affected by interpreting training compared to control groups? Or does the language switch mechanism in interpreters follow the same pattern as general switching ability as previously reported in longitudinal studies on task-switching?

1.2. Inhibition in interpreters

To address the inconsistency in the studies on the bilingual switching advantage in general, Friedman (2016) proposed that because the EF mechanisms are correlated to each other the reported advantage in some task-switching in bilinguals may not mean the key benefit is in switching ability but in a more general control mechanism which is shared across tasks. Taking this idea to the domain of interpreting, one may propose that the switching improvement reported in some interpreting studies but not others may not always be due to the switching specific control but rather to the common EF factor, namely response inhibition ability. Inhibition is considered as a general control process that is shared across other EF processes such as switching-specific and updating-specific control (Miyake et al., 2000; Friedman, 2016). Previous studies on Inhibition in interpreters showed mixed results which could be due to the differences in study designs, task specificity or linguistic backgrounds of the participants (Yudes et al., 2011; Timarová et al., 2014) (for review see Nour et al., 2020). The overall results showed no advantage when comparing interpreters to other bilingual groups (Dong and Xie, 2014; Babcock and Vallesi, 2017; Van de Putte et al., 2018). However, mixed results were reported when comparing interpreters to monolinguals (Woumans et al., 2015; Henrard and Van Daele, 2017; Van der Linden et al., 2018). Two studies by Woumans et al. (2015) and Henrard and Van Daele (2017) report better performance in the Simon task and the antisaccade task (tapping into the process of inhibition of a prepotent response) for professional interpreters and interpreting students compared to monolinguals but not to the bilingual control groups. In contrast, Van der Linden et al. (2018) reported no difference between interpreters and a monolingual control group on flanker and Simon tasks. The author discussed that the potential reason for this inconsistency may be due to the included participants; Woumans et al. (2015) tested students during their studies when they were still gaining L2 proficiency but Van der Linden et al. (2018) tested professional interpreters with at least 4 years of interpreting experience. However, the study by Henrard and Van Daele (2017) rejected this motive and reported a constant professional interpreters' advantage in inhibition across a broad range of age groups when comparing them to the monolingual matched controls. To better understand how training and experience may affect Inhibition in interpreters, if any, it would be advantageous to include both interpreting students and professional interpreters.

2. The present study

In this study, we aimed to investigate task switching ability in interpreters by including both a language switching task and a domain-general cognitive task. The main purpose of the present study was to understand to what extent the task switching ability in interpreters is language specific, and how much this could be affected by interpreting training. Additionally, by including a domain-general cognitive task, we aimed to investigate if the shared EF component of response inhibition is the main reason of improvement in task switching (Friedman, 2016) or if the improvement is switching-specific. We would like to further investigate the relationship between the different measures of language switching and domain-general control in interpreting and translation students. Both the bilingual categorization task and the Simon task contain unpredictable switches that required proactive control throughout the whole task (for a discussion about proactive control, see Declerck, 2019). Declerck (2019) explains that when the non-target language interrupts the choice of words in the target language, reactive language control is the process that is launched; however, proactive language control is the process that is used in advance of any non-target language interference that might interrupt the choice of words in the target language. Comparing different measures of both tasks will help us to better understand the role of proactive control in the comprehension task, such as the bilingual categorization task, as well as if the proactive language control is related to inhibition or not, using the Simon task (Declerck, 2019). In the first experiment, We put great effort into following the same study design as in previous longitudinal studies (Babcock and Vallesi, 2017; Dong, 2018; Van de Putte et al., 2018) comparing interpreting students with translation students before and after training during their academic Master's. All three studies used variants of the same color-shape switching task to test their participants, and the results showed inconsistency regarding the training-related improvement in switching (Dong and Liu, 2016; Babcock and Vallesi, 2017; Van de Putte et al., 2018). The training length (only one semester) in Dong and Liu (2016) which showed a significant training effect on switching, is shorter than the length of training in the two other studies. Additionally, they all used the same switching task, so task specificity could not be the main reason either.

In the present study we tried to follow the same study design but using a different switching task, a bilingual categorization task, to test language switching behavior (L1 and L2) in two groups of interpreting students and translation students. We propose that if general color-shape switching task showed different patterns in the above-mentioned studies, this inconsistency may be either due to other EF or to non-EF processes which might play a role in the color-shape task. The color-shape task needs both response inhibition and switching specific factors, but it also involves non-EF factors such as color vision and overall processing speed. So different scores may not only reflect different EF but also may reflect individual differences in non-EF processes. In the present study, we use a standard language switching task, for the first time so that we could investigate how interpreting training vs. translation training may affect language switching behavior specifically, both in their L1 and L2, in the two matched groups. We predict that interpreting training may have a specific effect on language switching ability and show better performance because during their studies the interpreting students focus on both speed and accuracy at the same time while translation training focuses more on the accuracy of the output without this time constraint. While previous studies found no group difference in the general switching ability between the two groups, we would like to find out if any group difference would appear at the linguistic level rather than in general switching. To answer these questions, we compared both groups in their general switching scores and switching directionality in either backward (from L2 to L1) and forward (from L1 to L2) switch before and after training.

In the second experiment, we added a third group of professional interpreters with more than 20 years of active interpreting experience and compared them with the two student groups after their training, using the Simon task. Two previous studies, which used the Simon task, found no behavioral differences comparing both interpreting students with a control group (Van de Putte et al., 2018) and professional interpreters with control groups (Van der Linden et al., 2018). However, the study, which used an antisaccade task (Henrard and Van Daele, 2017), showed group differences between professional interpreters and control groups. In the present study, we would like to include both student and professional interpreters with more than 20 years of experience using the Simon task to better understand if the inconsistencies are due to the task specificity (Simon vs. antisaccade) or to the amount of professional interpreting experience in Van der Leinden (at least 4 years) and Henrard (mean work experience $M =$ 17.78 years).

The Simon task is used in the current study design to examine general response inhibition in the student groups compared to the professional interpreters and to replicate the Van de Putte et al. (2018) study. In recent studies on different EF mechanisms, professional interpreters performed better than younger non-interpreting students both in working memory (Nour et al., 2020) and better than both interpreting and non-interpreting students on incongruent trials in the Attention Networks Task (Nour et al., 2019). These better performances of professionals showed themselves most pronounced in the accuracy scores; suggesting that while younger participants may rely more on speed, older adults might focus more on accuracy (Forstmann et al., 2011). We want to investigate if this response strategy for output accuracy in professional interpreters is present in the response inhibition task as well. Additionally, we look at the possible correlation between the general non-linguistic switch-directionality in the Simon task and the linguistic switch-directionality in the Bilingual categorization task in the student groups to find out how different scores of these two tasks were correlated. Furthermore, we intend to examine a possible interaction between the language background characteristics of the student groups, such as the age of L1 and L2 acquisition, recent exposure to L1 and L2 and initial translation or interpreting experience, and their language switching scores.

2.1. Material and methods

2.1.1. Tasks

2.1.1.1. Bilingual categorization task

The bilingual categorization task is used to test language switching behavior (L1 and L2). The task consisted of a total of 156 trials equally divided over two factors: animacy (animate/inanimate) and language (Dutch/ French). Each group of trials consisted thus of 39 nouns including: Dutch-animate, Dutch-inanimate, French-animate, and French-inanimate nouns. The nouns were selected from the CELEX data base (Baayen et al., 1995) and they were controlled for length and frequency in both languages. Furthermore, the stimuli contained no translation equivalents and cognates. The nouns were either in Dutch or French while the language switches were unpredictable and contained equal stimuli for language repeat and language switch trials throughout the task. The stimuli were presented in the center of the screen and participants were instructed to respond as accurately and quickly as possible by pressing either the right or left bottom of the keyboard where they detected an animate noun. Each trial started with a fixation cross which remained for 500 ms in the center of the screen and preceded the noun stimulus. Each noun stimulus was presented for up to 2,000 ms or until the participant responded.

2.1.1.2. Simon task

The Simon task (Simon and Rudell, 1967) is used to examine general response inhibition. The task consisted of a total of 156 trials. The trials consisted of a red or a green square presented either at the left or the right side of the screen which were equally divided over two factors: the color (red/green) and the location (left/right). Each group consisted of 39 trials including: red square-left, red square-right, green square-left, and green square-right. The color switches were unpredictable and contained equal number of red and green stimuli throughout the task; additionally, the same trial type did not occur more than three times in a row. The task contained an equal portion of congruent trials (overlap color-location) and incongruent trials (no overlap color-location). Participants were instructed to respond as accurately and quickly as possible to the color of the stimulus (green or red), ignoring its location. A red and a green bottom were marked with a colored sticker on an ordinary keyboard. Each trial started with a fixation cross that remained for 500 ms in the center of the screen before the stimuli appeared. Each stimulus was presented for up to 2,000 ms or until the participant responded.

2.1.1.3. Language background LEAP-Q

The linguistic backgrounds of the participants were collected using an adapted version of the Language Experience and Proficiency Questionnaire (LEAP-Q) (Kaushanskaya et al., 2011). The two student groups completed the Dutch version of the questionnaire, and the professional interpreters completed a shortened version of the test in English (Kaushanskaya et al., 2011: only the first 9 questions were included). The questions were about both the general linguistic background and the interpreting/translation background information, including the onset ages of language acquisition for L1 and L2, recent exposure to L1 and L2 in the last 12 months preceding the test in percentage, self-rated interpreting and translation proficiency on a 10-point scale, and the years of professional experience. The LEAP-Q information of the participants is presented in Table 1.

2.1.2. Participants

2.1.2.1. Longitudinal experiment

Thirty-eight Master students from the Dutch-medium Vrije Universiteit Brussel participated in the first experiment (29 females) and were tested longitudinally at the start and at the end of their one-year Master's program using a Bilingual Categorization Task. At pre-training, the student group was further divided in two sub-groups based on their Master's program. The first group included seventeen interpreting students (15 females) with a mean age of 22.2 years (SD = 1.8). The second group included twenty-one translation students (14 females) with a mean age of 23.1 years ($SD = 2.9$). Students in the master's program of interpreting received both theoretical and practical courses such as memory exercises and different interpreting models from and into Dutch and their chosen language (English, French, German, or Spanish). In the second semester, students completed an intensive 30-h internship in a multilingual company where they could immerse themselves in a real-life interpreting context. Students in the master's program of translation similar to

TABLE 1 Language background characteristics of participants.

	Translation student Means (SD)	Interpreting student Means (SD)	Professional interpreter Means (SD)
Age	23.11 (2.95)	22.28 (1.8)	52.73 (6.85)
AoA L2	6.78 (4.45)	5.44 (4.21)	8.03 (4.10)
Recent exposure L1	50.26 (18.83)	47.12 (14.51)	43.85 (17.36)
Recent exposure L2	22.53 (12.73)	16.71 (10.33)	19.21 (17.19)
TRA/INT into L1 (self-rated proficiency)	7.67 (0.71)	6.41 (1.41)	9.07 (0.45)
TRA/INT experience (pre-test)	n/a	n/a	24.60 (12.15)

L1, first language; L2, second language; AoA, age of acquisition expressed in years, recent exposure in L1 and L2 in the 12 months preceding the time of investigation expressed in percentages; TRA, translation; INT, interpreting, self-rated proficiency expressed on a 10-point scale; TRA/INT experience (pre-test), translation or interpreting experience before first test session expressed in years; n/a, not applicable.

interpreting master's program received a mixture of theoretical and practical courses. The internship of the second group focused on translation assignments for private or public companies. Both student groups had to choose at least two languages during their MA studies (one B-language). All participants had Dutch as their dominant (A) language. For both student groups the theoretical and practical parts are equally divided (each 30 ECTS of the 60 ECTS curriculum). At the post-training session, fourteen interpreting students (12 females) with a mean age of 22.00 years ($SD = 0.45$) and thirteen translation students (12 females) with a mean age of 24.10 years ($SD = 1.28$) from the pre-training session took part in the experiment.

2.1.2.2. Cross-sectional experiment

In the second experiment, three groups of translation students, interpreting students and professional interpreters were tested using the Simon task. The two student groups consisted of the same participants who took part in the first experiment at their post-training session which means after having finished their Master's programs. The interpreting student group included fourteen students (12 females) with a mean age of 22 years ($SD = 0.45$) and translation students included thirteen students (12 females) with a mean age of 24.10 years ($SD = 1.28$). The third group consisted of nineteen professional conference interpreters (10 females) with a mean age of 50.8 years ($SD = 4.8$), working for the European Commission in Brussels on a permanent basis with 24.60 years (SD = 12.15) of interpreting experience (see Table 1). The first language of the professional interpreters included eight different languages (one Bulgarian, two Danish, three Dutch, six English, two French, two German, one Romanian, two Spanish).

2.2. Procedure

Both the Bilingual categorization task and the Simon task were programmed and performed in E-Prime 2 software (Schneider et al., 2012). The participants were tested individually in well-equipped and sound-proof cabins of the behavioral lab at the Department of Psychology and Educational Sciences of the Vrije Universiteit Brussel. The instruction was given to each participant individually, first, orally before starting the tasks by the instructor, and second, in a written form which appeared on the monitor at the beginning of the tasks. The instructions were followed by practice trials for each task. All participants signed an informed consent form according to the university's ethical research guidelines before starting the experiment. For the Bilingual categorization task, the two student groups were tested at pre-training and post-training during their Master's programs and the interval between the two test sessions was 9 months. For the Simon task, the two student groups of interpreting students and translation students (at post-training) were compared to a group of professional interpreters. The students received either course credit (interpreting students) or reimbursement (translation students) for their participation. The professional interpreters were recruited through an open call on a voluntary basis.

3. Results

3.1. LEAP-Q

Inferential statistics of the LEAP-Q background information for three groups showed significant between-group differences on age, $F_{(2,55)} = 252.16$, $p < 0.000$, on interpreting and translation experience, $F_{(2,55)} = 217.96$, $p < 0.000$, and for self-rated interpreting and translation proficiency, $F_{(2,55)} = 21.36$, $p < 0.000$. In all cases *post-hoc* Bonferroni-corrected tests showed significant difference between professional interpreters and two student groups ($p < 0.001$), while both student groups did not differ from each other. Professional interpreters scored higher in self-rated interpreting proficiency, with higher age and higher experience compared to the students (for descriptive statistics, see Table 1). All other LEAP-Q measures did not reach statistical significance, all $p > 0.05$.

3.2. Bilingual categorization task

Firstly, mean accuracy scores and mean response times (RT) were calculated for each subject separately for all 156 trials of the task. For response time analysis the incorrect responses were excluded from further analysis. A three-way analysis of variance was conducted on mean response times and mean accuracy scores with language of current trial and language of previous trial, each with two levels (Dutch and French for language of current trial; repeat and switch for language of previous trial) and time (pre- and post-training) as within-subject variables, and group (interpreting students and translation students) as a between-subject variable.

The mean accuracy scores and mean response times (RT) were calculated for each subject separately. For the RT scores, the incorrect responses were excluded from further analysis, and the responses that

TABLE 2 Mean backward and forward switch costs on the categorization and Simon task in ms with standard deviations between brackets for the two student groups (TR, translation students; INT, interpreting students).

		TR		INT	
		*T1	T2	T1	T2
Bilingual categorization task	Backward switch cost	20.87 (27.16)	11.02 (26.08)	22.90 (48.10)	22.09 (32.11)
	Forward switch cost	0.30 (59.66)	−5.86 (59.76)	15.71 (52.02)	16.48 (52.63)
Simon task	Backward switch cost		12.00 (36.47)		32.66 (43.90)
	Forward switch cost		13.36 (28.91)		33.68 (30.38)

*T1: pre-training, T2: post-training.

were shorter than 240 ms and longer than 1,200 ms were removed to avoid outlier effects. With respect to the response times, the results showed a highly significant main effect of language of current trial, $F_{(1,24)} = 44.92$, $p < 0.001$, $\eta p2 = 0.652$, with faster response times on Dutch trials ($M = 717.60$; $SD = 18.48$) than on French trials ($M = 798.73$; $SD = 17.64$); and a significant main effect of time, $F_{(1,24)} = 26.93$, $p < 0.001$, $\eta p2 = 0.529$, with faster response time for post-training ($M = 734.90$; $SD = 17.29$) compared to pre- training ($M = 781.43$; $SD = 17.91$). We also found a nearly significant main effect of language of previous trial, $F_{(1,24)} = 3.96$, $p = 0.06$, $\eta p2 = 0.142$, with faster response times on repeat trials ($M = 752.63$; $SD = 16.67$) than on switch trials ($M = 763.70$; $SD = 17.81$). No significant main effect of group was found between interpreting and translation students; $F_{(1,24)} = 2.14$, $p > 0.05$, $\eta p2 = 0.082$. No interaction effects were detected, all $p > 0.05$.

With respect to the accuracy scores, the results showed a highly significant effect of language of current trial, $F_{(1,24)} = 29.86$, $p < 0.001$, $\eta p2 = 0.544$, with lower accuracy scores on French trials ($M = 61.56$; $SD = 2.01$) than on Dutch trials ($M = 73.16$; $SD = 1.53$); but we found no main effect of language of previous trial, $F_{(1,24)} = 0.21$, $p > 0.05$, $\eta p2 = 0.009$, and no main effect of time $F_{(1,24)} = 1.16$, $p > 0.05$, $\eta p2 = 0.045$. No significant main effect of group was found between interpreting and translation students, $F_{(1,24)} = 0.06$, $p > 0.05$, $\eta p2 = 0.00$. Additionally, we found a significant interaction effect between the variables of language of current trial and group, $F_{(1,24)} = 4.84$, $p = 0.03$, $\eta p2 = 0.162$. with a higher mean difference between French and Dutch trials for translation students ($M = 16.27$) than for interpreting students ($M = 6.93$). No other interaction effects were detected, all $p > 0.05$.

Additionally, to see the effect of switch directionality we calculated forward and backward switch costs both for accuracy scores and response times. The backward switch cost was calculated by subtracting mean response times or error rates on L1-repeat from the same measures on L1-switch for each participant. The forward switch cost was calculated by subtracting mean response times or error rates on L2-repeat trails from the same measures on L2-switch trails. A paired sample T-test on forward and backward switch costs showed no significant difference due to training for response times and accuracy scores for both student groups; all p ns. The descriptive statistics of the forward and backward switch costs are given in Table 2.

3.3. Simon task

Firstly, mean error percentages and mean response times (RT) were calculated for each subject separately for all 156 trials of the task. A two-way analysis of variance was conducted on mean response times and mean error percentages with congruency with two levels (congruent and incongruent) as within-subject variable, and group (interpreting students and translation students and professional interpreters) as a between-subject variable.

The mean accuracy scores and mean response times (RT) were calculated for each subject separately. For the RT scores, the incorrect responses were excluded from further analysis, and the responses that were shorter than 240 ms and longer than 1,200 ms were removed to avoid outlier effects. With respect to the response times, we found a highly significant main effect of congruency, $F_{(1,43)} = 61.84$, $p < 0.001$, $\eta p2 = 0.590$, with faster response times on congruent trials ($M = 455.21$; $SD = 8.06$) than on incongruent trials ($M = 484.07$; $SD = 9.36$); and a significant main effect of group; $F_{(2,43)} = 14.36$, $p < 0.001$, $\eta p2 = 0.401$. A *post-hoc* Tukey test showed slower response time for professional interpreters compared to both interpreting students ($p < 0.001$) and translation students ($p < 0.001$). There was no group difference between translation and interpreting students, p ns. Additionally, the results showed no significant interaction effect between congruency and group, p ns. With respect to error analysis, we found a significant main effect of congruency, $F_{(1,43)} = 4.19$, $p < 0.05$, $\eta p2 = 0.089$, with more errors on incongruent trials ($M = 1.49$; $SD = 0.26$) than on congruent trials ($M = 0.93$; $SD = 0.16$). However, unlike the response time, no main effect of group $F_{(2,43)} = 0.16$, $p > 0.05$, $\eta p2 = 0.007$ was found, indicating same performance in three groups for accuracy (Table 3).

Analogous to the analyses of the bilingual categorization task, forward and backward Simon switch costs were conducted for response times and accuracy scores for each participant. For the response times, the forward switch cost was calculated by subtracting mean response times on incongruent-repeat trials from incongruent-switch trails. The backward switch cost was calculated by subtracting mean response times on congruent-repeat trails from congruent-switch trails. For accuracy scores, the forward switch cost was calculated by subtracting mean accuracy scores on incongruent-switch from incongruent-repeat trails. The backward switch cost was calculated by subtracting mean accuracy scores on congruent-switch from congruent-repeat. An independent sample T-test on forward and backward switch costs showed no significant group difference both for response times and accuracy scores in the student groups, all p ns. The descriptive statistics of the forward and backward switch costs are presented in Table 2.

3.4. Bilingual categorization task and Simon (for student groups)

We have conducted further analyses between measures of language switch control (Bilingual categorization task) and cognitive

TABLE 3 Mean error rates and mean response times (RT) in Simon task, in ms with standard deviations between brackets for all the three groups.

	TRA		INT		PRO	
	M	SD	M	SD	M	SD
RT						
Congruent	426	(54)	427	(53)	513	(53)
Incongruent	453	(60)	450	(63)	548	(63)
Simon effect	27	(26)	23	(20)	35	(26)
Error rates						
Congruent	1.0	(1.1)	0.8	(0.7)	0.9	(1.3)
Incongruent	1.6	(2.4)	1.6	(1.6)	1.2	(1.4)
Simon effect	0.6	(2.5)	0.8	(1.6)	0.3	(1.3)

control (Simon task) to test the assumptions of domain-specificity or domain-generality for student groups. We conducted Pearson's correlational analyses between the measures of language control (Bilingual categorization task) including the global measures, L1/L2, and the switch costs, and for cognitive control (Simon task) including the global measures, congruency, and switch costs to test the possible dependency between the two tests. The results were shown in Table 4. Further analysis on the correlation between the language background data such as the age of L1 and L2 acquisition, recent exposure to L1 and L2 and initial translation or interpreting experience with both language control and cognitive control in student groups showed that only age of L2 acquisition (AOA2) in interpreting students ($M =$ 5.44 years, $SD = 4.21$) positively correlated with the L2-effect RTs in the Bilingual Categorization task ($r = 0.585$, $p < 0.05$), and the congruency-effect RTs in the Simon task ($r = 0.603$, $p < 0.05$) but not the AOA2 in the translation students ($M = 6.78$ years, $SD = 4.45$) (see Figures 1, 2).

4. Discussion

The present longitudinal study investigated language-specific and domain-general control in interpreters using a linguistic control task: the Bilingual Categorization Task, and a non-linguistic task: the Simon task. The results of the longitudinal study on language-switching behavior in translation and interpreting students showed improvement in response times (RTs) but not in accuracy after training; with no specific advantage in the interpreting students compared to translation students. The results of domain-general control, using the Simon task, by comparing the two student groups and the professional interpreters indicated faster RTs for the translation and interpreting students than for the professional interpreters. The accuracy scores in the three groups were at the same level. The correlation between the language switching scores and the domain-general scores in the student groups only showed significant correlations between the Global RTs in both tasks for two student groups, and between the forward-switch costs in both tasks, specifically for the translation students. Additionally, we found that the onset age of L2 acquisition (AOA2) in the interpreting students was significantly correlated with the language-effect in the Bilingual categorization task and with the congruency-effect in the Simon task.

4.1. Task-switching in interpreters

The present study for the first time used a bilingual categorization task to assess the language switching mechanism longitudinally in interpreting and translation students. The result was in line the with a previous longitudinal study by Babcock and Vallesi (2017) which showed that both students groups had faster switch costs post-training compared to pre-training but with no group differences between the two student groups. While the study by Babcock and Vallesi (2017) used a non-linguistic switching task (color-shape), our study was different because it used a language switching task and showed similar training effects as in domain-general control. Our results are not in line with Dong and Liu (2016), where both the translation and interpreting students improved in their switch costs after training but with a more pronounced improvement for the interpreting than for the translation student. Our results are also different from another longitudinal study that reported no effect of time in color-shape switch task for both the translation and interpreting students (Van de Putte et al., 2018). Given the correlation that we found between individual language background factors such as the onset age of language acquisition and performance on language control, we suggest that these inconsistencies in previous longitudinal studies using the Color-shape switching task may be due to other factors than the task itself, such as the linguistic profiles of the participants.

We want to highlight a few differences between the design of our study and those of previous related studies that might have driven the seemingly inconsistent results that came out of these studies. First, the participants in Dong and Liu (2016) were younger ($M =$ 19.69) unbalanced bilinguals and were tested in their BA studies before and after their first semester, while other longitudinal studies, including our study, tested MA students with a mean age between 22 and 24 years old and found no difference between translation and interpreting students. Master students usually receive their three-year BA training in a language major prior to the start of their MA in interpreting or translation. One possible explanation for more improvement in task switching of the interpreting students compared to the translation students in Dong and Liu (2016) is that they were at the start of their L2 training and their level of language proficiency along with the beginning the interpreting exercises may be more cognitively demanding than translation exercises and, as a result, the training effect on task switching, after only one semester, may

TABLE 4 Correlation coefficients among measures of domain-specific (language) control and domain-general (cognitive) control in terms of speed of processing (post-training).

Measure of language control	Measure of cognitive control	Correlation coefficient (TR)	Correlation coefficient (INT)
Global RT	Global RT	0.68**	0.72**
	Congruency difference	0.06	0.24
	Switch-cost difference	0.29	0.28
	Backward switch cost	0.01	0.42
	Forward switch cost	−0.45	0.12
Language difference	Global RT	−0.48	−0.48
	Congruency difference	0.05	0.1
	Switch-cost difference	−0.24	−0.26
	Backward switch cost	−0.21	−0.21
	Forward switch cost	0.12	0.15
Switch-cost difference	Global RT	−0.30	−0.12
	Congruency difference	0.16	−0.09
	Switch-cost difference	0.17	0.25
	Backward switch cost	−0.15	0.28
	Forward switch cost	−0.05	−0.05
Backward switch cost	Global RT	−0.42	−0.09
	Congruency difference	0.45	0.23
	Switch-cost difference	0.02	0.01
	Backward switch cost	0.05	0.15
	Forward switch cost	0.03	0.20
Forward switch cost	Global RT	0.17	0.11
	Congruency difference	−0.02	0.27
	Switch-cost difference	−0.19	−0.33
	Backward switch cost	0.21	−0.28
	Forward switch cost	0.57*	0.19

* $p < 0.05$; ** $p < 0.01$.

have shown itself more pronounced in the interpreting students. The only study that compared interpreters and translators at different ages confirmed that general task switching ability using a plus-minus task was the same in both groups at all these different ages (Henrard and Van Daele, 2017), and thus confirmed that the task switching mechanism develops at the same pace in interpreters and translators. Second, our study differs from previous studies in its usage of a bilingual categorization task with language stimuli to test control in interpreters and translators. This could explain why the improvement in our student groups after the MA programme was not found in Van de Putte et al. (2018), even though we used the same longitudinal design and the participants received almost the same academic training in the MA programs for Dutch universities in Belgium in terms of the length and the nature of the program. One interpretation is that the training of two semesters can generate behavioral improvement in language-specific switching in both students groups but it may not yet transfer into domain-general switching improvement, or the domain-specific mechanisms involved in the bilingual categorization task do not or only to a limited extent correspond to domain-general process that are tested using the Simon task (Van de Putte et al., 2018; Paap et al., 2019).

Interestingly, Van de Putte et al. (2018) confirmed that although no difference at behavioral level was detected; functional brain changes appeared after nine months of training for both student groups during color-shape task though in different patterns. It seems that the improvement in general task switching needs more time to show itself at behavioral level while language switching at the same period of time could make behavioral differences. This is in line with the study by Babcock and Vallesi (2017) that showed general task switching improvement in the translation and interpreting students using color-shape switch task after 2 years of MA program instead of the one-year programmes being tested in Van de Putte et al. (2018) and our study. The overall results in the above studies including the present study showed that the level of training (BA vs. MA) which may be influenced by L2 proficiency of the participants on the one hand, and the length of the training (one-year MA vs. two-year MA) on the other hand could affect the results of the switching studies in the interpreters. Additionally, our study confirms that improvement in the language specific switching could show itself sooner at the behavioral level than the general switching mechanism meaning the latter needs more time to show itself at the behavioral level.

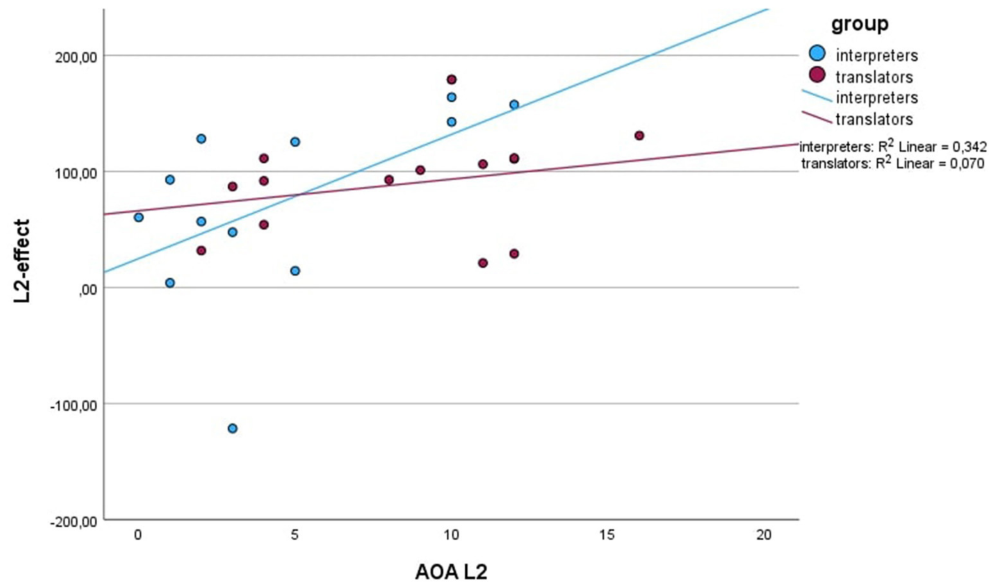

FIGURE 1
Scatterplot and regression fit lines demonstrating the relationship between the age of second language acquisition (AOA2) in interpreting and translation students and the L2-effect in the Bilingual Categorization task.

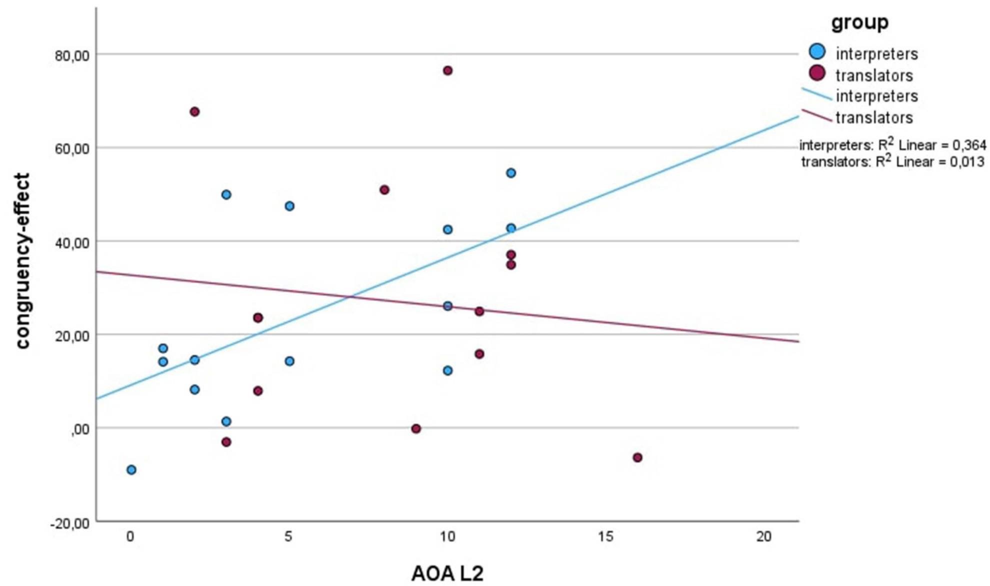

FIGURE 2
Scatterplot and regression fit lines demonstrating the relationship between the age of second language acquisition (AOA2) in interpreting and translation students and the congruency effect in the Simon task.

4.2. Inhibition in interpreters

The result of our study showed that both the interpreter and translation students performed the same on the Simon task both for RTs and accuracy. This confirms that both student groups have a similar ability in resistance to a prepotent response. The results are in line with previous research that reported no difference in response inhibition between two student groups (Van de Putte et al., 2018). However, it seems from previous studies that the absence of the group difference is not only restricted to the translation students but also extends to other bilingual students (Woumans et al., 2015; Dong and Liu, 2016) when all participants are at their young ages. To better understand the effects of age and the accumulation of interpreting experience on prepotent response inhibition, we included an additional group of professional interpreters with more than 20 years of experience. Comparing these three groups revealed the effect of age on the RTs but not on accuracy scores meaning that younger students respond faster than professional interpreters which is in line with previous studies that revealed better or the same accuracy scores for professional interpreters using the ANT compared to younger students groups (Nour et al., 2019). Research on prepotent response inhibition in professional interpreters is rare;

one study compared three groups of professional interpreters with a mean age of 36 years old to bilingual controls ($M = 25$ years) and younger monolinguals ($M = 21$ years) and found no group differences in the Simon task (Yudes et al., 2011). This result suggests that until the age of 36 in the professional interpreters no effect of age could be found in the RTs and accuracy scores at behavioral level. The mean age of the professional group in our study was 50.8 years (SD = 4.8) and the effect of age showed itself in RTs but not accuracy. This is in line with the study by Henrard and Van Daele (2017) which compared three groups of professional interpreters, professional translators, and monolingual controls and reported no group difference between them in the younger participants (aged 25–34 years), however the effect of accumulated interpreting experience appeared after this age in the Antisaccade task. The professional interpreters were more efficient than the two matched groups in their resistance to a prepotent response at the later ages (Henrard and Van Daele, 2017). It is also possible that the difference between professional and non-professional bilinguals' cognitive effects is due to differences in the quantity and quality of their regular language use practices (Korenar et al., 2022). While the effect of aging in the present was clearly visible in processing speed, with slower response times for professional interpreters than both student groups, a similar difference was not observed in error rates, with equal accuracy for the professional interpreters as compared to the student groups. While further research is needed to confirm this discrepancy between speed and accuracy, our results could suggest that professional experience might protect against a decline in accuracy that is visible in other studies (Forstmann et al., 2011; Nour et al., 2019).

4.3. Language control and domain general control in interpreters

We further looked in the present study at the relationship between the different measures of the language switching and domain-general control in interpreting and translation students. Both the Bilingual categorization task and the Simon task contained unpredictable switches which require proactive control during the whole task (Declerck, 2019). Our results revealed that only the global RTs in both tasks were correlated in the interpreting students and translation students, which might be interpreted as evidence that both tasks globally rely on similar proactive (sustained) control and in support of the idea that proactive language control might rely on inhibition (Declerck, 2019). These results are also in support of the proposal of Friedman (2016) to address the inconsistencies in the studies on the bilingual switching advantage. Applying this concept to the field of interpreting, our study suggests that the switching improvement seen in some studies (Dong and Liu, 2016; Babcock and Vallesi, 2017), but not in others (Van de Putte et al., 2018) may not necessarily be attributable to the switching-specific control but rather to proactive control a common EF element, namely response inhibition (Miyake et al., 2000; Friedman, 2016). This is also in line with a recent study by Struys et al. (2019) who tested bilingual students using the same tasks and found the global RTs in both tasks to be correlated. However, we did not find any further correlation such as between the switch-costs in the Bilingual categorization task and global RTs in the Simon task (Struys et al., 2019). Since both studies tested students with Dutch as their first language and French as their second language; we propose that the different results are due to the level of L2 training of the students at time of the tests; we have tested MA students in translation and interpreting studies who received longer L2 training (at least 3 years) compared to the first-year BA students in Applied linguistics in Struys et al. (2019). We proposed that with advance of L2 proficiency the correlation remains only at the global level for proactive control and disappears at the local level of reactive (and transient) control. We should consider that although both tasks shared some characteristics, they are also different in some ways. Our results line up with previous studies which report small or no correlation between the Simon task (Stimulus-Response) and the Stroop task (Stimulus-Stimulus) suggesting that they employ theoretically related but behaviorally only weakly or non-correlated control mechanisms (Friedman, 2016). Apart from the type of stimuli, the bilingual categorization task specifically relies on language switching between two languages while the Simon task switches between two distinct categories: color and location. Previous studies suggest that the switching RTs between non-competing response dimensions in this case in the Simon task (color and spatial location), may not measure switching ability at all (Segal et al., 2019). Even switching at the linguistic level showed that when bimodal bilinguals, whose languages are articulated using sign language and spoken language, produce their two languages simultaneously, it was not more costly than producing only one language because they use two different control mechanisms in the absence of motor constraints (Blanco-Elorrieta et al., 2018) meaning that they switch between non-competing response dimensions. Additionally, a recent longitudinal study in bilinguals also reported no correlation between switch costs in a non-linguistic switching task (color-shape) and linguistics switching task (Timmer et al., 2019) confirming that the modulation of the correlation between the tasks depends on how similar the tasks are (Declerck et al., 2017) in terms of response mode, stimuli type (linguistic or non-linguistic) and the level of competing responses.

There are several restrictions that must be handled. First, the present study's breadth is constrained by the small number of participants. Second, it would have been preferable to include a control group of professional interpreters who were the same age to better understand the long-term impacts of dual language experience on switching. If any advantage of interpreters is caused by individual differences or rather the result of an accumulation of interpreting experience, further research with a focus on the contrast between active and non-active interpreters at later ages could be more instructive. Third, a distinction between behavioral research and neuroimaging investigations should be made. For instance, even though Van de Putte et al. (2018) found no behavioral differences between interpreting and translating students following a year of masters-level training for a color-shape task, functional brain changes were found at the end of the program (nine months). Future research that uses different methods to examine how experience and training play a role in interpreting groups might be valuable.

5. Conclusion

In the present study, we investigated language-switching ability and domain-general cognitive control in interpreting students, translation students, and professional interpreters with more than 20 years of experience. The longitudinal and cross-sectional design of this study carefully included two important factors in bilingual experimental studies: the replication factor and the task factor. The general results shed light on how training length, language proficiency, onset age of second language acquisition, and task selection may influence the results at a behavioral level. We found that, in general, language-switching improvement may manifest itself sooner than general-switching improvement at a behavioral level. The results, along with previous research, suggest that more behavioral group differences may show themselves in participants with lower language proficiency at training onset. In addition, an interesting difference was found between accuracy and speed, with the latter being more impacted by aging than the former, as indicated by the absence of a significant difference between professional interpreters and student groups on accuracy. Concerning the effect of age on accuracy, we do not know if our results of professional interpreters' accuracy reflect an aging effect or an experience effect, especially in the absence of a control group. Comparing the results of previous studies with the present study also showed that the level of training (BA vs. MA), which may be influenced by the level of L2 proficiency of the participants on the one hand and the length of the training (1-year MA vs. 2-year MA) on the other, could affect the results of the switching studies in the interpreters.

Furthermore, the results show that there was a significant correlation between the lower onset age of L2 acquisition (AOA2) in the interpreting students (compared to translation students) and both the language effect in the bilingual categorization task and the congruency effect in the Simon task. This correlation between participant linguistic profiles and performance on language control tasks suggests that the inconsistencies in earlier studies may be related to the linguistic backgrounds of the participants rather than the tasks used. Our results also revealed that only the global RTs in both tasks were correlated in the interpreting and translation students, which might be interpreted as evidence that both tasks globally rely on similar proactive (sustained) control and support the idea that proactive language control might rely on inhibition but not the switching-specific factor; this can help us to address the inconsistencies in the studies on the bilingual switching advantage (Friedman, 2016; Declerck, 2019).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by VUB Ethics Committees & Data Protection Office. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SN contributed to the conception of the study, design of the experiments, collection and analysis of data, wrote the manuscript, and revised the manuscript critically for important intellectual content. ES advised on the conception, design of the study, and provided critical revisions on the manuscript for important intellectual content. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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