Attention Networks in Multilingual Adults Who Do and Who Do Not Stutter

Gizem Aslan[a*], Theo Marinis[b], & Kurt Eggers[a,c,d]

[a] Department of Rehabilitation Sciences, Ghent University, Ghent, Belgium; [b] Department of Linguistics, University of Konstanz, Germany; [c] Department of Speech-Language Therapy and Audiology, Thomas More, Antwerp, Belgium; [d] Department of Psychology and Speech-Language Pathology, University of Turku, Turku, Finland

* Correspondence concerning this article should be addressed to Gizem Aslan, Department of Rehabilitation Sciences, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium. Phone: +32 09 332 0869, Email: gizem.aslan@ugent.be

Author Note

Gizem Aslan https://orcid.org/0009-0004-2207-8922, gizem.aslan@ugent.be

Theo Marinis https://orcid.org/0000-0002-4120-3141, t.marinis@uni-konstanz.de

Kurt Eggers https://orcid.org/0000-0003-4221-2063, kurt.eggers@ugent.be

Abstract

This study investigated whether multilinguals who stutter differ from multilinguals who do not stutter in terms of attention networks. Towards that end, it measured (a) performance differences in attention networks between multilinguals who stutter and those who do not stutter and (b) the correlation between stuttering characteristics and attention networks. Twenty-four multilingual Dutch-English speaking adults (20-46y), half of whom were diagnosed with stuttering, completed the Attentional Network Task (ANT; Fan et al., 2002) that evaluates the attention networks of alerting, orienting, and executive control. A language and social background questionnaire and a lexical decision task (LexTALE; Lemhöfer & Broersma, 2012) assessed the participants' language proficiency. The Stuttering Severity Instrument 4th Ed. (Riley, 2009) and the Brief Version of the Unhelpful Thoughts and Beliefs About Stuttering Scale (Iverach et al., 2016) were used to evaluate stuttering characteristics. The two groups did not differ in the ANT in terms of reaction time and error rate scores. Furthermore, no differences were observed in the three attention networks between the groups. Lastly, no correlation was found between stuttering characteristics and attention networks. The results suggest that the attention abilities of multilinguals who stutter do not differ from multilinguals who do not stutter.

Keywords: attention networks; stuttering; multilingualism; bilingualism; adults

Introduction

Stuttering is a multifactorial neurodevelopmental speech disorder, influenced by a complex relationship between linguistic, physiological, environmental, and psychological factors (Smith, 1999; Smith & Weber, 2017). The speech of people who stutter is characterized by disfluencies such as repetitions of sounds, syllables, or monosyllabic words; prolongations of sounds; and/or the inability to initiate sounds, labelled as blocks. These types of '*stuttering-like disfluencies'* (SLD), also defined as overt stuttering behaviours (American Speech-Language-Hearing Association, n.d.), differ from '*other disfluencies'* (e.g., interjections, phrase repetitions) and occur more frequently in the speech of individuals who stutter (Tumanova et al., 2014; Yairi & Seery, 2023). Stuttering may result in speech anxiety and avoidance behaviours and may impact effective communication and social participation (American Psychiatric Association, 2022).

Studies in the field of stuttering are predominantly oriented at monolingual speakers (e.g., Bakhtiar & Eggers, 2023; Byrd et al., 2015; Saad Merouwe et al., 2023). Even though the relationship between stuttering and multilingualism has been studied since 1937 (Travis et al., 1937), the data on multilingualism and stuttering are limited and, consequently, systematic research on their relationship is rare (Gahl, 2023; Saad Merouwe et al., 2022). The initial focus of the studies on stuttering and multilingualism was on exploring whether multilingualism was a risk factor for stuttering. Based on a large survey of school-aged children, out of which almost half were multilinguals, Travis et al. (1937) found a higher prevalence of stuttering in multilinguals than in monolingual children. Recently, Gahl (2020) scrutinized Travis et al.'s study and found the raw counts and prevalence rates reported in the study internally inconsistent, thus refuting the conclusions of the study. Also, others have documented the lack of evidence for multilingualism being a risk factor for stuttering (Byrd, Watson, et al., 2015; Packman et al., 2009; Saad Merouwe et al., 2022).

Multilingualism refers to making use of two or more languages in one's daily life (Grosjean, 2010), no matter where, when, and how these languages have been learned and applied (Laviosa & González-Davies, 2019). Chin and Wigglesworth (2007) define multilingualism as 'a continuum with individuals showing varying degrees of competence in each of the language macro skills (speaking, writing, reading, and listening).' (p.6). Existing research on multilingualism and stuttering has largely focused on how stuttering occurs in multilinguals who stutter (MuWS) and in which language they tend to stutter more (Krawczyk, 2018; Lim et al., 2008). Nwokah (1988) suggested three possible patterns for the manifestation of stuttering in multilinguals: a) stuttering only in one language, b) equal severity of stuttering in all languages and c) less stuttering in (any) one language. The last pattern has received the most support in the literature. Lately, the role of language proficiency on the stuttering severity in different languages of MuWS has also been studied. Language proficiency can be defined as the general ability to produce and comprehend a language, both verbally and written (Werle et al., 2020). The main finding has been that MuWS have a higher stuttering severity in their non-dominant language or in the language they are less proficient in (Al'Amri & Robb, 2021; Kashyap & Maruthy, 2020).

Both in people who stutter (e.g., Doneva et al., 2018) as well as in multilinguals (e.g., Chung-Fat-Yim et al., 2022), attention has been studied as a potential contributing factor to sensory, cognitive, and/or emotional between-group differences. Attention is a mechanism that underlies our perception of the world and the self-regulation of our thoughts and emotions (Posner & Rothbart, 2007). Posner and Petersen (1990) have suggested that the attention system can be divided into three separate subareas: alerting, orienting, and executive control (conflict). Alerting refers to the ability to achieve and maintain a state of vigilance to be ready to respond to environmental stimuli; orienting is defined as the selection of information from sensory input; and executive control includes resolving and monitoring conflict among responses

(Petersen & Posner, 2012). The alerting network reaches the adult level by late childhood, orienting by mid-childhood and executive control by early adolescence (Rueda & Posner, 2013).

Stuttering and attention networks

Producing speech relies on both language as well as motor speech production mechanisms (Maxfield et al., 2016). This process requires attentional resources to facilitate the activation of these mechanisms for establishing the necessary movements for fluent speech production (Roelofs & Piai, 2011). Several models (e.g., WEAVER++ model; Roelofs, 2008) propose that attentional resources are required across different stages of the word production process, extending from the word planning phase to the phonological encoding phase (Levelt et al., 1999). The potential link between stuttering and attentional resources has also been addressed (e.g., Eichorn et al., 2019; Singer et al., 2020). According to Ofoe et al. (2018), weaknesses in attention might influence speech, language, and motor skill development, and all of these skills have been involved to some degree in developmental stuttering. Attention skills of adults who stutter (AWS) have been studied using a variety of instruments, ranging from behavioural paradigms (e.g., Test of Everyday Attention; Robertson et al., 1996) to computerized testing of attention networks (e.g., Attention Network Test (ANT); Fan et al., 2002).

Doneva et al. (2018) investigated the attention skills of 25 pairs of AWS and adults who do not stutter (AWNS) using the Test of Everyday Attention. This test evaluates sustained, selective, and divided attention as well as attentional switching. The results revealed that AWS performed significantly worse on the visual selection and divided attention subtests. Furthermore, a significant negative correlation was found between stuttering severity, as measured by the percentage of stuttered syllables, and performance on these two subtests. The authors concluded that better attention skills might be associated with fewer speech disfluencies in speech production. Eggers et al. (2012) used the children's version of the ANT to examine the attention abilities of 41 pairs of children with and without stuttering. The efficiency of the orienting network was found to be significantly lower in the stuttering compared to the nonstuttering group. Albeit limited in number, these studies seem to point to lowered attentional abilities in individuals who stutter. A meta-analysis by Doneva (2020) on stuttering and attention also showed that AWS performed significantly worse than AWNS. Doneva (2020) stated that these findings could also suggest that stuttering sometimes co-occurs with poorer attention abilities.

Attention has also been well-researched in relation to anxiety (Hirsch & Mathews, 2012). Evidence for an impaired executive control network in clients with anxiety disorders has been found (Coussement et al., 2022) as well as links between rumination, perseverative thinking, and decreased executive control (Bernstein et al., 2017). Different studies in the field of stuttering have reported that increased anxiety is common in AWS due to the lifelong stuttering experience (Craig & Tran, 2014; Manning & Beck, 2013). Some have suggested that the need to regulate negative thoughts and experiences might take cognitive resources away from attentional regulation (Johnson et al., 2012) and lower attentional control skills (O'Bryan et al., 2017).

Multilingualism and attention networks

Costa et al. (2008) tested the attention networks of 200 young adults (100 monolinguals, 100 bilinguals) via the ANT. Results showed that bilinguals performed faster than monolinguals on the test. They were more efficient in alerting and executive control subareas. The authors suggested that the group of bilinguals has better attention mechanisms compared to the group of monolinguals. Similarly, Tao et al. (2011) used the ANT to assess the attention networks of 36 early bilinguals, 30 late bilinguals, and 34 monolingual young adults. This study looked at the relationship between the age of acquisition and executive control. Findings revealed that bilinguals had more advantages in executive control than monolinguals and early bilinguals were found to have a greater advantage than late bilinguals. Another study by Marzecová et al. (2013) investigated the impact of multilingualism on three subareas of attention networks in 35 young adults (17 monolinguals, 18 multilinguals) using the ANT. Marzecová et al. (2013) found that multilinguals had a significantly larger effect in alerting than monolinguals. The multilingual group had also a significantly smaller effect in executive control compared to the monolingual group. Given the discussion on whether or not multilingualism brings an advantage performing in non-verbal tasks (see Grundy, 2020), Bialystok and Craik (2022) suggested that attention control provides a more sufficient explanation for the variety of findings and group differences which would only occur when attention demands of a task go beyond the control abilities of one of the groups. Learning and using a second language depends upon attention networks due to processing and managing more than one language, suppressing interference from language(s) not in use, and navigating and switching between languages (Van den Noort et al., 2019). The latter sometimes results in code-switching (switching between languages either between and/or within utterances; Treffers-Daller et al., (2021)). It is believed that bilingualism may provide beneficial effects on attention networks, and this is why the term *‘bilingual advantage’* has been used (Grundy, 2020). On the other hand, some studies reported no bilingual advantage on non-verbal behavioural tasks (Paap, 2019; Paap et al., 2017; Ware et al., 2020). For instance, Paap et al. (2017) examined the bilingual advantage hypothesis by testing 122 bilinguals and 108 monolinguals using non-linguistic tasks such as Colour-Shape switching, Digit-Letter, and Semantic-Category tasks. The bilingual and monolingual groups did not perform significantly different across these tasks.

Purpose of the present study

So far, no study has investigated the attention networks of MuWS. Only two studies in the literature examined the executive functions of bilingual adults who stutter (Kornisch et al., 2017a, 2017b). Executive functions are essential for controlling, managing, and monitoring cognitive behaviours and they modulate attention (Zelazo, 2020). Findings from Kornisch et al. studies revealed that the bilingual stuttering group did not differ from the bilingual non-stuttering group in terms of reaction time and error rate performances. The authors claimed that bilingualism seems to offset deficits in executive functions attributed to stuttering. In light of this, the current study aims to investigate the relationship between stuttering in the non-dominant language and multilingualism in terms of attention networks to provide a better understanding of the relationship between these factors. The research questions of the current study are:

1) Do MuWS differ from multilinguals who do not stutter (MuWNS) in terms of attention networks? It is difficult to formulate a specific hypothesis for this question because it is unclear how previous findings in monolingual children who stutter can be applied to multilingual adults who stutter.
2) Is there a correlation between stuttering characteristics and attention networks? We hypothesise that there will be a negative correlation between some of the attention networks and stuttering characteristics, in line with Doneva's et al. (2018) study.

Method

Participants

Twenty-four adults (11 M, 13 F) between 20 and 46 years (*M* = 27.83; *SD* = 7.63) participated in the study. They were all paid volunteers and recruited online through word of mouth and social media announcements. All participants spoke Dutch as their first language and English as their second language. Based on a self-reported questionnaire, the participants were divided into two groups: 12 MuWS (6M, 6F) as the study group and 12 MuWNS (5M, 7F) as the control group. Specific inclusion criteria for MuWS were (a) a diagnosis of stuttering by a speech-language therapist, (b) no history of any speech-language impairment other than stuttering, and (c) no history of any vision and/or hearing impairment. Specific inclusion criteria for MuWNS were to have no history of any speech-language, vision and/or hearing impairment. As shown in Table 1, 21 participants (10 MuWNS, 11 MuWS) reported speaking additional languages. Informed consent was taken at the beginning of testing under a protocol approved by the ethical committee of the University of Konstanz. [Table 1 near here]

Materials and procedure

The study was designed as an online study using Gorilla Experiment Builder (Anwyl-Irvine et al., 2020). This is a cloud-based research platform used by researchers to create and implement online behavioural experiments. A unique web link is provided for each experiment to share with participants; thus, they can open and complete the experiment in their computer browsers (e.g. Google Chrome). This platform was found to be accurate and reliable to run online studies and provide high precision in measuring reaction time (Anwyl-Irvine et al., 2021). To avoid the influence of different browser types, our participants could only access the experiment via Google Chrome. Data were collected during one session for the control group and two sessions for the study group with each online session lasting approximately 45 minutes. Both test sessions started with the first author meeting each participant online via Zoom. The unique Gorilla link was shared with the participants who opened the experiment on their computer. The first author remained on Zoom until the end of each session to ensure that the participants understood the experiment well and were able to ask questions if needed. During the first session, the participants were informed about the different steps of the study, followed by administering a questionnaire, the Attention Network Test, and for the control group a lexical decision test. During the second session (only for the MuWS), a speech sample was collected, followed by completing questionnaires regarding their stuttering history and negative thoughts and beliefs towards stuttering and administering the lexical decision test. The participants were asked to be in a quiet environment where a secure internet connection was ensured during the sessions. They were allowed to have short breaks in between the tasks in both sessions.

Evaluation of multilingualism

A *language and social background questionnaire* (see Appendix A) was developed based on Coalson et al.'s (2013) and Choo and Smith's (2020) suggestions to allow for a precise description of the language profiles and demographics of the participants and incorporated some items from the Language History Questionnaire (Li et al., 2006) and the Bilingualism and Emotions Questionnaire (Dewaele, 2010). The questionnaire consisted of five main sections: (a) early language history, i.e. when and how participants' early language skills were acquired (e.g., '*What language or languages did you use in the home when you were a child?*'), (b) language proficiency, i.e. the current language level in four language modalities: speaking, reading, listening, and writing (e.g., '*List all languages you have learned and estimate your level of speaking, listening, reading, and writing in each language.*'), (c) current language use, i.e. the relative use of language during daily routines (e.g., '*Please indicate your current language use.*'), (d) frequency of code-switching, i.e. the frequency and context of switching languages (e.g., '*Please indicate how often you code-switch.*'), and (e) affective variables, i.e. the level of anxiety regarding speaking in other languages (e.g., '*How anxious are you when speaking your different languages?*').

In addition, the Lexical Test for Advanced Learners of English (LexTALE; Lemhöfer and Broersma, 2012) was administered. LexTALE is a lexical decision task, in which participants see words on a computer screen and have to decide whether or not these are existing words in English. It consists of 60 trials, with 40 existing English words and 20 non-existing words. Participants can take as much time as they need for the decision, but the whole task takes about 3 to 5 minutes to complete. The scoring is made based on correct answers, and is determined by the following calculation formula: ((Number of words correct/40*100) + (Number of nonwords correct/20*100)) / 2. LexTALE scores have been found to be good predictors of vocabulary knowledge and provide a fair indication of English proficiency (LexTALE; Lemhöfer and Broersma, 2012).

To examine differences between the control and study groups, descriptive analyses, student and Welch's t-tests, and Wilcoxon sum rank tests were carried out on the subareas of the language questionnaire and LexTALE. The results of the questionnaire and the LexTALE can be found in Table 2. The findings showed that the study group had significantly higher scores on Dutch language usage and affective variables in Dutch, while the control group scored significantly higher on the LexTALE. The two groups did not differ in any of the other variables.

[Table 2 near here]

Evaluation of attention networks

The Attention Network Task (ANT; Fan et al., 2002) is a computer-based task in which alerting, orienting, and executive control are measured. A summary of the ANT procedure is shown in Figure 1. [Figure 1 near here] During the task, participants needed to decide as fast as possible whether the middle arrow of a set of arrows points to the left or the right direction. The arrows were shown either above or below a fixation cross and were supplemented by flankers. The ANT included four cue conditions (no cue, centre, double, spatial) to measure alerting and/or orienting and three flanker conditions (congruent, incongruent, neutral) to measure executive control. Each cue condition provided information on the forthcoming appearance of the flanker condition. If a cue was either at the centre or double sides of the fixation cross, it indicated that the arrows would appear shortly. If a cue was spatial, it indicated both that the arrows would occur shortly and where they would occur. The test comprised one practice block and three experimental blocks. The practice block consisted of 24 trials with full feedback, whereas each of the three experimental blocks consisted of 96 trials without feedback. The practice block took almost 2 minutes to complete, while each experimental block took about 5 minutes.

In each trial, five events were presented. First, there was the fixation cross which was shown for a random variable time of 400–1600 msec. Following this, one of the cue conditions was presented for 100 msec. Next, the fixation cross was shown again, but this time for 400 msec. This was followed by the presentation of the flanker condition for up to 1700 msec. After a participant gave a response (the '*E*' key for the left and the '*I*' for the right), the flanker condition disappeared right away, and the fixation cross appeared again for a variable duration which was based on the duration of the first fixation cross (D1) and reaction times (RT) in the flanker condition (3500 msec minus the D1 minus RT). Each trial followed the same procedure, and this lasted for 4000 msec. Moreover, the fixation cross was always present in the centre of the screen during the whole trial.

The attention network scores were calculated by measuring how RTs were influenced by the types of cue and flanker conditions. Alerting efficiency was estimated by subtracting the mean RT of the double-cue conditions from the mean RT of the no-cue conditions (Eff.alert.=mean RTno cue – mean RTdouble cue). The efficiency of the orienting network was estimated by subtracting the mean RT of the spatial cue conditions from the mean RT of the central cue conditions (Eff.orient. = mean RTcentral cue – mean RTspatial cue). Lastly, the efficiency of the executive control effect was calculated by subtracting the mean of all RTs for congruent flanker conditions from the mean of all RTs for incongruent flanker conditions (Eff.exec. = mean RTincongruent flanker – mean RTcongruent flanker).

Stuttering assessment

A short questionnaire was created to obtain information on the participants' stuttering history. The MuWS were specifically asked to: (a) provide information about when they were diagnosed with stuttering, (b) rate their stuttering severity using an 8-point self-rating scale (O'Brian et al., 2018; 0 = no stuttering, 8 = extremely severe), and (c) provide information on any treatment they might have had (see Table 3). [Table 3 near here]

Stuttering characteristics were evaluated using the Stuttering Severity Instrument – Fourth Ed. (SSI-4; Riley, 2009) and the Brief Version of the Unhelpful Thoughts and Beliefs About Stuttering Scales (UTBAS-6; Iverach et al., 2016). The SSI-4 is a valid, standardized tool evaluating stuttering severity based on: (a) the frequency of stuttering occurrences, (b) the duration of stuttering occurrences, and (c) the physical concomitants. To obtain a representative sample of their stuttering behaviour, two types of speech samples were collected: (a) a reading sample and (b) a conversational speech sample. The UTBAS-6 is a scale that is used to measure negative thoughts and beliefs that are associated with social anxiety due to stuttering. MuWS were requested to rate six items (e.g., '*I'll never be successful because of my stutter*') that evaluate the frequency of unhelpful thoughts and beliefs about their stuttering using a 5-point self-rating scale (1 = never or not at all and 5 = always or totally). More specifically, they were asked about how frequently they have these thoughts, how much they believe these thoughts, and how anxious these thoughts make them feel.

All speech samples were video recorded on Zoom. Participants were asked not to use any fluency techniques they might have learned during therapy. The 10 to 15-minute conversational speech sample was collected by the first author based on standard closed and open questions (e.g., hobbies, vacation plans, university/college, work). During the speech sample collection, there was an intentional attempt to begin with a familiar topic to avoid any possible breakdowns in the communication. Then, more open-ended questions were gradually provided to increase language output. Samples were only collected in English (not also in

Dutch), as the aim of this study was not to examine differences in stuttering manifestations across the languages. The topics of conversations contained a range of topics and the participants were encouraged to produce exclusively English words during the conversation. The first minute of the sample was not included in the analysis: the following 300 consecutive syllables were analysed. For the reading task, the English passage from the SSI-4 was used which consisted of 364 syllables.

The entire analysis was done by the first author, an experienced speech and language therapist with specific training in disfluency analyses. To determine inter-rater reliability, 10% of the samples were analysed independently by the last author. The inter-rater reliability for these samples (point-by-point for location and type, see Ambrose & Yairi, 1999) was calculated based on the 'agreement index' percentage, that is the number of agreements divided by the sum of agreements and disagreements (Suen & Ary, 2014). The inter-rater reliability was 0.94.

Statistical analyses

Statistical analyses were undertaken using R Studio (RStudio Team, 2022). Homogeneity in group variance and normality distribution were calculated for each research group using Levene's and Shapiro-Wilk's tests. The rstatix package was used on R Studio to measure analyses of covariances (ANCOVAs) for investigating the ANT components. It was crucial to consider the performance differences in the LexTALE between the groups during these analyses. Thus, the influence of multilingualism on attention networks was taken into account. Therefore, all between-group analyses included the LexTALE score as a covariate.

Results

Between-group differences in the ANT

RTs and error rates

Trials with RTs greater than 2 SD (approximately 3%) and trials with errors (approximately 2%) were excluded from the RT analysis. To measure differences for each cue and flanker combination, ANCOVAs were performed separately for RTs and error rates. Group was set as independent variable, RT data in each cue and flanker combination as dependent variables, and LexTALE scores as covariate. Results showed no significant between-group effects for RTs, $F(1, 21) = 1.50$, $p = 0.23$, and error rates $F(1, 21) = 0.04$, $p = 0.83$.

Three (flanker type: neutral, congruent, incongruent) × four (cue condition: no, centre, double, spatial) ANCOVA calculations for RTs and error rates were separately carried out for each group with the LexTALE scores as covariate. The interaction between the cue and flanker combination is depicted in Figures 2 and 3. For the MuWS, significant RT main effects of flanker type, $F(2, 131) = 35.17$, $p < 0.001$, and cue condition, $F(3, 131) = 4.75$, $p < 0.01$, were found (Figure 2a). Tukey's post hoc comparisons indicated that the average RTs in the incongruent flanker type ($M = 597.48$, $SD = 64.49$) were significantly higher than those in the congruent ($M = 501.91$, $SD = 78.17$, $p < 0.001$) and the neutral ($M = 481.87$, $SD = 78.42$, $p < 0.001$) flanker types. Tukey's post hoc comparisons showed that the average RTs in the no-cue condition ($M = 561.48$, $SD = 75.43$) were significantly higher than in the spatial-cue condition ($M = 498.30$, $SD = 91.40$, $p < 0.01$). No significant interaction effects were observed for RT, $F(6, 131) = 0.46$, $p = 0.83$. [Figure 2 near here]

A significant main effect of error rate was found only in the flanker type, $F(2,131) = 25.13$, $p < 0.001$(Figure 2b). Tukey's post hoc comparisons indicated that the average error rate in the incongruent flanker type ($M = 1.93$, $SD = 2.28$) was significantly higher than that in the congruent ($M = 0.14$, $SD = 0.42$, $p < 0.001$) and the neutral ($M = 0.26$, $SD = 0.68$, $p < 0.001$) flanker types. No significant interaction effects were observed for error rates, $F(6, 131) = 1.40$, $p = 0.21$.

For the MuWNS, a similar pattern emerged. Significant RT main effects of flanker type, $F(2, 131) = 96.07$, $p < 0.001$ and cue condition $F(3, 131) = 14.14$, $p < 0.001$(Figure 3a) were observed. Tukey's post hoc comparisons indicated that: (a) the average RTs in the incongruent flanker type ($M = 560.13$, $SD = 53.15$) were significantly higher than those in the congruent ($M = 470.20$, $SD = 47.46$, $p < 0.001$) and the neutral ($M = 442.42$, $SD = 46.17$, $p < 0.001$) flanker types and (b) the average RTs in the neutral flanker type ($M = 442.42$, $SD = 46.17$) were significantly lower than in the congruent type ($M = 470.20$, $SD = 47.46$, $p < 0.01$). Tukey's post hoc comparisons showed that: (a) the average RTs in the no-cue condition ($M = 523.13$, $SD = 57.63$) were significantly higher than in the spatial-cue condition ($M = 456.75$, $SD = 62.23$, $p < 0.001$), (b) the average RTs in the double-cue condition ($M = 488.49$, $SD = 74.32$) were significantly lower than in the no-cue condition ($M = 523.13$, $SD = 57.63$, $p < 0.01$) and higher than the spatial-cue condition ($M = 456.75$, $SD = 62.23$, $p < 0.05$), and (c) the average RTs in the centre-cue condition ($M = 495.30$, $SD = 71.09$) were significantly lower than in the no-cue condition ($M = 523.13$, $SD = 57.63$, $p < 0.05$) and higher than in the spatial-cue condition ($M = 456.75$, $SD = 62.23$, $p < 0.01$). No significant interaction effects were observed for RT, $F(6, 131) = 0.93$, $p = 0.47$. [Figure 3 near here]

A significant error rate main effect was also found only in the flanker type, $F(2,131) = 24.87$, $p < 0.001$ (Figure 3b). Tukey's post hoc comparisons indicated that the average error rate in the incongruent flanker type ($M = 1.41$, $SD = 1.47$) was significantly higher than the one in the congruent ($M = 0.05$, $SD = 0.40$, $p < 0.001$) and the neutral ($M = 0.31$, $SD = 0.77$, $p < 0.001$) flanker types. No significant interaction effects were observed for error rates, $F(6, 131) = 0.85$, $p = 0.52$.

Attention networks

Between-group differences in attention network scores were examined using ANCOVAs. Participant group was set as independent variable, alerting, orienting, and conflict scores as dependent variables, and LexTALE scores as covariate. Table 4 shows the efficiency scores of each attentional network in both groups. No significant between-group differences were observed for the alerting scores $F(1,21) = 1.18$, $p = 0.28$, $\eta_p^2 = 0.053$, orienting scores $F(1,21) = 1.71$, $p = 0.20$, $\eta_p^2 = 0.075$, and executive control scores $F(1,21) = 0.02$, $p = 0.87$, $\eta_p^2 = 0.001$ (see Figure 4). [Table 4 and Figure 4 near here]

Correlation between stuttering characteristics and attention networks

Pearson correlational analyses were performed to evaluate the correlation between attention networks and stuttering characteristics in MuWS. The correlation examination of stuttering characteristics and attention networks was done between the SSI-4 scores (frequency, physical concomitants, and duration) and three attention networks as well as between the UTBAS-6 total scores and three attention networks. None of these analyses reached statistical significance ($p > 0.05$) (see Table 5). [Table 5 near here]

Discussion

This study addressed the efficiency of attention networks in MuWS. The limited research so far in bilinguals who stutter has shown no differences in executive functions between bilinguals who stutter and those who do not stutter. The present study aimed at filling this gap by comparing the attention networks between MuWS and MuWNS, and by investigating the relationship between stuttering characteristics and attention network performance. No prior study so far has used the ANT paradigm in MuWS.

MuWS and MuWNS did not differ in RT and error rate

No significant between-group differences were found for RTs or error rate percentages for the cue flanker combinations. Incongruent flankers led to an increase in RTs and error rates in both groups, similar to the findings from previous adult studies (Costa et al., 2008; Fan et al., 2002; Marzecová et al., 2013). Spatial cues reduced RTs for both groups, similar to the findings from the previous studies (Costa et al., 2008; Fan et al., 2002); however, it did not have any effect on the percentage of errors. These similarities with the previous literature confirm the validity of the current testing procedures. In our study, we did not find an interaction effect between cue type and flanker conditions, which is different from the findings of Costa et al. (2008) and Fan et al. (2002). The reason for that could possibly be attributed to methodological differences in statistical analysis (ANCOVA with LexTALE as covariate versus ANOVA) or participant criteria (multilingual stuttering and non-stuttering participants versus mono-/bilingual nonstuttering).

In comparison to Fan et al. (2002), who had a similar age group as the participants in our study, the mean error rates were considerably lower in our multilingual group. In other words, both MuWS and MuWNS in our study made less errors than the monolingual participants in Fan et al. Mean error percentages for multilinguals in the current study and the participants in Fan et al. were respectively 0.09 (*SD* = 0.41) and 0.57 (*SD* = 0.19) for the congruent trials, 1.67 (*SD* = 1.87) and 4.03 (*SD* = 0.63) for the incongruent trials, and 0.28 (*SD* = 0.73) and 1.11 (*SD* = 0.26) for neutral trials. In addition, based on the previous literature (Doneva, 2020), one would expect the stuttering group to have lower RTs but our MuWS had comparable RTs to both our MuWNS and Fan et al.'s participant group. Therefore, these findings seem to map onto the previously reported bilingualism advantage (e.g., Kornisch et al., 2017b). However, one cannot be certain that these differences might not also have been influenced by methodological differences between our study and Fan et al. In the study by Kornisch et al., 40 bilingual adults (half of whom stuttered) and 40 monolinguals (also half of whom stuttered) were presented with a selective identification task where objects were presented simultaneously to both visual fields with an arrow in between. Based on the direction of the arrow, participants had to select the correct word in a subsequent screen. No significant differences were found between the bilingual stuttering and nonstuttering groups. However, the bilingual participants, regardless of stuttering, had faster reaction times and fewer identification errors than monolingual participants. The authors also interpreted this finding as indicative of a bilingualism benefit.

MuWS and MuWNS did not differ in attention networks

Doneva et al. (2018) observed that monolingual AWS performed significantly worse than AWNS on visual selection (overlapping with the orienting network) and divided attention (overlapping with the executive control network) subtests. In our study with multilingual adults, we did not find such a difference between the stuttering and nonstuttering groups. According to D'Souza et al. (2020), multilinguals alternate their attention more frequently than monolinguals because they continuously have to navigate or shift between two or more languages and this shifting between languages results in better adaptation skills in the attention system of adults (D'Souza et al., 2021). Some ANT-based studies actually documented that bilinguals, compared to monolinguals, have an advantage in the efficiency of attentional networks, especially in the executive control network (Costa et al., 2008; Marzecová et al., 2013; Tao et al., 2011). The fact that we did not find any between-group differences in multilingual adults, might map onto the claim by Kornisch et al. (2017a) that bilingualism might counterbalance some of the deficits in attention networks that are attributed to stuttering. The same participant group as in Kornisch et al. (2017b), discussed higher up, was administered a dual-task paradigm. Their results also showed that there were no performance differences between bilinguals who stutter and those who do not stutter, and monolinguals who stutter experienced more dual-task interference compared to bilinguals who stutter and monolinguals who do not stutter.

No correlation between stuttering characteristics and attention networks

No significant correlations between stuttering characteristics, as measured by the SSI-4 and UTBAS-6, and the three attentional networks. This is in line with the nonsignificant results of previous studies correlating SSI-4 scores with inhibitory control, which conceptually overlaps with the executive control network (Tendera, 2019; Treleaven & Coalson, 2020, 2021). In contrast, Doneva et al. (2018) did find a significant negative correlation between SLD frequency and the performance on the visual selection and divided attention resources subcomponent of the Test of Everyday Attention. Somewhat oddly however, they defined SLD as “repetitions, prolongations, blocks, interjections, and revisions in speech.” (p.548), while it is well known that interjections and revisions are no indicators of stuttering severity and should be classified as ‘other disfluencies’ and not SLD (Yairi & Seery, 2023). So, this could be one of the reasons for their dissonant finding.

No studies have looked into the correlation between the UTBAS-6 and attentional networks previously but there were some studies correlating inhibitory control performance with the Overall Assessment of the Speaker’s Experience with Stuttering (OASES; Yaruss & Quesal, 2006). OASES and UTBAS-6 tap into slightly different aspects of stuttering characteristics; while UTBAS-6 only measures negative thoughts and beliefs, OASES evaluates general perspectives, reactions to stuttering, functional communication difficulties, and the impact on the quality of life. The UTBAS-6 overlaps most with the OASES section on reactions to stuttering. The findings from these studies are ambiguous. Some studies, such as Treleaven and Coalson, (2021), did not find a correlation, while others (Tendera, 2019; Treleaven & Coalson, 2020) observed correlations—albeit sometimes specifically with the overall OASES score or *Quality of Life* subsection. Furthermore, the aforementioned studies did not provide clear information on their participants’ language profiles. It seems that their AWS groups were a mix of bilingual and monolingual adults. Therefore, comparison with these studies is very difficult as well as making statements about the possible effect of bilingualism on negative emotions and thoughts related to stuttering.

Limitations and future research directions

The current study has some limitations. First, the experimental group is rather limited which warrants some caution in interpreting these findings and replication with a larger participant group would be appropriate. On the other hand, the domain of multilingualism and stuttering is an unexplored area so the findings add value and will prompt additional research in this population. Second, the fact that there is no other study that has compared attention networks in MuWS allows us only to compare the current findings to previous studies mainly based on monolinguals who stutter. Third, the current study was conducted online while the other studies took place in person. Fourth, because stuttering severity scores might have been impacted by treatment, future studies would benefit from collecting more detailed information about the kind of treatment, and if possible in this age group, to have a better balance between participants with and without treatment. Finally, the inclusion of a monolingual participant group in this study would have been ideal to obtain a more detailed insight into whether current findings were impacted by a bilingual advantage or not. However, in countries like Belgium and the Netherlands bilingualism is the norm, making it very difficult to find an adequate number of monolingual Dutch (young) AWS.

Further research in the field of multilingualism and stuttering should help determine whether attentional processes differ between multilinguals who do and do not stutter and could further our present understanding of the manifestation of stuttering as well as to what extent attentional processes play a role in stuttering characteristics of both MuWS and MuWNS.

Conclusion

The current study provides some emerging insights into the relationship between stuttering, multilingualism, and attention networks. The efficiency of attention networks in multilingual stuttering adults was statistically equal to their nonstuttering counterparts. Stuttering characteristics were not related to attention networks.

Declaration of interest

The authors report no conflicts of interest.

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Appendix A

A Language and Social Background Questionnaire

1. General information

1.1 Age: _____________

1.2 Sex: F [ ] M [ ] Other [ ] NA(I'd prefer not to answer) [ ]

1.3 Country of birth: _____________

1.4 If you were not born in Belgium or the Netherlands, which year did you move to Belgium or the Netherlands? ___________ (year)

1.5 Current country of residence: Belgium [ ] The Netherlands [ ]

Other (Please specify) [ ] ___________

1.6 What is the highest level of education you have completed?

None [ ] Primary school [ ] Secondary school [ ] Vocational education and training(MBO) [ ]

BA[ ] MA [ ] PhD[ ]

1.7 What do you do professionally?

University student [ ] Employee/Self-employed [ ] Unemployed/Seeking employment

Other(Please specify) [ ] _______

1.8 Have you ever had a hearing impairment or speech and language disorder?

No [ ] Yes(Only stuttering) [ ]

Yes (If it is other than stuttering, please specify) [ ] _________________________

1.9 Do you have a vision problem? No [ ] Yes(Please specify) [ ] _____________

1.10 What is your dominant hand? Right [ ] Left[ ]

2. Language History/Proficiency

2.1 Your first language(s): ____

2.2 List all languages you have learned & the age of first intensive contact *(if from birth, then write 0),* and estimate your level for speaking, listening, reading & writing *(1=Beginner, 7=Native-like).*

Language	Age	Speaking	Listening	Reading	Writing
		1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
		1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
		1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
		1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
		1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

2.3 What language or languages did you use at home before age 4?

____

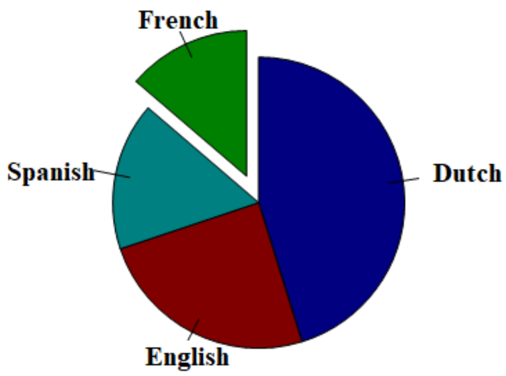
2.4 What language or languages do/did you use at university (if applicable)?

____

2.5 If you have taken any standardized language proficiency tests (e.g., TOEFL), then specify the name of the test, the language assessed, and the score you have obtained for each. If you do not remember the exact score, then write an "*Approximate score*" instead.

Test	**Language**	**Score**	**Approximate Score**

3. Language Function



3.1 Please indicate your **current** relative use of Dutch, English, and/or any other languages with percentages for the following activities like in the picture: For example: Dutch 45%, English 30%, French 13%, Spanish 12%

	Dutch	English	…… (another language)	……(another language)	..…(another language)
Speaking	%	%	%	%	%
Listening	%	%	%	%	%
Reading	%	%	%	%	%
Writing	%	%	%	%	%

4. Language Mode (Code-Switching)

4.1 Some people switch languages within a single conversation (e.g., while speaking one language, they use words or even sentences from another language). This is known as "**Code-Switching**". Please indicate how often you code-switch in the following situations:

	Never	Rarely	Sometimes	Often	Always
With parents, family members (incl. partner)	☐	☐	☐	☐	☐

With friends	☐	☐	☐	☐	☐
On social media (Facebook, Twitter, Instagram) and gaming	☐	☐	☐	☐	☐

4.2 Please indicate how often you code-switch when talking about certain matters.

	Never	Rarely	Sometimes	Often	Always
When speaking about neutral matters	☐	☐	☐	☐	☐
When speaking about personal matters (something related to income or political conviction, or family business etc)	☐	☐	☐	☐	☐
When speaking about emotional matters (anything that gets the heart beat faster)	☐	☐	☐	☐	☐

5. Affective Variables

5.1 How anxious are you when speaking your different languages with different people in different situations?

When speaking Dutch	Never	Rarely	Sometimes	Often	Always
With family members	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With colleagues	☐	☐	☐	☐	☐
With strangers	☐	☐	☐	☐	☐
On the phone	☐	☐	☐	☐	☐
In public	☐	☐	☐	☐	☐

When speaking English	Never	Rarely	Sometimes	Often	Always
With family members	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With colleagues	☐	☐	☐	☐	☐
With strangers	☐	☐	☐	☐	☐
On the phone	☐	☐	☐	☐	☐
In public	☐	☐	☐	☐	☐

	Never	Rarely	Sometimes	Often	Always
When speaking another language (*If it is applicable*) (**Please also specify the language below!**)					

<u>Language:</u>

With family members	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With colleagues	☐	☐	☐	☐	☐
With strangers	☐	☐	☐	☐	☐
On the phone	☐	☐	☐	☐	☐
In public	☐	☐	☐	☐	☐

When speaking another language (*If it is applicable*) (**Please also specify the language below!**) **<u>Language:</u>**	Never	Rarely	Sometimes	Often	Always
With family members	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With colleagues	☐	☐	☐	☐	☐
With strangers	☐	☐	☐	☐	☐
On the phone	☐	☐	☐	☐	☐
In public	☐	☐	☐	☐	☐

When speaking another language (*If it is applicable*) (**Please also specify the language below!**) **<u>Language:</u>**	Never	Rarely	Sometimes	Often	Always
With family members	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With colleagues	☐	☐	☐	☐	☐
With strangers	☐	☐	☐	☐	☐
On the phone	☐	☐	☐	☐	☐
In public	☐	☐	☐	☐	☐

Tables

Table 1. Demographic and language characteristics.

	Sex		Age		L1	L2	L3 users	L4 users	L5 users
	Female	Male	*M*	*SD*					
MuWNS	6	6	27	7.27	Dutch	English	3	2	5
MuWS	5	7	28.86	8.21	Dutch	English	5	3	3

Table 2. Descriptive and inferential statistics of self-rated language proficiency, age of acquisition, affective variables, code-switching of Dutch and English, and LexTALE in both groups.

	MuWNS (*n* = 12)			MuWS (*n* = 12)					
	Mean	SD	Min-Max	Mean	SD	Min-Max	*t*	*df*	*p*
Dutch									
Self-rating (7-point scale)[c]	6.93	0.15	6.5 - 7	6.47	1	4 - 7	-	-	0.17
Age of acquisition (years)[c]	0.58	2.02	0 - 7	0.66	1.61	0 - 5	-	-	0.65
Use (%)[c]	36.47	15.41	13.75 - 64.75	56.28	20.58	13.12 - 77.70	-	-	0.01*
Affective variables (4-point scale)[c]	0.38	0.59	0 - 1.6	1.56	0.99	0 - 3.6	-	-	<.01**
English									
Self-rating (7-point scale)[c]	6.29	0.38	5.75 – 7	5.91	1.04	3.25 – 7	-	-	0.40
Age of acquisition (years)[b]	10	2.41	5 – 13	11.58	1.72	8 – 14	-1.84	22	0.07
Use (%)[b]	49.95	18.59	16.25 – 77.50	37.02	18.90	12.50 – 83.75	1.69	22	0.10
Affective variables (4-point scale)[a]	0.48	0.43	0 – 1.3	1.73	0.96	0 – 2.83	-4.09	15.31	0.99
Code-switching[b]	2.11	0.74	0.5 – 3	1.97	0.95	0.3 - 3	0.39	22	0.69
LexTALE (%)[a]	86.09	5.87	73.91 - 94.30	76.28	11.32	62.27 - 96.47	2.66	16.51	<.01**

*Note: a: Welch's t-test, b: Student t-test, c: Wilcoxon rank sum; * p < 0.05, ** p < 0.01.*

Table 3. Individual participant information, stuttering history, and treatment history for multilinguals who stutter along with their overall stuttering rating, Stuttering Severity Instrument – Fourth Ed. (SSI-4), and the Brief Version of the Unhelpful Thoughts and Beliefs About Stuttering Scales (UTBAS-6).

Participant	Age of onset of stuttering (years)	Treatment	Duration of treatment (years)	Rating (8-point scale)	Frequency	Duration	Physical Concomitant	SSI-4	UTBAS-6
P1	4	Yes	14	6	7	6	7	Mild	65
P2	8	Yes	6	3	14	8	5	Moderate	26
P3	4	Yes	4*	3	15	14	9	Very Severe	50
P4	3	Yes	10*	2	12	6	2	Mild	49
P5	4	Yes	10	5	11	8	4	Mild	42
P6	6	Yes	4*	3	13	4	6	Mild	48
P7	3	Yes	10*	3	13	8	6	Moderate	41
P8	5	No	-	3	7	2	2	Very Mild	31
P9	2.5	Yes	7	2	13	10	5	Moderate	47
P10	7	Yes	2	6	7	4	2	Very Mild	45
P11	4	Yes	10	7	17	10	7	Severe	22
P12	5	Yes	12	2	9	6	4	Mild	23

*Note: *: Stuttering treatment was ongoing at the time of the experiment.*

Table 4. Efficiency scores in alerting, orienting, and conflict in multilinguals who stutter (MuWS) and multilinguals who do not stutter (MuWNS).

	MuWNS		MuWS	
	Mean	SD	Mean	SD
Alerting	34.60	14.95	44.21	15.83
Orienting	37.49	16.22	29.63	18.46
Executive Control	89.69	19.29	95.36	23.65

Table 5. Pearson Correlation Matrix between stuttering characteristic measurements and three attention networks.

	SSI-4								UTBAS-6	
	Frequency		Physical Concomitant		Duration		Total Score			
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Alerting	-0.24	0.43	-0.12	0.70	-0.33	0.29	-0.27	0.38	-0.22	0.47
Orienting	-0.10	0.75	-0.29	0.34	0.18	0.55	-0.05	0.87	0.12	0.70
Executive Control	-0.23	0.45	-0.24	0.44	-0.22	0.47	-0.26	0.40	0.11	0.71

Figures

Figure 1. Schematic overview of the Attentional Networks Test. (a) The cue conditions; (b) The flanker condition; and (c) The procedure. Redrawn from Fan et al. (2002).

Figure 2. Mean RT (a) and error rate (b) in each cue and flanker conditions for multilinguals who stutter (MuWS).

Figure 3. Mean RT (a) and error rate (b) in each cue and flanker conditions for multilinguals who do not stutter (MuWNS).

Figure 4. Attention network scores for the multilinguals who stutter (MuWS) and multilinguals who do not stutter (MuWNS).