Bilingualism: Language and Cognition

cambridge.org/bil

Choice reaction time differences among monolinguals, bilinguals and trilinguals: Testing global and specific cognitive effects using the Attentional Network Test

Mayco Tunqui-Flores[1], Genny Lubrini[2], Marcos Ríos-Lago[2] and Jose Antonio Periáñez[1]

[1]Experimental Psychology, Complutense University of Madrid, Spain and [2]Basic Psychology II, UNED, Spain

Research Article

Cite this article: Tunqui-Flores, M., Lubrini, G., Ríos-Lago, M. and Periáñez, J.A. (2026). Choice reaction time differences among monolinguals, bilinguals and trilinguals: Testing global and specific cognitive effects using the Attentional Network Test. *Bilingualism: Language and Cognition* 1–12. https://doi.org/10.1017/S136672892610128X

Received: 15 July 2025
Revised: 16 January 2026
Accepted: 27 February 2026

Keywords:
Attentional Networks Test; cognitive control; executive functions; speed of processing; trilingualism

Corresponding author:
Jose Antonio Periáñez;
Email: japerian@ucm.es

This research article was awarded Open Data badge for transparent practices. See the Data Availability Statement for details.

Abstract

Research on the non-linguistic cognitive consequences of bilingualism remains inconclusive, with ongoing debate over which characteristics of bilinguals drive potential effects and which cognitive abilities may be involved. The impact of bilingualism and trilingualism on attentional performance was studied using a computerized Attentional Network Test. It was administered to 97 adults, assuming progressive improvement with increasing language experience. Reaction times and errors were examined across global and specific attentional network measures (alerting, orienting and executive control). Results indicated that the locus of improvement between bilinguals and trilinguals relative to monolinguals emerged primarily in global reaction times and errors, with no specific effects in any attentional network. Although differences between bilinguals and trilinguals showed only a non-significant trend, regression analyses revealed a significant logarithmic relationship whereby speaking more languages predicted faster global reaction times. The observed processing-speed improvement is discussed in relation to ongoing hypotheses proposing an adaptive response in multilinguals.

Highlights

- The ANT paradigm proved sensitive to the positive cognitive effects associated with multilingualism.
- Bilingual and trilingual participants showed better performance in reaction times and accuracy on attentional tasks.
- No significant differences were found in alerting, orienting or executive attention scores as a function of linguistic background.
- In line with the Adaptive Response Hypothesis, a greater number of languages predicted faster responses.
- The findings suggest cognitive benefits of bilingualism and trilingualism in processing speed.

1. Introduction

The question of whether bilingualism drives cognitive benefits has spurred significant debate over past decades. Literature has presented evidence supporting the bilingual advantage hypothesis, suggesting that the constant management of two languages enhances cognitive functions (Antoniou, 2019; Bialystok & Craik, 2022; Grundy, 2020; Grundy & Timmer, 2017). Alternative viewpoints exist regarding the locus of cognitive effects of bilingualism. On the one hand, specific cognitive benefits have been reported in various executive functions such as switching (Prior & MacWhinney, 2010) or working memory (Cockcroft & Alloway, 2012). On the other hand, broader advantages in domain-general processes such as conflict monitoring or more general attentional abilities have been suggested (Luk et al., 2011; Bialystok & Craik, 2022; Costa et al., 2009). Contrasting the bilingual advantage view, some studies have either identified strong inconsistencies in the literature or biases in the methods, concluding that the current evidence does not substantiate the claim of enhanced cognitive abilities in bilinguals, or that the bilingual effect may be minor or limited to specific contexts and tasks (Degirmenci et al., 2022; Donnelly et al., 2019; Grundy, 2020; Hilchey et al., 2015; Lehtonen et al., 2018; Paap, 2019; Paap et al., 2015; Privitera et al., 2022).

A related question in the bilingual effects debate is whether learning additional languages leads to improved cognitive functions. This interest has motivated research examining the extent to which the so-called bilingual effects extend to trilingualism (Chen et al. 2025; Chertkow et al., 2010; Kavé et al., 2008; Perquin et al., 2013; Schroeder & Marian, 2017). Recent evidence on the

© The Author(s), 2026. Published by Cambridge University Press. This is an Open Access article, distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives licence (http://creativecommons.org/licenses/by-nc-nd/4.0), which permits non-commercial re-use, distribution, and reproduction in any medium, provided that no alterations are made and the original article is properly cited. The written permission of Cambridge University Press or the rights holder(s) must be obtained prior to any commercial use and/or adaptation of the article.

effects of multilingualism has further strengthened this line of inquiry. For instance, a recent large-scale study involving 86,149 participants from 27 European countries found that multilingualism acted as a protective factor in both cross-sectional and longitudinal analyses, with effects persisting even after controlling for linguistic, physical, social and sociopolitical exposomes (Amoruso et al., 2025). Building on this evidence and considering the extended Adaptive Response Hypothesis proposed by Bialystok (2024), the experience of managing an additional language may further enhance attentional efficiency. This framework therefore predicts that trilinguals could exhibit even greater attentional benefits as a form of cognitive adaptive response by increasing resource allocation. Thus, managing multiple languages would impose additional cognitive demands, and repeated engagement with these demands is thought to strengthen the underlying cognitive mechanisms, ultimately leading to more efficient processing (see this idea formalized also in the Supply–Demand Cognitive Plasticity Hypothesis by Schroeder & Marian, 2017).

The relevance of attention as a plausible mechanism accounting for the potential effect of bilinguals has been previously analysed with the Attention Network Test (ANT). Indeed, the ANT developed by Fan et al. (2002) is rooted in one of the most well-established theoretical frameworks of attentional processing, which identifies three independent brain networks, i.e., alerting, orienting and executive, as proposed by Posner and Petersen (1990) and Petersen and Posner (2012). Although the number of studies employing the ANT in bilingual populations remains relatively limited, a recent meta-analysis by Arora and Klein (2020) synthesized data from 16 identified studies. Using Bayesian hierarchical modelling, the authors analysed reaction time (RT) data across three distinct age groups: children (six studies), young adults (nine studies) and middle-aged adults (two studies). Their findings indicated a bilingual effect specifically in the executive control network among young adults, while no significant differences were observed in any attentional network measures or global RT scores for the child and middle-aged adult groups. However, the generalizability of these findings may be limited by the relatively small number of studies included in the review, the demographic and linguistic variability of the samples and the inconsistencies observed between the conclusions of individual studies and those of the meta-analysis. It should also be noted that none of the reported studies involving adult participants examined bilingual cognitive effects by including a multilingual comparison group, an approach that could yield valuable insights into potential cognitive adaptations associated with trilingualism.

The present study aimed to assess the impact of bilingualism and trilingualism, relative to monolingualism, on attentional performance across global and specific attentional network measures (alerting, orienting and executive control) using the ANT. Employing three homogeneous groups – monolinguals, bilinguals and trilinguals – offers an innovative design that refines and extends current theoretical predictions regarding the cognitive consequences of bilingualism. Based on the Adaptive Response Hypothesis, it was expected that the experience in managing additional languages would promote greater cognitive adaptation, leading to enhanced attentional efficiency as reflected in RTs and error rates (Bialystok, 2024). Bilinguals were expected to outperform monolinguals, and trilinguals to outperform both bilinguals and monolinguals. In addition, if the bilingual effect is attributable to domain-specific attentional processes, differences will be expected in specific attentional network measures. Alternatively, if the bilingual effect is linked to a domain-general process, differences will be limited to global measures. To address previous limitations related to potential group inhomogeneities, the study recruited three samples of undergraduate students from the same university, ensuring homogeneity across key variables such as age, education, general fluid intelligence, motor speed, age of second-language acquisition, residential environment and the types of languages spoken.

2. Materials and methods

2.1. Participants

A power analysis was conducted using G*Power v. 3.1 statistical software (Faul et al., 2009) to determine the sample size required for a repeated measures ANOVA assuming an effect size (f) of 0.314 from Costa et al. (2009) due to its strong compatibility and similarity to this study. A significance level (α) of 0.05, and power of 0.80 were adopted. The results indicated that 101 participants would be necessary to achieve the target significance level (α) and power, respectively.

A total of 97 adult university students (mean age = 23.5 ± 0.5 years; 88 women) from Madrid, Spain, with Spanish as their native language, participated in this study as volunteers and received extra-academic credits for their involvement. A power analysis conducted with these data at a significance level of 0.05 revealed a high observed statistical power for the contrast (0.99), indicating a very low probability of committing a Type II error. General exclusion criteria included history of neurological disease, psychiatric illness or any other difficulty that could interfere with testing. Three participants were identified as outliers based on a Mahalanobis distance greater than 25 in their behavioural scores and were subsequently excluded from the analyses, resulting in a final sample size of 94 participants (Mahalanobis, 1936).

Participants responded to a multilingual questionnaire about their language experience and proficiency that allowed us to divide them into different groups (modified from Weber-Fox & Neville, 1996). The questionnaire evaluates information about language history including place of birth, age of acquisition of Spanish and any other languages, modes of language acquisition (family, school, other), language dominance, language preference and self-perceived proficiency in understanding, speaking, reading and writing each language, using a 4-point scale (1 = scarcely, 2 = sufficiently, 3 = well and 4 = perfectly). A total proficiency score in each language (0-to-16 point scale) was calculated by adding the four proficiency scores. The demographic and linguistic characteristics of the three established groups were as follows.

2.1.1. Monolingual second-language learners' group

These participants were 35 young adults (mean age = 19.4 ± 0.3 years; 30 females) with 13.3 ± 0.3 years of education. They were native Spanish speakers who, as described above, had received mandatory English language instruction at school starting at the age of 6, but had not had any continuous exposure or immersion in any language other than Spanish.

2.1.2. Bilingual group

These participants were 37 young adults (mean age = 18.8 ± 0.1 year; 33 female), with 13.3 ± 0.1 years of education. The mean age of English acquisition was 3.5 ± 0.2 years, with 24 participants growing up bilingually in both Spanish and English, and 9 participants being exposed to English sequentially at the age of 6 or earlier. Self-reported mean proficiency in Spanish and English were 16 ± 0 and

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

15.6 ± 0.2, respectively, in a 0-to-16 point scale. None of these individuals had any continuous exposure or immersion in any other language apart from Spanish and English.

2.1.3. Trilingual group

These participants were 22 young adults (mean age = 19.9 ± 0.2 years; 19 female), with 13.7 ± 0.2 years of education. The mean age of English acquisition was 2.8 ± 0.4 years, with 16 participants growing up bilingually in both Spanish and English, and 6 participants being exposed to English sequentially at the age of 6 or earlier. The mean age of acquisition of the third language was 8.9 ± 0.8 years, with 2 participants growing up trilingually in both Spanish and English, and in a third language, 3 participants being exposed to the third language sequentially at an early age (6 years or earlier), and 17 participants being exposed to the third language sequentially at a latter age (between 7 and 13 years). The third language were French (16 participants), German (3 participants), Italian (1 participant), Catalan (1 participant) and Euskara (1 participant). Self-reported mean proficiencies in Spanish, English and the third language were 16 ± 0, 15.7 ± 0.2 and 12.1 ± 0.2, respectively in a 0-to-16-point scale.

The study was approved by the ethics committee of the institution and was completed in compliance with institutional standards for human research and following the Declaration of Helsinki. All participants gave informed consent, and their rights were protected in accordance with the ethical standards of the university's Academic Board.

2.2. Materials and procedure

The Attention Network Test (ANT), as designed by Fan et al. (2002), was used within the context of a larger examination to explore three attentional networks: alerting, orienting and executive control. The stimuli were presented via Presentation software (https://www.neurobs.com/) on a computer with a 15-inch monitor. The computer was set to 60 Hz and resolution 1680 x 1050 pixels and was placed at about 65 centimetres of distance from participants. Stimuli consisted of a row of five visually presented white arrowheads pointing rightward or leftward, against a black background. There were two types of target stimuli: a congruent target (> > > > > or < < < < <), when the centre arrow was flanked by other arrows pointing in the same direction, and an incongruent target (> > < > > or < < > < <), when the center arrow was flanked by other arrows pointing in the opposite direction. Target stimuli represented a total length of 5.3 cm on the x axis and 0.8 cm on the y axis. The congruent and incongruent trials occurred in equal proportions. Under each condition (congruent or incongruent), half were pointing to the left and half to the right. The participant's task was to indicate the direction of the centre arrow by pressing the left and right buttons from a keyboard with their left and right index fingers. The target was presented in one of two locations, either 1.5 cm above or below a fixation cross that remained in the centre of the visual display throughout the entire experiment. To engage the alerting and orienting processes, a cue consisting in a white circle with a diameter of 0.7 cm was shown before the appearance of the target. There were four cue conditions: no cue, centre cue, double cue and spatial cue. All cues occurred equiprobably. While centre cues were presented in the screen overlapping the fixation cross, double and spatial cues were presented 1.5 cm above or below it. As a result of the combination of target and cue conditions, the following eight orthogonal conditions were applied: no cue-congruent, no cue-incongruent, centre cue-congruent, centre cue-incongruent, double cue-congruent, double cue-incongruent, spatial cue-congruent and spatial cue-incongruent. The task consisted of 96 trials (24 of each condition). Following Fan et al. (2002), each trial consisted of five events. First, there was a fixation period for a random variable duration (400–1600 ms). Then a warning cue was presented for 100 ms. There was a short fixation period 400 ms after the warning cue and then the target and flanker appeared simultaneously. The targets were presented until participants responded, with a time limit of 1700 ms (see Figure 1). Target location was always uncertain except when spatial cue was presented. Individuals had a practice session of 20 trials before performing the task.

2.3. Data analyses

2.3.1. Demographic and background analysis

Group differences in demographic variables (sex, age and education), motor speed (Finger Tapping Test; Sherman et al., 2022; Roivainen, 2011) and general fluid intelligence (Digit Span – WAIS-IV; Wechsler, 2012; Gignac & Weiss, 2015) were explored by means of 1-way ANOVA or Chi square tests where appropriate.

The homogeneity of the groups regarding the age of acquisition of English (comparison between bilingual and trilingual) was determined by means of Student t-test. The proficiency in Spanish and English was compared among monolinguals, bilinguals and trilinguals by means of a one-way ANOVA, and a Student t-test, respectively. Kolmogorov–Smirnov test was used to assess normality in the distribution of the variables as a prerequisite for comparisons.

2.3.2. Analysis of Group Differences in Cognitive Variables

Several analyses were performed in RTs to correct trials and percentage of errors to address the presence of differences in attentional performance among individuals of the three different linguistic groups. First, an initial three-way ANOVA using group (monolinguals, bilinguals, trilinguals), cue type (no cue, double cue, central cue, spatial cue) and flanker condition (congruent, incongruent) as the factors was performed in RTs and percentage of errors to explore global effects, and to set a reference point with preceding literature. Second, a series of two-way ANOVAs allowed for direct contrasts between the specific conditions relevant to the assessment of the three attentional networks of interest. Particularly, the effects of Group in the attentional networks were examined using two complementary approaches. On the one hand, a series of two-way ANOVAs were used to identify significant interactions in RTs and percentage of errors in the three attentional networks. Thus, the alerting network was assessed with an ANOVA using group (monolinguals, bilinguals and trilinguals) x cue (no cue and double cue trials) as factors. The Orienting network was assessed with an ANOVA using group x cue (centre cue and spatial cue trials) as factors. The Executive network was assessed with an ANOVA using group x condition (congruent and incongruent trials) as factors. On the other hand, three network scores were computed according to Fan et al. (2002). Specifically, the alerting score was calculated by subtracting the mean RTs of the double cue from the mean RTs of the no cue. The orienting score was calculated by subtracting the mean RTs of the spatial cue from the mean RTs of the centre cue, and the executive score was calculated by subtracting the mean of the congruent condition from the mean of the incongruent condition in both RTs and percentage of errors. Homologous non-parametric statistical tests were used when the assumption of normality was not met for RTs or percentage of errors scores (see Results section below). The degrees of freedom

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

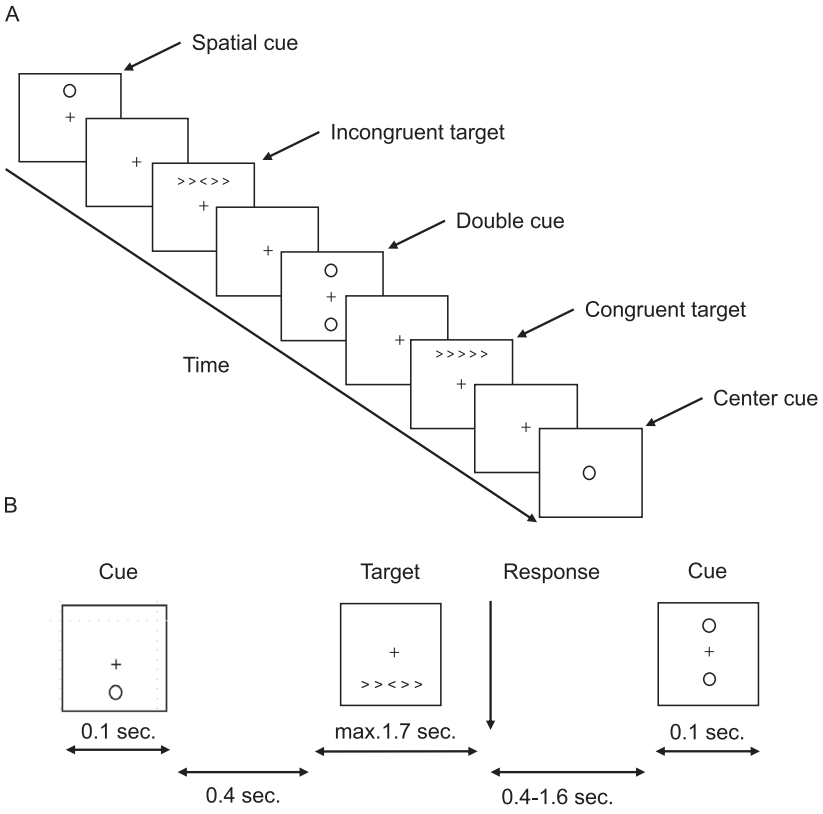


Figure 1. The figure illustrates the stimulus material and experimental conditions. (A) Schematic representation of trial sequences illustrating the experimental conditions (cues and targets) analysed. Trials included two types of target stimuli: congruent targets (> > > > >), in which the central arrow was flanked by arrows pointing in the same direction, and incongruent targets (> > < > >), in which the flanking arrows pointed in the opposite direction. (B) Each trial began with a visual cue (i.e., the "o" symbol), followed by the presentation of a flanker display containing either a congruent or incongruent target. Participants were instructed to respond to the direction of the central arrow.

were adjusted where appropriate using the Greenhouse–Geisser correction, as a precaution against inhomogeneities in the variances of the means. A significance level of $p < .05$ was set for all analyses, with a Bonferroni-corrected level of $p < .05$ applied for tests involving multiple comparisons. All statistical analyses were conducted using SPSS version 26.0. Additionally, G*Power version 3.1 (Faul et al., 2009) was employed to estimate the required sample size.

2.3.3. Regression analyses

Simple regression analysis was conducted to examine the potential statistical trend, suggesting that individuals speaking a greater number of languages might exhibit faster RTs. Thus, a linear regression analysis explored the relationship between language group (monolingual, bilingual, trilingual) as the predictor variable, and global RTs as the criterion. Non-linear regression analyses were also conducted on transformed scores (quadratic and logarithmic) to assess alternative curvilinear relationships between the variables.

3. Results

3.1. Demographic and background results

Between-group comparisons revealed an absence of differences among monolinguals, bilinguals and trilinguals in gender, age, education, motor speed, general fluid intelligence, Spanish and English age of acquisition and Spanish and English proficiency (Table 1).

3.2. Group Differences in Cognitive Variables

A three-way mixed ANOVA on RTs (2 × 4 × 2) was conducted to examine the effects of group, cue type and flanker condition on task performance. Significant effects were found for group, ($F(2, 90) = 11.9$; $p < .001$; $\eta^2 = .21$), cue type ($F(2,204) = 340.4$; $p < .001$; $\eta^2 = .79$) and flanker condition ($F(1, 90) = 25.9$; $p < .001$; $\eta^2 = .22$). Post hoc comparisons indicated that both bilinguals and trilinguals responded significantly faster than monolinguals ($p < .002$ and $p < .001$, respectively), with a non-significant trend towards a difference between bilinguals and trilinguals ($p = .336$). No significant two-way or three-way interactions were found among group, cue type or flanker type ($p > .370$ in all cases; see Table 2). The percentage of errors was analysed using Kruskal–Wallis tests due to a lack of normal distribution. Comparisons among the three groups and cue type (no cue, double cue, centre cue and spatial cue) revealed no significant group differences ($p > .129$ in all cases). Comparisons among the three groups revealed significant differences in incongruent condition ($p < .001$) and congruent condition ($p < .001$). Post hoc analyses on congruent trials showed differences in errors between monolingual and bilingual groups ($p < .001$) and monolingual and trilingual groups ($p < .001$), but not between the later groups ($p > .097$). Post hoc analyses on incongruent trials showed differences in errors between monolinguals and bilinguals ($p < .001$) and monolinguals and trilinguals ($p < .001$) but not between the later groups ($p > .795$). In summary, the RT analyses revealed significant group effects, with both bilinguals and trilinguals responding faster than monolinguals. Additionally, bilinguals and trilinguals exhibited a

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

Table 1. Summary of participants: demographic and background characteristics in the groups

	Monolingual	Bilingual	Trilingual	p-value
N (female)	35 (30)	37 (33)	22(19)	.681
Age	19.4 ± 0.3	18.8 ± 0.1	19.2 ± 0.2	.102
Education in years	13.3 ± 0.3	13.3 ± 0.1	13.7 ± 0.2	.394
Motor speed[a]	54.0 ± 1.0	54.9 ± 1.0	56.2 ± 1.5	.163
Fluid intelligence[b]	8.9 ± 0.3	9.5 ± 0.3	9.7 ± 0.4	.208
Age of acquisition Spanish	Native	Native	Native	–
Age of acquisition English	–	3.4 ± 0.18	2.8 ± 0.4	.153
Age of acquisition 3rd language	–	–	8.9 ± 0.8	–
Proficiency in Spanish	16 ± 0	16 ± 0	16 ± 0	1
Proficiency in English	–	15.6 ± 0.2	15.7 ± 0.2	.543
Proficiency 3rd language	–	–	12.1 ± 0.7	–

Note: Mean ± Standard Error of Measurement; *p*-value: Statistical significance; [a]: Mean number of taps in the Finger Tapping Test; [b]: Digit Span score of the WAIS-IV.

Table 2. Behavioural performance (RTs and % Er) in all ANT conditions

	Flanker condition					
	Congruent			Incongruent		
	Monolingual	Bilingual	Trilingual	Monolingual	Bilingual	Trilingual
RT						
No cue	535.7 ± 14.0	489.2 ± 9.0	474.0 ± 10.1	603.9 ± 13.0	552.9 ± 10.7	527.6 ± 12.1
Double cue	502.1 ± 12.5	464.2 ± 8.7	429.1 ± 9.9	615.0 ± 15.2	576.9 ± 13.4	545.3 ± 13.8
Centre cue	504.8 ± 12.0	468.8 ± 10.2	440.8 ± 9.4	614.7 ± 12.8	560.0 ± 8.2	547.9 ± 11.6
Spatial cue	499.3 ± 12.1	451.4 ± 8.6	427,6 ± 8.9	586.8 ± 14.3	535.4 ± 9.5	509.9 ± 12.2
% Er						
No cue	11.7 ± 0.1	11.2 ± 0.1	11.9 ± 0.2	11.1 ± 0.4	11.1 ± 0.2	11.7 ± 0.1
Double cue	11.9 ± 0.1	11.6 ± 0.1	11.9 ± 0.1	11.9 ± 0.4	10.6 ± 0.2	10.9 ± 0.2
Centre cue	11.8 ± 0.1	11.7 ± 0.1	11.9 ± 0.2	11.1 ± 0.4	11 ± 0.2	10.9 ± 0.3
Spatial cue	11.7 ± 0.1	11.7 ± 0.1	1.1 ± 0.6	11.9 ± 0.1	10.9 ± 0.2	11.1 ± 0.3

Note: Mean ± Standard Error of Measurement. RT: Reaction Time in milliseconds; % Er: Percentage of errors.

lower percentage of errors compared to monolinguals in both congruent and incongruent conditions.

As noted above, a series of two-way mixed ANOVAs were conducted to explore the specific effects of the three attentional networks. Thus, a two-way mixed ANOVA was conducted to analyse RT effects in the alerting network using group (monolingual, bilinguals, trilingual) and cue type (no cue, double cue) as the factors (see Table 3 and Figure 2). It revealed the presence of group effect ($F(2,91) = 9$; $p < .001$; $\eta^2 = .17$) being monolinguals slower than both bilinguals, and trilinguals ($p < .016$ in all cases) with no differences between bilinguals and trilinguals ($p = .329$). As expected, the significant cue effect ($F(1,91) = 7.5$; $p < .007$; $\eta^2 = .08$) revealed that responses were faster in the double cue condition than in the no cue condition ($p < .007$). Importantly, no interaction effects were found ($p > .242$). The percentage of errors in responses was analysed using Kruskal–Wallis tests, and comparisons among the three groups revealed no significant differences in no cue and double cue ($p > .244$ in all cases). In summary, although the RT analysis revealed significant effects of group and cue type, with monolinguals exhibiting slower responses than bilinguals and trilinguals, the absence of interactions indicated a lack of effects on the alerting network.

A two-way mixed ANOVA was conducted to analyse RT effects in the orienting network using group (monolingual, bilinguals, trilingual) and cue type (centre cue, spatial cue) as the factors (see Table 3 and Figure 2). It revealed the presence of main group effect ($F(2,91) = 11.8$; $p < .001$; $\eta^2 = .21$) showing that monolinguals were slower than both bilinguals and trilinguals ($p < .002$ in all cases) with no differences between bilinguals and trilinguals ($p = .411$). As expected, the presence of a cue effect ($F(1,91) = 41$; $p < .001$; $\eta^2 = .31$) revealed differences between spatial cue and the central cue conditions ($p < .001$). No other main effects or interaction reached significance ($p > .370$). The percentage of errors in responses was analysed using Kruskal–Wallis tests, and comparisons among the three groups revealed no significant differences in centre cue and spatial cue ($p > .129$ in all cases). In summary,

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

Table 3. Behavioural performance (RTs and % Er) in the three attentional network measures

	Conditions	Monolingual	Bilingual	Trilingual
RT				
Alerting network	No cue	567.3 ± 12.8	520 ± 9.3	500.4 ± 10.2
	Double cue	554.6 ± 12.8	518.3 ± 10.3	484 ± 11.2
Orienting network	Centre cue	556.3 ± 11.7	512.6 ± 8.6	491.6 ± 9.5
	Spatial cue	542.6 ± 11.9	492 ± 8.5	467.5 ± 10.1
Executive network	Congruent	510.5 ± 11.4	468.4 ± 8.4	442.9 ± 8.3
	Incongruent	606.4 ± 12.4	556.4 ± 9.7	533 ± 11.4
% Er				
Alerting network	No cue	7.7 ± 2.9	4.8 ± 1.4	2.6 ± 1.1
	Double cue	8.9 ± 3.1	7.9 ± 2.2	8.3 ± 2
Orienting network	Centre cue	7.2 ± 2.9	4.9 ± 1.4	7.4 ± 2.7
	Spatial cue	7.4 ± 2.7	5.6 ± 1.7	5.7 ± 2.2
Executive network	Congruent	0 ± 0	0.5 ± 0	0.5 ± 0
	Incongruent	0.1 ± 0	0.5 ± 0	0.5 ± 0

Note: Mean ± Standard Error of Measurement. RT: Reaction Time in milliseconds; % Er: Percentage of errors.

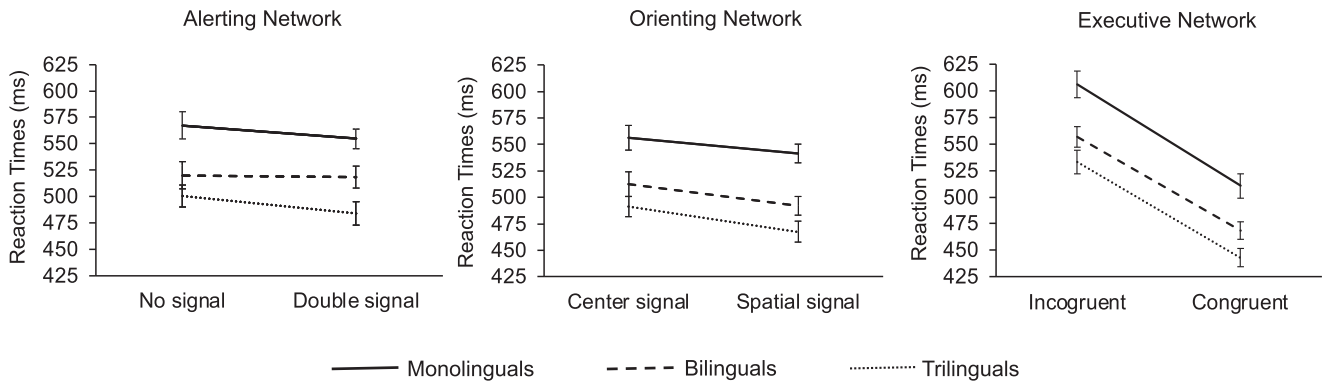


Figure 2. The figure illustrates mean RTs in milliseconds and standard error of measurement in the ANT conditions used to identify the function of the alerting, orienting and executive networks. The different lines identify monolingual (solid line), bilingual (dashed line) and trilingual (dotted line) groups.

although the RT analysis revealed significant effects of group and cue type, with monolinguals exhibiting slower responses than bilinguals and trilinguals, the absence of interactions indicated a lack of effects on the orienting network.

A two-way mixed ANOVA was conducted to analyse RT effects in the executive network using group (monolingual, bilinguals, trilingual), and flanker condition (congruent, incongruent) as the factors (see Table 3 and Figure 2). It revealed the presence of main group effect ($F(2,90) = 11.9$; $p < .001$; $\eta^2 = .210$) showing that monolinguals were slower than both bilinguals and trilinguals ($p < .002$ in all cases) with no differences between bilinguals and trilinguals ($p = .336$). As expected, the presence of a flanker effect ($F(1,90) = 575.3$; $p < .001$; $\eta^2 = .87$) revealed differences between incongruent and congruent conditions being RTs to the former trials slower than to the later. Importantly, no other main effects or interaction reached significance. The percentage of errors in responses was analysed using Kruskal–Wallis tests, and comparisons among the three groups revealed significant differences in incongruent ($p < .001$) and congruent ($p < .001$) conditions. Congruent and incongruent post hoc analyses showed differences between monolingual and trilingual groups ($p < .001$) and monolingual and bilingual groups ($p < .001$), but not in the remaining comparisons ($p > .097$ in all cases). In summary, although the RT analysis revealed significant effects of group and flanker condition, with monolinguals exhibiting slower responses than bilinguals and trilinguals, the absence of interactions indicated a lack of effects on the executive network. Additionally, bilinguals and trilinguals exhibited a lower percentage of errors compared to monolinguals in both congruent and incongruent conditions, thus indicating a lack of effects on the executive network.

Three additional one-way ANOVAs using group as a factor (monolingual, bilinguals, trilingual) were conducted to analyse the results on the attentional scores as described by Fan et al. (2002). The calculations of the difference scores are presented in Table 4. The analysis of the alerting score (double cue minus no cue) revealed an absence of group effect in RTs ($F(2,91) = 1.4$; $p < .242$; $\eta^2 = .03$). Similarly, the analysis of the orienting score (spatial cue

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

Table 4. Behavioural performance in attentional network scores

	Monolingual	Bilingual	Trilingual
RT			
Alerting score	12.6 ± 6.4	1.8 ± 5.6	16.4 ± 7.1
Orienting score	13.7 ± 6.1	20.6 ± 3.7	24.1 ± 5.1
Executive score	94.1 ± 7.1	88 ± 5.2	90.1 ± 6.9
% Er			
Alerting score	1.2 ± 1.2	3.1 ± 2	5.7 ± 1.9
Orienting score	−0.2 ± 1.4	−0.7 ± 0.9	1.7 ± 2
Executive score	0.1 ± 0	0 ± 0	0 ± 0

Note: Mean ± Standard Error of Measurement. RT: Reaction Time in milliseconds; % Er: Percentage of errors; Alerting score: Calculated by subtracting the mean of the double cue from the mean of the no cue; Orienting score: Calculated by subtracting the mean of the spatial cue from the mean of the center cue; Executive score: Calculated by subtracting the mean of the congruent condition from the mean of the incongruent condition.

minus centre) revealed an absence of group effect in RTs ($H(2) = 1.9$; $p < .392$). In addition, the analysis of the executive score (incongruent condition minus congruent conditions) revealed an absence of group effect in RTs ($F(2,90) = 0.3$; $p < .763$; $\eta^2 = .01$). The percentage of errors was analysed using Kruskal–Wallis and revealed no differences across groups on attentional scores ($p > .084$ in all cases). In summary, no significant differences were found between monolinguals, bilinguals and trilinguals on the alerting, orienting or executive attentional scores.

3.3. Regression analyses

Simple regressions were conducted to explore the plausible association observed between global RT measures (dependent variable) and linguistic group (i.e., monolingual, bilingual, trilingual; independent variable). The linear regression analysis revealed an absence of a significant linear relationship between the variables ($p = .072$; $R^2 = .039$). However, non-linear regression analyses revealed a significant quadratic association ($F(1, 91) = 20.43$; $p < .001$; $R^2 = .183$), in which the number of languages spoken was associated with faster global RTs. Similarly, a significant logarithmic association was observed ($F(1, 91) = 23.8$; $p < .001$; $R^2 = .208$), with the number of languages spoken also associated with faster global RTs (see Figure 3).

4. Discussion

The aim of the present study was to investigate the impact of speaking more than one language on attentional processing. Three groups of healthy monolinguals, bilinguals and trilinguals were matched in gender, age, education, motor speed, general fluid intelligence and age of acquisition of their first language. In addition, bilinguals and trilinguals were matched in the age of acquisition of their second language. Following the Adaptive Response Hypothesis (Bialystok, 2024), it was expected that if the experience of handling more languages entails greater cognitive demands due to the constant management of two languages, this would adapt the attentional system to be more efficient. Accordingly, bilinguals were expected to outperform monolinguals, and, by extension, trilinguals were expected to outperform both bilinguals and monolinguals in attentional abilities. Additionally, the present study examined whether any observed effects

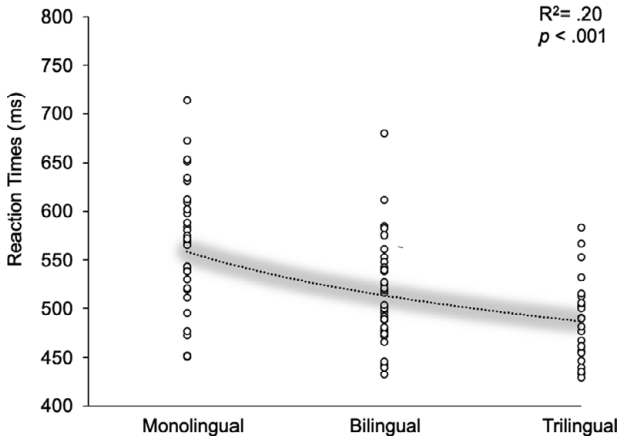


Figure 3. The figure illustrates a logarithmic trend in global RTs, measured in milliseconds, across monolingual, bilingual and trilingual groups. Individual data points are represented by open circles, with each point corresponding to a participant within the respective language group. The results reveal a general trend whereby global RTs improved as the number of languages spoken increases.

could be attributed to domain-specific attentional mechanism namely, alerting, orienting or executive control, or alternatively, to a domain-general one.

The results of the general analysis (three-way ANOVA) indicated that speaking more than one language was associated with improved speed during ANT performance. Specifically, the bilingual and trilingual groups exhibited faster RTs compared to monolinguals. The accuracy analyses also revealed that the bilingual and trilingual groups exhibited a reduced number of errors compared to monolinguals. The relevance of these findings is highlighted by the fact that the monolingual comparison group was not entirely naïve to English, having received formal academic instruction in the language, albeit without sustained or immersive bilingual experience. These results replicate a pattern reported in the existing ANT literature with adults, as summarized in Table 5, showing that of the ten studies reviewed, nine analysed global RTs, with six reporting faster RTs in bilinguals, two finding no differences between groups and only one reporting a monolingual advantage. In addition, the present data revealed that the direct comparison of global RTs between bilinguals and trilinguals were non-significant. The lack of a significant difference between these groups, despite the trend observed in the data (see Figure 2), may reflect a potential ceiling effect. Given the present samples, the expected improvement in RT performance among healthy adults with a high educational level is likely to be small, approaching both psychological and physiological limits. This interpretation was preliminary supported by a non-linear regression analysis, which indicated that a greater number of languages spoken predicted better global RTs, with a logarithmic trend providing the best model fit (see Figure 3). Taken together, these findings provide partial support for the predictions of the Adaptive Response Hypothesis (Bialystok, 2024) and its extension, which propose that bilingual and trilingual experiences can influence cognitive processes by inducing adaptive changes. Both bilinguals and trilinguals demonstrated more efficient performance on the attentional task than monolinguals, in terms of both speed and accuracy. However, the results only provide modest support for the notion that trilingualism confers additional benefits beyond bilingualism, as this was supported statistically solely by a logarithmic association between the number of languages spoken and processing speed.

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

Table 5. Overview of studies using the ANT in bilingual adults

Autor (year)	Groups (N)	Age Mean ± SD	Bilingual languages	Global statistical analyses	Network statistical analyses	Global effect	Alerting network effect	Orienting network effect	Executive network effect
Costa et al. (2008)	Monolinguals (100) Bilingual (100)	22.0 ± N.R. 22.0 ± N.R.	Spanish* – Catalan	*3-way ANOVA*	*3-way ANOVA*	Yes[a]	Yes[a]	No[a]	Yes[a]
Limberger and Buchweitz (2014)	Monolinguals (19) Bilingual early (20) Multilingual (20)	30.0 ± 6.1 28.0 ± 5.9 28.9 ± 6.3	Portuguese* – Gemerman Hunsruckisc	*1-way ANOVA*	N.R.	Yes[b]	N.R.	N.R.	N.R.
Pelham and Abrams (2014)	Monolinguals (30) Bilingual early (30) Bilingual late (30)	19.3 ± 2.2 22.0 ± 3.4 20.3 ± 1.8	English* – Spanish	*2-way ANOVA*	*2-way ANOVA and t-test*	No[a]	N.R.	N.R.	Yes[a]
Nair et al. (2017)	Monolinguals (18) Bilingual (18)	50.8 ± 4.3 51.2 ± 3.9	Mayalam* – Telu	*3-way ANOVA*	*3-way ANOVA*	Yes[a]	No[a]	No[a]	No[a]
Rodrigues and Zimmer (2016)	Monolinguals (20) Bilingual (20)	47.2 ± N.R. 48.1 ± N.R.	Portuguese* – Mixed	*N.R.*	*t-test*	N.R.	No[b]	No[b]	No[b]
Yang et al. (2016)	Monolinguals (19) Bilingual (19)	19.9 ± 0.9 20.7 ± 1.2	Korean* – English	*2-way ANOVA*	*2-way ANOVA and t-test*	Yes[a]	No[a,b]	Yes[b]	Yes[a]
Vivas et al. (2017)	Monolinguals (45) Bilingual (45)	26.7 ± 9.5 27.3 ± 6.9	Greek* – Albanian	*3-way ANOVA*	*3-way ANOVA*	Yes[a,†]	No[a]	No[a]	No[a]
Desideri and Bonifacci (2018)	Monolinguals (25) Bilingual (25)	26.4 ± 7.0 26.5 ± 7.8	Italian* – German	*3-way ANOVA*	*3-way ANOVA and t-test*	Yes[a]	No[a,b]	No[a,b]	Yes[a,b]
Ooi et al. (2018)	Monolinguals (64) Bilingual early A (48) Bilingual early B (70) Bilingual late (63)	21.4 ± 3.0 21.3 ± 3.1 21.8 ± 2.2 22.1 ± 3.0	English* – Mixed	*1-way ANOVA*	*2-way ANOVA*	Yes[a,b]	No[a]	No[a]	Yes[a]
Sabourin and Vinerte (2019)	Monolinguals (30) Bilingual simul. (23) Bililingual early (20) Bilingual late (22)	18.5 ± 2.7 18.5 ± 0.8 19.1 ± 1.7 18.4 ± 1.7	English* – French	*3-way ANOVA*	*1-way ANOVA*	No[a]	No[a,b]	No[a,b]	Yes[b]

Note: N.R.: Not reported; *: Language corresponding to monolinguals; Global Statistical Analyses: Statistical test used to demonstrate overall RT effects between monolinguals and bilinguals; Network Statistical Analyses: Statistical test used to demonstrate differences in RT between monolinguals and bilinguals in attentional networks; Global effect: Presence or absence of RT differences among groups; Alerting Network effect: Presence or absence of differences among groups in measures of the alerting network; Orienting Network effect: Presence or absence of differences among groups in measures of the orienting network; Executive Network effect: Presence or absence of differences among groups in measures of the executive network; [a]: Statistical effects identified in an interaction from an ANOVA; [b]: Statistical effects identified in a *1-way* ANOVA or Student's t-test; [†]: Monolinguals outperformed bilinguals.

The analysis of behavioural performance in the three attentional networks, on the one hand, closely replicates the classical effects using the ANT (Fan et al., 2002; Rueda et al., 2004). On the other hand, the analyses of the interactions between language and attentional networks suggested that, despite the faster RTs associated to bilingual and trilingual individuals as compared to monolinguals, such an effect was not related to a specific enhancement of any particular attentional mechanisms, i.e., alerting, orienting or executive networks (see Figure 2). In this regard, and as shown in Table 5, there is relative consensus in the ANT literature with healthy adults regarding the lack of a significant bilingual effect in relation to the alerting network (Desideri & Bonifacci, 2018; Limberger & Buchweitz, 2014; Nair et al., 2017; Ooi et al., 2018; Pelham & Abrams, 2014; Rodrigues & Zimmer, 2016; Sabourin & Vīnerte, 2019; Vivas et al., 2017; Yang et al., 2016), with the only exception being the study by Costa et al. (2008), which reported that bilinguals benefited more than monolinguals from the presence of an alerting cue compared to no-cue trials. Importantly, this effect was not replicated in a later study by the same research group, thereby calling its reliability into question (Costa et al., 2009). Likewise, and as shown in Table 5, literature is homogeneous regarding the description of a lack of a bilingual effect in the orienting network (Costa et al., 2008; Desideri & Bonifacci, 2018; Limberger & Buchweitz, 2014; Nair et al., 2017; Ooi et al., 2018; Pelham & Abrams, 2014; Rodrigues & Zimmer, 2016; Sabourin & Vīnerte, 2019; Vivas et al., 2017) with the only exception of Yang et al. (2016) showing differences between groups in the orienting score (difference between Spatial and Central cues). However, this study did not account for an interaction effect between group and cue, thus preventing the possibility of disentangling specific effects from generalized ones. Regarding the executive networks, results were more heterogeneous. Specifically, six out of ten studies from Table 5 concluded that bilingualism confers an effect on the executive network (Costa et al., 2008; Desideri & Bonifacci, 2018; Ooi et al., 2018; Pelham & Abrams, 2014; Sabourin & Vīnerte, 2019; Yang et al., 2016). However, these effects were based on different statistical analyses that could limit the consistency of this finding. For example, using multivariate ANOVA, Costa et al. (2008) and Ooi et al. (2018) reported group by congruency interactions in RTs, but only Costa et al. (2008) found a significant post hoc effect with differences between incongruent and congruent trials being larger for monolinguals than for bilinguals. However, these effects disappeared in a subsequent study by the same group when the probability of congruent and incongruent trials was manipulated (Costa et al., 2009), as will be discussed later. On the other hand, the executive effects reported by Desideri and Bonifacci (2018), Sabourin and Vīnerte (2019) and Yang et al. (2016) were based on Student's t-tests and one-way ANOVAs, which again precluded the identification of reliable interaction effects and, consequently, the possibility of disentangling specific effects from generalized ones.

Taken together, the present results support the idea that no specific behavioural effects, aside from a global improvement in speed and accuracy among bilingual and trilingual individuals, were observed across the attentional networks measured by the ANT. It should be noted that, in the meta-analysis by Paap (2019), only 16.7% of the studies reporting statistical tests of global RTs found a significant bilingual advantage, with effect sizes being statistically small; in contrast, 81.1% of the studies reported null effects, and 2.3% reported monolingual advantages. This pattern contrasts with the consistent findings in the ANT literature showing faster global RTs among bilinguals (see Table 5). Moreover, the present study provides preliminary evidence that trilingualism may confer an extra advantage in task performance relative to both bilingualism and monolingualism, as revealed by the logarithmic association found between the number of languages spoken and processing speed. Different authors have interpreted bilingual effect in global RT of the kind observed here as an effect in a domain-general executive process functions such as 'monitoring' (Costa et al., 2009), 'coordination' (Bialystok, 2011), or 'mental flexibility' (Kroll & Bialystok, 2013). For instance, Costa et al. (2009) manipulated the proportion of congruent and incongruent trials in a version of the ANT to explore the effects of low-monitoring demands (when most trials were of the same type) versus high-monitoring demands (when most trials were of varying types). A bilingual effect in global RTs was observed only under high-monitoring conditions, in which congruent and incongruent trials were presented in equal proportions (i.e., 50%). In this regard, our results obtained using an ANT version with a 50/50 distribution of congruent and incongruent trials replicate the findings of Costa et al. (2009) and may support the hypothesis that bilingual and trilingual individuals benefit from a more efficient monitoring system. Alternatively, some researchers have suggested that the global RT effect observed in bilinguals cannot be attributed to monitoring in the absence of more specific experimental controls. For instance, Paap et al. (2015) argued that a monitoring-based interpretation would require a control condition involving no conflict across an extended block of trials (and thus minimal monitoring demands), in addition to a global RT condition that includes the average of both congruent and incongruent trials, or simply the mean RT on congruent trials. A more rigorous test, therefore, would involve calculating a difference score between congruent trials from a mixed block and the same type of trials from a pure block containing no conflict trials, i.e., mixing costs. When Bialystok (2011) implemented this experimental control, they found no differences in mixing costs between bilinguals and monolinguals, thereby undermining the monitoring account. Alternative explanations challenging other monitoring-like interpretations have been proposed by Paap (2019). Based on this, it is possible that the group differences in global RT observed here reflect a more general effect associated with cognitive processing speed, rather than monitoring (see also Paap et al., 2014; Paap & Greenberg, 2013). For instance, Ebert (2021), using a classical speed of processing task (i.e., a choice visual detection task), found enhanced processing speed in Spanish–English bilinguals compared to monolinguals, thus providing evidence for the speed of cognitive processing hypothesis in bilingualism. All in all, the aforementioned findings provide partial support for the predictions of the Adaptive Response Hypothesis (Bialystok, 2024) and its extension for trilingualism, suggesting that bilingual and trilingual experience induces general adaptive changes, as both groups demonstrated more efficient performance on the attentional task compared to monolinguals in terms of speed and accuracy. However, analysis of the three attentional networks measured by the ANT revealed no specific attentional effects accounting for group differences. Future research should explore additional hypotheses to explain these general effects, which have been less studied in bilinguals and multilinguals. For instance, the Supply–Demand Cognitive Plasticity Hypothesis proposed by Schroeder and Marian (2017) suggests that when the demands imposed by multilingual language management exceed the system's available resources, cognitive plasticity mechanisms generate an adaptive response by increasing resource allocation. With repeated exposure to such high-demand conditions, as occurs in bilingual and particularly trilingual language use, these adaptations may ultimately lead to

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

lasting enhancements in general cognitive efficiency, with improvements in processing speed being a plausible behavioural manifestation of some of the adaptations described in both grey and white matter of the bilingual brain (DeLuca et al., 2019).

Our results may also contribute to current research on the effects of different bilingual experiences by conceptualizing our three groups along a continuum of linguistic knowledge, particularly given that our monolinguals were not entirely naïve to English. In line with previous ANT studies, recent work has highlighted that specific dimension of bilingual experience rather than simple monolingual–bilingual contrasts modulate cognitive outcomes. Higher L2 proficiency and frequent language switching have been linked to faster global RTs (Ooi et al., 2018; Privitera et al., 2022), whereas less balanced experience or age-related factors may attenuate these patterns (Nour et al., 2019), with some studies reporting no global RT differences at all (Xing & Yang, 2023). Within this broader framework, our findings offer preliminary evidence that managing multiple languages may confer additional, domain-general facilitation, supporting the idea of a continuum in which greater linguistic experience is associated with enhanced global information processing speed. It should be noted, however, that the effects of bilingual experience reported across the four previous investigations emerged only in global RTs and not in specific attentional network effects assessed by the ANT, consistent with the present study.

This study is not without limitations. First, although the present sample was highly homogeneous and controlled for variability in participant characteristics observed in many previous studies, the results may not generalize to more heterogeneous samples. Accordingly, the findings should be replicated in future research in individuals with different demographic characteristics. Second, the use of a single experimental task to assess cognitive performance may limit the scope of conclusions regarding other aspects of cognitive functioning. Third, linguistic proficiency was measured using a self-report questionnaire. To ensure greater accuracy, future studies should combine self-reports with more objective proficiency level measures, like official language certification exams. Fourth, caution is warranted when considering the current control group as purely monolingual, as participants in the "monolingual" condition were not entirely naïve to a second language. As mentioned above, conceptualizing participants according to low versus high bilingual proficiency through complementary measures of bilingual experience may help refine existing classification methods in bilingualism research and position individuals along a continuum of linguistic experience, thereby providing complementary perspectives for the study of bilingualism. This is particularly important because continuous exposure to non-native linguistic input in modern societies, driven by globalization, increasingly challenges traditional monolingual–bilingual distinctions. Lastly, this study used the Digit Span score from the WAIS-IV to control for differences in general fluid intelligence, based on its reported correlation with this construct (Gignac & Weiss, 2015). However, Digit Span does not constitute a broad measure of intelligence; therefore, future studies should include more canonical indicators, such as Raven's Progressive Matrices. In addition, although we controlled for motor speed across groups, future studies should also account for other speed-related factors (e.g., perceptual speed or simple processing speed) using tasks that do not overlap with the attentional mechanisms under investigation.

In conclusion, the findings of this study contribute to the growing body of evidence supporting the existence of a bilingual effect in domain-general factors during attentional performance such as processing speed, without producing specific effects on the three attentional networks outlined in the classical model by Petersen and Posner (2012). Additionally, the results suggest a potential added benefit of trilingualism over bilingualism in global RTs, although this effect may be limited by a ceiling effect within the current sample of well-educated young adults. Furthermore, the findings suggest that the additive benefits of multilingualism may follow a logarithmic trend, a hypothesis that warrants further investigation in future research. Future research aiming to elucidate the sources of bilingual and multilingual effect in processing speed would benefit from the adoption of novel methodologies, such as neurophysiological and neuroimaging approaches, as well as more comprehensive and fine-grained classifications of bilingual experience for identifying additional relevant factors. Addressing these aspects would contribute to a deeper and more precise understanding of multilingualism and its cognitive effects.

Data availability statement. The data that support the findings are available in the Center for Open Science repository at https://osf.io/6upxk/files/osfstorage/6861bd3d0a8b1c2833e05fcc

Competing interests. The authors declare that they have no competing interests.

Funding statement. This research did not receive any specific grant from funding agencies in the public, commercial or not for profit sectors.

References

Amoruso, L., Hernandez, H., Santamaria-Garcia, H., Moguilner, S., Legaz, A., Prado, P., Cuadros, J., Gonzalez, L., Gonzalez-Gomez, R., Migeot, J., Coronel-Oliveros, C., Cruzat, J., Carreiras, M., Medel, V., Maito, M. A., Duran-Aniotz, C., Tagliazucchi, E., Baez, S., García, A. M., & Ibanez, A. (2025). Multilingualism protects against accelerated aging in cross-sectional and longitudinal analyses of 27 European countries. *Nature Aging*. https://doi.org/10.1038/s43587-025-01000-2

Antoniou, M. (2019). The advantages of bilingualism debate. *Annual Review of Linguistics*, **5**, 1–21. https://doi.org/10.1146/annurev-linguistics-011718-011820

Arora, S., & Klein, R. M. (2020). Comparing bilingual and monolingual performance on the attention network test: Meta-analysis of a literature inspired by Albert Costa. *Journal of Cultural Cognitive Science*, **4**, 243–257. https://doi.org/10.1007/s41809-020-00068-z

Bialystok, E. (2011). Coordination of executive functions in monolingual and bilingual children. *Journal of Experimental Child Psychology*, **110**, 461–468. https://doi.org/10.1016/j.jecp.2011.05.005

Bialystok, E. (2024). Bilingualism modifies cognition through adaptation, not transfer. *Trends in Cognitive Sciences*, **24**(11), 987–997. https://doi.org/10.1016/j.tics.2024.07.012

Bialystok, E., & Craik, F. I. (2022). How does bilingualism modify cognitive function? Attention to the mechanism. *Psychonomic Bulletin & Review*, **29**, 1246–1269. https://doi.org/10.3758/s13423-022-02057-5

Chen, J., Jiang, C., & Liu, F. (2025). Do trilingual individuals exhibit an advantage over bilinguals in executive function tasks? *Acta Psychologica*, **259**, 105354. https://doi.org/10.1016/j.actpsy.2025.105354

Chertkow, H., Whitehead, V., Phillips, N., Wolfson, C., Atherton, J., & Bergman, H. (2010). Multilingualism (but not always bilingualism) delays the onset of Alzheimer disease: Evidence from a bilingual community. *Alzheimer Disease & Associated Disorders*, **24**(2), 118–125. https://doi.org/10.1097/WAD.0b013e3181ca1221

Cockcroft, K., & Alloway, T. (2012). Phonological awareness and working memory: Comparisons between south African and British children. *Southern African Linguistics and Applied Language Studies*, **30**, 13–24. https://doi.org/10.2989/16073614.2012.693706

Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, **113**, 135–149. https://doi.org/10.1016/j.cognition.2009.08.001

Costa, A., **Hernández, M.**, & **Sebastián-Gallés, N.** (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition*, **106**, 59–86. https://doi.org/10.1016/j.cognition.2006.12.013

Degirmenci, M. G., **Grossmann, J. A.**, **Meyer, P.**, & **Teichmann, B.** (2022). The role of bilingualism in executive functions in healthy older adults: A systematic review. *International Journal of Bilingualism*, **26**, 426–449. https://doi.org/10.1177/13670069211051291

DeLuca, V., **Rothman, J.**, & **Pliatsikas, C.** (2019). Linguistic immersion and structural plasticity in the bilingual brain: A longitudinal study. *Bilingualism: Language and Cognition*, **22**(6), 1160–1175.

Desideri, L., & **Bonifacci, P.** (2018). Verbal and nonverbal anticipatory mechanisms in bilinguals. *Journal of Psycholinguistic Research*, **47**, 719–739. https://doi.org/10.1007/s10936-017-9556-1

Donnelly, S., **Brooks, P. J.**, & **Homer, B. D.** (2019). Is there a bilingual advantage on interference-control tasks? A multiverse meta-analysis of global reaction time and interference cost. *Psychonomic Bulletin & Review*, **26**, 1122–1147. https://doi.org/10.3758/s13423-019-01567-z

Ebert, K. D. (2021). Revisiting the influences of bilingualism and developmental language disorder on children's nonverbal processing speed. *Journal of Speech, Language, and Hearing Research*, **64**, 3564–3570. https://doi.org/10.1044/2021_jslhr-21-00156

Fan, J., **McCandliss, B. D.**, **Sommer, T.**, **Raz, A.**, & **Posner, M. I.** (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, **14**, 340–347. https://doi.org/10.1162/089892902317361886

Faul, F., **Erdfelder, E.**, **Buchner, A.**, & **Lang, A. G.** (2009). Statistical power analyses using G*power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, **41**, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Gignac, G. E., & **Weiss, L. G.** (2015). Digit span is (mostly) related linearly to general intelligence: *Every extra bit of span counts*. *Psychological Assessment*, **27**(4), 1312–1323. https://doi.org/10.1037/pas0000105

Grundy, J. G. (2020). The effects of bilingualism on executive functions: An updated quantitative analysis. *Journal of Cultural Cognitive Science*, **4**, 177–199. https://doi.org/10.1007/s41809-020-00062-5

Grundy, J. G., & **Timmer, K.** (2017). Bilingualism and working memory capacity: A comprehensive meta-analysis. *Second Language Research*, **33**, 325–340. https://doi.org/10.1177/0267658316678286

Hilchey, M. O., **Saint-Aubin, J.**, & **Klein, R. M.** (2015). Does bilingual exercise enhance cognitive fitness in traditional non-linguistic executive processing tasks? In J. W. Schwieter (Ed.), *The Cambridge handbook of bilingual processing* (pp. 586–613). Cambridge University Press.

Kavé, G., **Eyal, N.**, **Shorek, A.**, & **Cohen-Mansfield, J.** (2008). Multilingualism and cognitive state in the oldest old. *Psychology and Aging*, **23**(1), 70–78. https://doi.org/10.1037/0882-7974.23.1.70

Kroll, J. F., & **Bialystok, E.** (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology*, **25**, 497–514. https://doi.org/10.1080/20445911.2013.799170

Lehtonen, M., **Soveri, A.**, **Laine, A.**, **Järvenpää, J.**, **de Bruin, A.**, & **Antfolk, J.** (2018). Is bilingualism associated with enhanced executive functioning in adults? A meta-analytic review. *Psychological Bulletin*, **144**, 394–425. https://doi.org/10.1037/bul0000142

Limberger, B. K., & **Buchweitz, A.** (2014). The effects of bilingualism and multilingualism on executive functions. *Revista Brasileira de Linguística Aplicada*, **21**, 27–51. https://doi.org/10.5007/1984-8412.2014v11n3p261

Luk, G., **de Sa, E.**, & **Bialystok, E.** (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition*, **14**, 588–595. https://doi.org/10.1017/S1366728911000010

Mahalanobis, P. C. (1936). On the generalized distance in statistics. *Proceedings of the National Institute of Sciences of India*, **2**, 49–55. https://www.jstor.org/stable/48723335

Nair, V. K., **Biedermann, B.**, & **Nickels, L.** (2017). Effect of socio-economic status on cognitive control in non-literate bilingual speakers. *Bilingualism: Language and Cognition*, **20**, 999–1009. https://doi.org/10.1017/S1366728916000778

Nour, S., **Struys, E.**, & **Stengers, H.** (2019). Attention network in interpreters: The role of training and experience. *Behavioral Sciences* (Basel, Switzerland), **9**(4), 43. https://doi.org/10.3390/bs9040043

Ooi, S. H., **Goh, W. D.**, **Sorace, A.**, & **Bak, T. H.** (2018). From bilingualism to bilingualisms: Bilingual experience in Edinburgh and Singapore affects attentional control differently. *Bilingualism: Language and Cognition*, **21**, 867–879. https://doi.org/10.1017/S1366728918000020

Paap, K. R. (2019). The bilingual advantage debates. In J. W. Schwieter & M. Paradis (Eds.), *The handbook of the neuroscience of multilingualism* (pp. 547–564). Wiley. https://doi.org/10.1002/9781119387725.ch34

Paap, K. R., & **Greenberg, Z. I.** (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology*, **66**, 232–258. https://doi.org/10.1016/j.cogpsych.2012.12.002

Paap, K. R., **Johnson, H. A.**, & **Sawi, O.** (2014). Are bilingual advantages dependent upon specific tasks or specific bilingual experiences? *Journal of Cognitive Psychology*, **26**, 615–639. https://doi.org/10.1080/20445911.2014.944914

Paap, K. R., **Johnson, H. A.**, & **Sawi, O.** (2015). Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex*, **69**, 265–278. https://doi.org/10.1016/j.cortex.2015.04.014

Pelham, S. D., & **Abrams, L.** (2014). Cognitive advantages and disadvantages in early and late bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **40**, 313–325. https://doi.org/10.1037/a0035224

Perquin, M., **Vaillant, M.**, **Schuller, A.**, **Pastore, J.**, **Dartigues, J.**, **Lair, M.**, **Diederich, N.**, & **on behalf of the MemoVie Group**. (2013). Lifelong exposure to multilingualism: New evidence to support cognitive reserve hypothesis. *PLoS One*, **8**(4), e62030. https://doi.org/10.1371/%20journal.pone.0062030

Petersen, S. E., & **Posner, M. I.** (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience*, **35**, 73–89. https://doi.org/10.1146/annurev-neuro-062111-150525

Posner, M. I., & **Petersen, S. E.** (1990). The attention system of the human brain. *Annual Review of Neuroscience*, **13**, 25–42. https://doi.org/10.1146/annurev.ne.13.030190.000325

Prior, A., & **MacWhinney, B.** (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition*, **132**, 253–262. https://doi.org/10.1017/S1366728909990526

Privitera, A. J., **Momenian, M.**, & **Weekes, B.** (2022). Task-specific bilingual effects in mandarin-English speaking high school students in China. *Current Research in Behavioral Sciences*, **3**, 100066. https://doi.org/10.1016/j.crbeha.2022.100066

Rodrigues, L. R., & **Zimmer, M. C.** (2016). Inhibitory and attentional control: The interaction between "professional activity" and bilingualism. *Psicologia: Reflexão e Crítica*, **29**, 36. https://doi.org/10.1186/s41155-016-0034-8

Roivainen, E. (2011). Gender differences in processing speed: A review of recent research. *Learning and Individual Differences*, **21**(2), 145–149. https://doi.org/10.1016/j.lindif.2010.11.021

Rueda, M., **Fan, J.**, **McCandliss, B.**, **Halperin, J.**, **Gruber, D.**, **Lercari, L.**, & **Posner, M.** (2004). Development of attentional networks in childhood. *Neuropsychologia*, **42**, 1029–1040. https://doi.org/10.1016/j.neuropsychologia.2003.12.012

Sabourin, L., & **Vīnerte, S.** (2019). Cognitive control among immersed bilinguals: Considering differences in linguistic and non-linguistic processing. *Bilingualism: Language and Cognition*, **22**, 590–605. https://doi.org/10.1017/S1366728918000524

Schroeder, S. R., & **Marian, V.** (2017). Cognitive consequences of trilingualism. *International Journal of Bilingualism*, **21**, 754–773. https://doi.org/10.1177/1367006916637288

Sherman, E. M. S., **Tan, J. E. E.**, & **Hrabok, M.** (2022). *A compendium of neuropsychological tests: Fundamentals of neuropsychological assessment and test reviews for clinical practice* (4th ed.). Oxford University Press.

Vivas, A. B., **Ladas, A. I.**, **Salvari, V.**, & **Chrysochoou, E.** (2017). Revisiting the bilingual advantage in attention in low SES Greek-Albanians: Does the level of bilingual experience matter? *Language, Cognition and Neuroscience*, **32**, 743–756. https://doi.org/10.1080/23273798.2016.1271442

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press

Weber-Fox, C. M., & **Neville, H. J.** (1996). Maturational constraints on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. *Journal of Cognitive Neuroscience*, **8**, 231–256. https://doi.org/10.1162/jocn.1996.8.3.231

Wechsler, D. (2012). *Escala de inteligencia de Wechsler Para adultos – IV*. Pearson.

Xing, S., & **Yang, J.** (2023). The impact of interpreting training experience on the attentional networks and their dynamics. *Brain Sciences*, **13**(9), 1306. https://doi.org/10.3390/brainsci13091306

Yang, H., **Hartanto, A.**, & **Yang, S.** (2016). The importance of bilingual experience in assessing bilingual advantages in executive functions. *Cortex*, **75**, 237–240. https://doi.org/10.1016/j.cortex.2015.11.018

https://doi.org/10.1017/S136672892610128X Published online by Cambridge University Press