



Cognitive-Affective Modeling of Speech Disfluency in Simultaneous Interpreting

- Elaheh Ghanavati***  *Corresponding Author, MA in Translation Studies, Department of English Language and Literature, Azarbaijan Shahid Madani University, Tabriz, Iran; elaheghanavati01@gmail.com*
- Reza Yalsharzeh**  *Assistant Professor, Department of English Language and Literature, Azarbaijan Shahid Madani University, Tabriz, Iran; r.yalsharzeh@azaruniv.ac.ir*
- Davoud Amini**  *Associate Professor, Department of English Language and Literature, Azarbaijan Shahid Madani University, Tabriz, Iran; d.amini@azaruniv.ac.ir*
- Mehran Soleymani**  *Associate Professor, Department of Educational Sciences and Psychology, Azarbaijan Shahid Madani University, Tabriz, Iran; msoleymani21@yahoo.com*

Abstract

This study examined simultaneous interpreting as an exceptional bilingual mode, focusing on relationships between cognitive and affective variables and their influence on speech disfluency. Cognitive tasks, self-report questionnaires, and an interpreting task assessed 71 proficient Persian–English bilingual adults; data were analyzed using Partial Least Squares Structural Equation Modeling. Path analysis revealed two significant direct effects: greater cognitive flexibility deficits were associated with higher anxiety levels, while greater selective attention deficits were linked to lower neuroticism. No other direct effects or mediation effects were statistically significant in this sample. These findings suggest that specific cognitive vulnerabilities may shape interpreters' emotional experience during high-demand bilingual performance, with implications for interpreter training and bilingual cognitive-affective interventions.

Keywords: Cognitive flexibility, emotional intelligence, selective attention, simultaneous interpreting, speech disfluency, working memory

Cite this article: Ghanavati, E., Yalsharzeh, R., Amini, D., & Soleymani, M. (2026). Cognitive-affective modeling of speech disfluency in simultaneous interpreting. *Translation and Interpreting Research*, 3(12), 1-17.
<https://doi.org/10.22054/tir.2026.94520.1073>



© 2026 – Allameh Tabataba'i University Press
Translation and Interpreting Research is licensed under a Creative Commons
Attribution-NonCommercial 4.0 International license.

Print ISSN: 3092-6599

Online ISSN: 3060-7019

Publisher: Allameh Tabataba'i University Press

Published: 30.12.2026

Accepted: 08.10.2026

Received: 16.09.2026

1. Introduction

According to Grosjean (1997, 2001, 2008, 2013), there exist exceptional situations in which bilinguals operate with both languages fully activated, a state that departs from the more common bilingual mode in which one language is clearly more active than the other. Two particularly salient cases illustrate this exceptional configuration: (1) when a bilingual is listening to two interlocutors who are each speaking a different language, and (2) when a bilingual is interpreting between two languages. In these circumstances, the source language and the target language are equally activated because both are indispensable for ongoing comprehension and production. Nevertheless, although two languages are active equally, the processing mechanisms remain unequal: the production system of the target language is fully engaged, whereas the production system of the source language is either deactivated or, in some cases, even inhibited.

Generally, interpreting is perceived as a form of verbal transfer, speech production, cognitive information processing, discourse management, or mediation (Pöchhacker, 2015). Interpreting is distinct from normal speaking due to its intricate cognitive demands, necessitating simultaneous processing capacities within a restricted timeframe (Gile, 2015). Despite the advancements made until now, the intricate nature of simultaneous interpreting and the challenge of pinpointing a single crucial variable among the many interacting factors in the entire process continue to pose challenges for psycholinguistic and cognitive approaches in simultaneous interpreting research (Diriker, 2015). Advances in cognitive science allow for theorizing about different components of speech comprehension and production, but the specific way in which these components work together to produce the intricate interpreting process is mostly a subject of speculation (Gile, 2015; see also Camayd-Freixas, 2011). Studies on speech disfluencies produced by typical speakers have been conducted since the 1950s as a window into the cognitive processes of speech planning (Bock & Levelt, 1994; Fromkin, 1973; Maclay & Osgood, 1959). Additionally, a consistent body of research has established that typical bilingual speakers display significantly elevated rates of speech disfluencies relative to monolingual speakers, with these rates frequently surpassing the clinical thresholds traditionally established for monolingual populations (Aslan & Eggers, 2025; Saad Merouwe et al., 2024).

In this study, we seek to investigate the bilingual process of simultaneous interpreting, as a special case of the bilingual mode (Grosjean, 2001). To accomplish this, we have established two primary objectives. The first objective is to assess the direct interrelationships between cognition, affect, and speech disfluency. The second objective is to examine the indirect interrelationships, focusing on the mediating role of affective variables in the relationship between cognition and speech disfluency.

Accordingly, the study addresses the following research question:

1. What relationship exists among cognitive variables (working memory, selective attention, and cognitive flexibility), affective variables (emotional intelligence, anxiety, and personality traits), and speech disfluency during simultaneous interpreting?

2. Literature Review

Speech disruptions can occur when individuals face articulatory disfluencies and are accompanied by a range of linguistic, physical, behavioral, and emotional symptoms (Bayerl et al., 2023). Articulatory disfluencies stem from challenges in speech planning, lexical or syntactic uncertainty, problems in production, and difficulties inherent in the cognitive processes involved in interpretation (Ashouri et al., 2021, Liu et al., 2004, Moser-Mercer, 2000, Pöchhacker, 2013, Setton, 2026, Shreve et al., 2011, Song & Li, 2020, Timarová, 2015, Timarová et al., 2014, Togato & Macizo, 2023, Tóth, 2011, Yudes et al., 2011, Zhao, 2022).

Moreover, for the psychological side, trait anxiety can present a significant challenge (Eysenck et al., 2007; Ilkowska & Engle, 2010; Matthews, 2020; Moran, 2016; Munoz et al., 2013). As a result, the ability to manage anxiety has long been considered a requirement (Alexieva, 1997; Cooper et al., 1982; Dong et al., 2013; Moser-Mercer et al., 1998). While there is limited empirical research on the effects of anxiety on interpreting performance, there is a widespread agreement that anxiety is inherent to interpreting, even though its precise impact is not well-defined (Zhao et al., 2023). Expanding on this, emotional intelligence (Goleman, 1995) and personality traits/affect (Humphreys & Revelle, 1984; Matthews, 2008, 2020; Walczyński, 2019) are also important factors.

Research in the field of “interpreter psychology” can be examined in terms of both cognitive and psycho-affective traits. While these two aspects are discussed separately, it is important to note that “by no means should such an organization of the discussion suggest that cognition is separated from emotionality and psycho-affectivity as they do go hand in hand and interact in the interpreting process” (Walczyński, 2019, p. 144). However, it seems that the psycho-affective aspect remains underrepresented among interpreting scholars, as there are still significant lacunae in our understanding of how an interpreter’s psycho-affectivity works and how it may influence interpreting performance (Walczyński, 2020).

Brisau et al. (1994) emphasized the strong relationship between cognitive and affective factors and interpreting performance. Similarly, Mead (2002) highlighted the potential influence of interpreters’ psycho-affective characteristics on the quality of their output. In examining disfluencies in interpreting, Mead also noted that such disruptions may arise not only from the demands of the interpreting process but also from external factors, such as nervous tension.

Linnenbrink and Pintrich (2004) stated that “there are many separate models of affect and cognition, but few models that attempt to integrate affect and cognition” (p. 57). There have been some theoretical breakthroughs in understanding the relationship between affect and cognitive processing (e.g., Dalgleish & Power, 1999; Forgas, 2000b, 2000c; Linnenbrink & Pintrich, 2004). Two distinct types of theories concerning the relationship between affect and cognitive processing have been developed (Linnenbrink & Pintrich, 2004). The first, known as appraisal theories (e.g., Boekaerts, 1993; Scherer, 1999; Smith & Lazarus, 1990), focuses on how cognitive appraisals of a given situation shape the emotions experienced, emphasizing the influence of cognition on affect (Linnenbrink & Pintrich, 2004). The second line of research investigates how affect impacts cognition (Bless, 2000; Fiedler, 2000; Forgas, 2000a; Linnenbrink & Pintrich, 2004). Drawing on these foundational insights, our study aimed to push the boundaries further by expanding our model to explore a relatively underexamined aspect of communication in the bilingual mode (when both languages are fully active), integrating an analysis of speech disfluency.

Zhao (2022) investigated how an interpreter’s cognitive traits (language proficiency, working memory, and anxiety) affect speech disfluencies in target language output among 53 student interpreters. The findings indicated that higher anxiety levels increased the overall occurrence of disfluencies, while language proficiency and working memory did not show a significant impact. Zhao stated that the observation made regarding the effects of anxiety aligns with previous theories suggesting that controlling anxiety plays a crucial role in interpreting ability (Alexieva, 1997; Cooper et al., 1982; Gile, 2009; Moser-Mercer et al., 1998). In a follow-up study, Zhao et al. (2023) further explored the influence of these cognitive traits on speech errors in consecutive interpreting, revealing that overall speech errors decreased with higher proficiency in the source (second) language and increased with greater anxiety among interpreters. Moreover, Song and Li (2020) conducted a longitudinal study with 28 participants on cognitive fluency and utterance fluency during simultaneous interpretation training. The analysis results supported the link between the efficiency of lexical access and the development of simultaneous interpretation utterance fluency. Also, in another study by Lin et al. (2018), to identify the factors contributing to fluency in simultaneous interpreting, a group of 22 interpreting students

undertook a series of tasks to test their language proficiency and working memory. The findings indicate that when considering overall fluency, both working memory and directionality significantly affect fluency. Notably, working memory is the sole variable that predicts fluency in both directions, accounting for 50% and 51% of the variability in disfluencies (Lin et al., 2018).

Surprisingly, the study by Lin et al. (2018) revealed that language proficiency has a limited role in predicting interpreting fluency, challenging the intuitive assumption that stronger second-language skills would directly enhance smooth target-language delivery. Similarly, Zhao (2022) found no effect of language proficiency on interpreting speech disfluencies (unlike their speech errors), with anxiety driving fillers and repetitions. These findings suggest that while proficiency may support overall comprehension and accuracy in interpreting, it does not significantly mitigate disfluencies, which are more deeply rooted in cognitive and emotional demands. Instead, these studies highlight the critical role of executive functions, particularly working memory, in enhancing interpreting fluency, alongside the affective dimension, with anxiety exerting a strong influence on fillers and repetitions (Zhao, 2022). While Song and Li (2020) focused exclusively on cognitive predictors, they overlooked affective factors such as anxiety, which Zhao (2022) identified as a significant contributor to disfluencies.

Collectively, these findings raise the question of whether the interplay between executive functions and affective variables constitutes a more powerful explanatory pathway for performance in the bilingual mode, especially given the intense cognitive and emotional demands of simultaneous interpreting. However, empirical research on the interaction between cognitive and affective factors in this context remains scarce. In particular, there is a notable gap in the application and empirical testing of Grosjean's (2001) bilingual mode framework, despite its clear relevance to understanding simultaneous interpreting, where both languages are fully active.

3. Methodology

This study employed a quantitative, non-experimental, cross-sectional design to examine the relationships among cognitive, affective, and speech-disfluency measures in simultaneous interpreting. The study involved 71 Iranian adult bilinguals, comprising 8 (PhD) university professors (11.2%), 16 master's students (22.6%), and 47 bachelor's students (66.2%), selected through purposive sampling to ensure their proficiency in Persian (L1) and English (L2) to accurately reflect potential cognitive and affective deficits rather than merely oscillations in language skills. Participants included individuals from Azarbaijan Shahid Madani University of Iran, trained in the subfields of English translation, English literature, and English language teaching (all completed the interpreting and translation courses). Participants were between the ages of 20 and 50 years. This age diversity was intended to enhance the richness and comprehensiveness of the data collected, ensuring understanding of the research topic across different life stages.

The assessments of participants were conducted individually in a language laboratory to ensure a systematic and focused approach to data collection. This one-on-one testing procedure provided each participant with sufficient attention and support, aiming to minimize confounding variables. Each session lasted one hour and thirty minutes and was structured to thoroughly explore participants' competencies. Prior to the main study, the procedure was pilot-tested with two English language professors (the second and third authors) to pinpoint and rectify any procedural issues. Additionally, data that did not meet the required standards of language proficiency were systematically excluded from analysis.

Initially, a speaking test was administered to all participants to evaluate their English proficiency and speech fluency, with the assessment conducted using AI from the *Speechace* website to maintain objectivity. Three uniform questions were posed to ensure consistency. To qualify for participation in

subsequent tests, participants were required to obtain a minimum IELTS band score of 7 on at least one question. In addition to the automated scores, each participant was monitored in real time to confirm that they met the eligibility criteria.

Upon confirmation of each participant's speaking proficiency in English, three self-report questionnaires were administered with the intent of measuring the participants' selected affective traits:

1. Big Five Inventory (BFI) for the analysis of personality traits (44-item inventory) by John and Srivastava (1999).
2. Beck (1988) Anxiety Inventory (BAI) for the assessment of trait anxiety levels (21-item inventory).
3. Emotional Intelligence (EI) questionnaire developed by Goleman (1995) for the evaluation of emotional intelligence (50-item inventory).

Seven affective-related variables, namely anxiety, emotional intelligence, extraversion, agreeableness, conscientiousness, neuroticism, and openness, were examined. Moreover, all three questionnaires were administered in English, without any modifications or alterations to their original format.

Following the completion of the questionnaires, participants were instructed to engage in three cognitive tasks. All cognitive tasks were conducted using the PEBL software (The Psychology Experiment Building Language) (Mueller & Piper, 2014).

1. N-Back Task, used to assess working memory.
2. Color Stroop Task, utilized to evaluate selective attention.
3. Berg Card Sorting Test (BCST), employed to measure cognitive flexibility.

In reporting the results of the cognitive tasks, we presented the total number of errors. For working memory, our analysis was focused exclusively on the dual-task trials of 1-, 2-, and 3-Back tasks, in which participants were simultaneously engaged in two tasks, namely auditory (letters) and visual (squares). Total Errors = auditory error + visual error.

Following completion of the cognitive tasks, participants performed a simultaneous interpreting task. They first listened to the initial four minutes of a TED Talk by Celeste Headlee (2015), titled "*10 Ways to Have a Better Conversation*," to familiarize themselves with the topic, speaker's accent, pace, and information density. From the fifth minute onward, participants interpreted a 5-minute-13-second segment from English (L2) into Persian (L1) in real time. The audio was played without pauses or replays, and compliance was monitored by the first author.

All interpretations were audio-recorded and analyzed using Sonic Visualiser (version 5.0.1). The first author conducted the primary analysis through repeated listening, with systematic manipulation of playback speed to facilitate accurate identification of disfluencies. Disfluencies were coded according to a structured framework (see Figure 1) comprising nine categories adapted from Ambrose and Yairi (1999) and Stes (2004). A speech block was defined as a silence lasting five seconds or longer (with each additional five-second interval counted separately) to distinguish extreme disfluency from ordinary pauses or strategic queuing. Queuing was operationalized as brief (2–3 second) strategic pauses to accommodate dense, rapid, low-volume, or unclear input (Camayd-Freixas, 2011). Analysis focused on the frequency (rather than duration) of disfluent markers. Revisions were examined at both sentence and word levels.

To assess interpretation completeness and distinguish true fluency from avoidance or omission, a reference Persian translation of the source speech was obtained from the *Downsub* website and cross-checked for accuracy. Abandoned sentences were identified by comparing participant outputs against

this reference. The source speech contained 82 sentences, coded for final analysis; abandoned sentences were aggregated with revisions for a combined “Revision and Abandoned Sentences” score.

To ensure transparency and reliability of the coding scheme, five recordings were randomly selected and independently rated by a third author (an English professor with 23 years of experience and prior publications in speech analysis; Rahimpour & Amini, 2013). Inter-rater agreement was quantified using a two-way mixed-effects intraclass correlation coefficient (ICC) in IBM SPSS (version 26).

	Disfluency type (abbreviation)	Description	Examples in English
Stuttering like disfluencies (SLD)	Part word repetition (PWR)	Repetition of a sound or syllable within or in the beginning of the word	thi thi this
	Monosyllabic word repetition (MonWR)	Repetition of a monosyllabic word	and and
	Prolongation (P)	Prolongation of a sound resulting in an atypical duration of that sound	mmmy cookie
	Block (B)	Stopping airflow and sound during or before production of a vowel or consonant	...girl
	Broken words (BW)	Stopping of airflow in the middle of a vowel within a word	o...pen
Other disfluencies (OD)	Filled pause (FP)	Filler words or non-linguistic sounds used within an utterance	Hey look uhmm at that
	Revision and abandoned sentences (R)	Correction of word choice, grammatical or phonological errors or add or delete lexical information	Mom ate fixed dinner. I want Hey look at that
	Multisyllabic word repetition (MulWR)	Repetition of a multi-syllabic word	because because
	Phrase repetition (PR)	Repetition of a phrase within an utterance	I want I want to go

Figure 1. Speech Disfluency Classification

Note. Ambrose and Yairi (1999); Stes (2004). Reprinted from Jansson-Verkasalo et al. (2020, p. 10).

Also refer to Natarrelli (2018).

All the data extracted from the three affective-related questionnaires, cognitive tasks, and audio recordings were subjected to analysis using IBM SPSS Statistics and were processed using SmartPLS software. We reported each question’s score (per questionnaire) separately in SPSS for detailed statistical analysis, ensuring a comprehensive evaluation of the data collected. Moreover, to ensure the clarity of our findings, we also opted to report the average score of the questionnaires. Subsequently, the data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM).

4. Results and Discussion

4.1. Descriptive Statistics of Cognitive Measures

The data (Table 1) reveal that working memory has the highest mean error rate, followed by cognitive flexibility, and selective attention (with the lowest). This pattern suggests that participants in this sample made the most errors in working memory tasks, indicating poorer performance in this domain compared to cognitive flexibility and selective attention. The difficulty indicated by these error rates points to working memory tasks as the most cognitively taxing, far exceeding cognitive flexibility and selective attention (Figure 2). This is reinforced by the wide range and high variability in working memory, where the error span suggests that while some participants managed relatively well, others struggled significantly. This variability contrasts with selective attention’s tighter range and lower standard deviation, indicating more consistent performance and less difficulty across participants. Cognitive flexibility shows moderate variability and difficulty, falling between the other two measures.

Table 1. Descriptive Statistics of Cognitive and Affective Measures

	Participants	Minimum	Maximum	Mean	Std. Deviation
Cognitive Flexibility	71	6.00	33.00	13.6197	5.44680
Selective Attention	71	.00	20.00	4.4930	4.37484
Working Memory	71	9.00	51.00	23.0000	7.85403
Anxiety	71	2.00	40.00	17.2676	9.30738
Emotional Intelligence	71	114.00	212.00	167.6056	20.19086
Extraversion	71	11.00	37.00	24.0423	6.18393
Agreeableness	71	16.00	41.00	33.1268	5.90382
Conscientiousness	71	18.00	42.00	29.8592	5.21891
Neuroticism	71	13.00	36.00	24.5634	5.57733
Openness	71	19.00	49.00	38.3944	6.22318

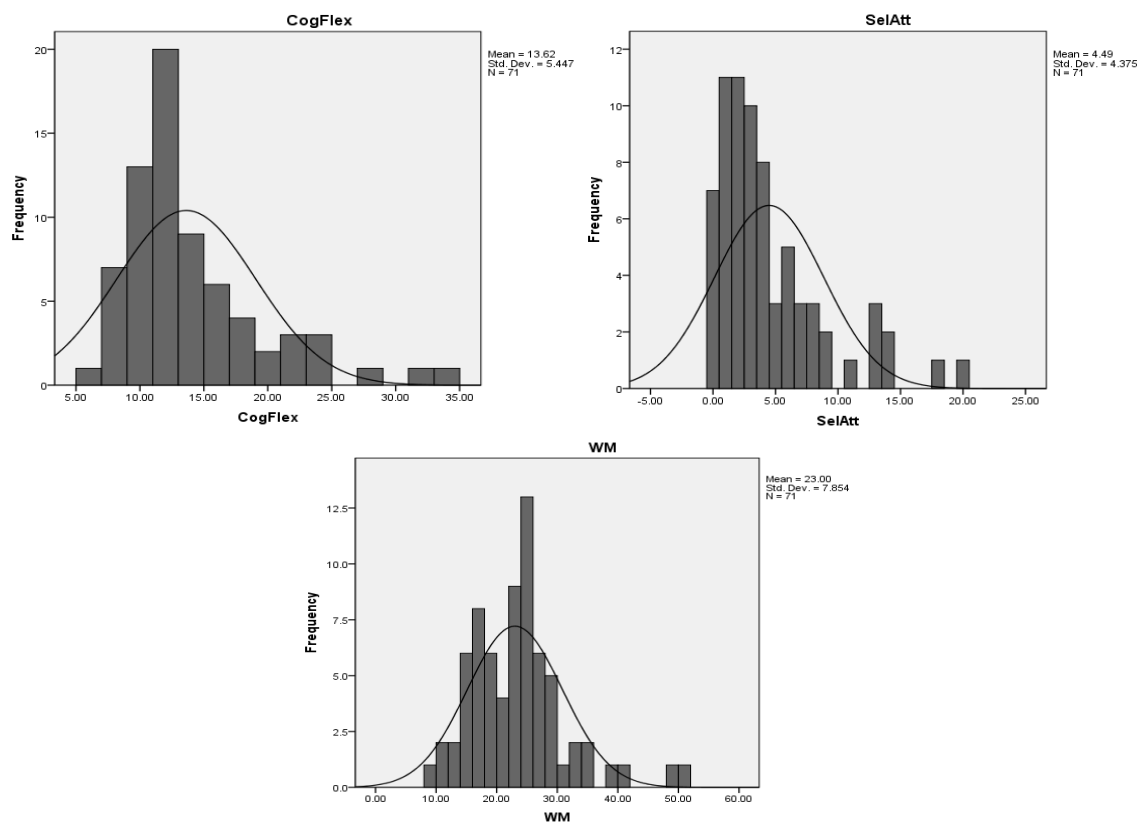


Figure 2. Histograms of Cognitive Measures

4.2. Reliability Analysis

Table 2. The Cronbach's Alpha Values for the Affective Measures

Test	Anxiety	EI	EX	Ag	Con	Neur	Op
Alpha	0.850	0.867	0.800	0.743	0.696	0.735	0.823

Note. Emotional Intelligence (EI), Agreeableness (Ag), Conscientiousness (Con), Extraversion (Ex), Neuroticism (Neur), Openness (Op).

The Cronbach's alpha values for the affective measures (Table 2) indicate their internal consistency among the whole group. All alpha values exceed 0.70, except for conscientiousness, which is marginally below but still considered acceptable, indicating reliable measurement scales.

4.3. Inter-rater Reliability

In this study, two raters independently evaluated five audio recordings to assess the occurrence of nine disfluency markers (Figure 1). To assess inter-rater reliability, a two-way mixed-effects intraclass correlation coefficient (ICC) was calculated with absolute agreement. The two raters' scores were compared on 45 cases (5 recordings $\times$ 9 disfluency markers). Agreement was good for single measures (ICC = .887, $p < .001$) and excellent for average measures (ICC = .940, $p < .001$).

4.4. Path Coefficient Analyses

Disfluency was treated as a single construct, and individual disfluency markers were not analyzed separately, as per the study design. Also, it should be noted that cognitive functions were assessed based on the number of errors recorded. Consequently, higher values in reported cognitive performance metrics indicate greater deficits in cognitive execution. Moreover, it is important to clarify that the term “revision” refers to the total number of both revised and abandoned sentences; however, for conciseness, it will be referred to simply as “revision.”

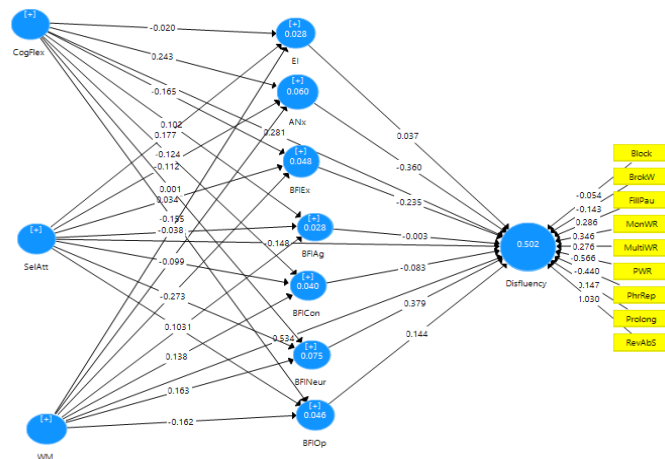


Figure 3. Structural Equation Modeling

Note. Anxiety (ANx), Agreeableness (BFIg), Conscientiousness (BFIcon), Extraversion (BFEx), Neuroticism (BFINeur), Openness (BFIOp), Cognitive Flexibility (CogFlex), Emotional Intelligence (EI), Selective Attention (SelAtt), Working Memory (WM), and Disfluency (part-word repetitions (PWR), monosyllabic word repetitions (MonWR), prolongations (Prolong), blocks (Block), broken words (BrokW), filled pauses (FillPau), revisions and abandoned sentences (RevAbS), multi-syllable word repetitions (MultiWR), and phrase repetitions (PhrRep).

4.4.1. Direct Effects

Cognitive Flexibility $\rightarrow$ Anxiety ($p = 0.017$, significant): Cognitive flexibility significantly predicted anxiety, showing a positive relationship whereby greater deficits in cognitive flexibility were associated with higher anxiety. Cognitive flexibility is essential for managing stress and adapting to new situations (Cañas et al., 2003). Deficits in this domain may impair coping mechanisms, leading to elevated anxiety when individuals struggle to adjust to environmental or emotional demands. This finding aligns with existing research linking anxiety to impairments in executive functioning. Specifically, attentional control theory (Eysenck et al., 2007) suggests that anxiety reduces the efficiency of the goal-directed attentional system, which is critical for tasks requiring cognitive flexibility, such as shifting attention. Anxiety can also impair working memory capacity (Moran, 2016) and the suppression of irrelevant

information, both key processes for effective task switching. These mechanisms are further supported by Derakshan and Eysenck (2009), who demonstrated that anxiety negatively affects cognitive performance on tasks demanding attentional control and flexibility.

Selective Attention -> Neuroticism ($p = 0.026$, significant): Selective attention significantly predicted neuroticism, revealing a negative relationship whereby greater selective attention deficits were associated with lower neuroticism. This finding contrasts with previous literature suggesting that attention deficits usually increase neuroticism due to distractibility (Eysenck et al., 2007). One possible explanation is that individuals with higher neuroticism exhibit increased vigilance and arousal, which may enhance performance on selective attention tasks by improving sensitivity to relevant stimuli and facilitating the filtering of distractions. This pattern is consistent with the inverted-U hypothesis of arousal and performance (Yerkes & Dodson, 1908), whereby moderate levels of arousal, often associated with neuroticism, can optimize cognitive performance. Attentional control theory (Eysenck et al., 2007) further suggests that anxiety-related components of neuroticism may shift attention toward stimulus-driven processes, potentially benefiting certain selective attention tasks. Additionally, compensatory strategies such as increased effort and caution driven by fear of failure may also contribute to this relationship (Munoz et al., 2013).

4.4.2. Additional Observations of Regression Coefficients

Extraversion -> Disfluency ($p = 0.228$, not significant): Extraversion showed a moderate negative association with disfluency, suggesting that higher levels of extraversion are related to lower disfluency, although the relationship did not reach statistical significance. This pattern is consistent with previous research (Dewaele & Furnham, 1999) and can be explained by the tendency of extraverts to possess stronger social skills and greater verbal fluency. Extraverts are generally more comfortable in communicative situations, which may reduce the occurrence of disfluencies (McCrae & Costa, 1999).

Neuroticism -> Disfluency ($p = 0.237$, not significant): Neuroticism showed a positive association with disfluency, suggesting that higher levels of neuroticism are related to increased disfluency, although the relationship was not statistically significant. This direction aligns with theoretical expectations, as individuals high in neuroticism tend to experience greater anxiety and emotional arousal, which can lead to more frequent speech hesitations and disfluencies (Arnaiz & Pérez-Luzardo, 2014; Craig, 1990; Menzies et al., 1999; Messenger et al., 2004; Zhao, 2022).

Working Memory -> Disfluency ($p = 0.172$, not significant): Working memory emerged as the strongest predictor of disfluency, showing a strong positive association, although the effect did not reach statistical significance. Importantly, the effect size was large ($f^2 = 0.469$), indicating substantial practical relevance. Specifically, greater deficits in working memory were associated with higher levels of disfluency. This finding is theoretically meaningful, as working memory is critical for maintaining and producing fluent speech through effective planning, monitoring, and self-correction (Baddeley, 2003; Ilkowska & Engle, 2010; Lin et al., 2018). Deficits in working memory are therefore expected to increase hesitations and other disfluencies.

4.4.3. Indirect Effects

Cognitive Flexibility -> Disfluency: $\beta = -0.061$, $T = 0.616$, $p = 0.538$ (not significant)

Selective Attention -> Disfluency: $\beta = -0.042$, $T = 0.298$, $p = 0.766$ (not significant)

Working Memory -> Disfluency: $\beta = -0.009$, $T = 0.083$, $p = 0.934$ (not significant)

All the mediated paths from cognitive flexibility, selective attention, and working memory to disfluency, through anxiety, personality traits, and emotional intelligence, were non-significant, suggesting no evidence of mediation in the model. The absence of significant indirect effects suggests that anxiety, personality traits, and emotional intelligence do not mediate the relationships between cognitive variables and disfluency in this sample. For instance, although cognitive flexibility predicts anxiety, the subsequent path from anxiety to disfluency is not significant, breaking the mediation chain. This lack of mediation may indicate that disfluency is influenced by unmodeled variables. The influence of additional variables can lead to a reduction or an enhancement of the significance of a given variable. Here, this observation is evident in the rising p-values for the indirect effects of cognitive flexibility, selective attention, and working memory. Notably, coefficients have shifted markedly further from statistical significance, a trend that is especially evident for working memory.

4.5. Model Fit

The overall model fit was assessed using several indices. The SRMR was 0.062 for the saturated model and 0.091 for the estimated model, both below the recommended threshold of 0.10 (and close to the more conservative cutoff of 0.08), indicating acceptable fit. The discrepancy measures d_{ULS} (0.725 saturated / 1.579 estimated) and d_G (0.219 saturated / 0.495 estimated) showed some deviation, though interpretation relies primarily on comparison with bootstrap confidence intervals. The Chi-Square statistic (74.507 saturated / 149.467 estimated) was significant, which is common in PLS-SEM with smaller samples. The NFI was 0.821 (saturated) and 0.641 (estimated). Overall, the fit indices suggest an acceptable but not excellent model fit, likely influenced by the relatively small sample size ($n = 71$) and the complexity of the proposed relationships.

4.6. R-squared, F-squared, and Predictive Power

The regression model accounted for 50.2% of the variance in Disfluency ($R^2 = 0.502$; adjusted $R^2 = 0.419$), indicating moderate explanatory power. Nearly half of the variance remains unexplained, likely due to unmeasured variables and the small sample size ($n = 71$). The higher R^2 for Disfluency (0.502) suggests that the model effectively captures factors influencing speech disfluency.

The f^2 effect sizes revealed varying predictor importance. Working Memory showed a large effect ($f^2 = 0.469$), followed by moderate effects from Neuroticism ($f^2 = 0.207$) and Anxiety ($f^2 = 0.184$). The remaining predictors had small or negligible effects: Cognitive Flexibility (0.132), Extraversion (0.102), Openness (0.032), Selective Attention (0.033), Conscientiousness (0.008), Agreeableness (0.000), and EI (0.001). Notably, working memory exerted the strongest influence on disfluency despite its non-significant path coefficient, consistent with prior findings (Lin et al., 2018). Overall, Working Memory, Neuroticism, and Anxiety emerged as the key predictors of disfluency.

The relatively small sample size ($N = 71$) likely reduced statistical power and limited the generalizability of the results. Although our sample is larger than those in several similar studies, such as 22 participants (Lin et al., 2018), 28 (Song & Li, 2020), 53 (Zhao, 2022; Zhao et al., 2023), and 54 (Jansson-Verkasalo et al., 2020), it remains modest for complex PLS-SEM models. A larger sample would likely improve model fit and increase the detection of smaller effects.

Additionally, ceiling/floor effects in some cognitive measures and multicollinearity among predictors may have obscured certain relationships. Regarding disfluency coding, although inter-rater reliability was assessed, the primary analysis was conducted by a single researcher (the first author), with a second rater evaluating five recordings. Similar studies, such as Zhao (2022), employed two additional raters to evaluate two audio recordings. Although we used one fewer rater, the analysis of a greater number of recordings improves the representativeness of our dataset and enhances the reliability of

our validation process. Furthermore, unlike the current study, most previous works (Lin et al., 2018; Song & Li, 2020; Zhao, 2022; Zhao et al., 2023) did not report specific inter-rater reliability scores or means, limiting direct comparisons.

5. Conclusion

The present model accounted for 50.2% of the variance in Disfluency, with working memory emerging as the strongest predictor. Although this effect was not statistically significant, the findings align with theoretical accounts emphasizing the critical role of working memory in fluent speech production (Baddeley, 2003; Lin et al., 2018). Significant direct effects were observed between cognitive flexibility and anxiety, and between selective attention and neuroticism. No mediation effects were found, suggesting that anxiety, personality traits, and emotional intelligence did not serve as intermediaries in this model. Overall, while the model captured important relationships, the relatively modest R^2 values indicate the influence of additional unmodeled factors.

The present findings offer some insights for identifying bilinguals who are particularly vulnerable to affective-cognitive strains when operating in the bilingual mode. According to Grosjean's (2001) language-mode continuum, bilinguals rarely function in a purely monolingual mode; rather, they typically operate toward the bilingual end of the continuum, where both languages are co-activated. The higher rates of disfluency commonly observed in bilinguals (Aslan & Eggers, 2025; Saad Merouwe et al., 2024) can thus be viewed as a natural consequence of this dual-language activation and the ongoing cognitive control processes it demands. By integrating cognitive and affective factors, the current study highlights the value of examining these dimensions jointly to better understand bilingual functioning, especially at the more demanding end of the continuum. These insights may hold practical relevance for educational and interpreting programs designed for bilingual populations. Future research can systematically manipulate the degree of bilingual-mode activation to examine its effects on disfluency and affective-cognitive strain.

Authors' Contributions

Elaheh Ghanavati (elahehghanavati01@gmail.com): conceptualization, data collection, data analysis, investigation, methodology, writing (original draft, review and editing);
 Reza Yalsharzeh: conceptualization, supervision, writing (review and editing);
 Davoud Amini: conceptualization, supervision, inter-rater, writing (review and editing);
 Mehran Soleymani: conceptualization, supervision.

AI Declaration

During the preparation of this article, the author(s) used Grok3 and QuillBot to assist with literature summarization, paraphrasing, and formalizing text. After using these tools, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Acknowledgements

This article is based on research conducted as part of the first author's master's thesis at Azarbaijan Shahid Madani University of Iran, Tabriz. Consequently, it is essential to acknowledge that this article is one of the three publications extracted from the thesis that investigate various dimensions of a shared dataset, with each publication employing a distinct analytical method to address different research questions. The results presented in this work are designed to complement the findings

documented in the other publications. Therefore, given the interconnected nature of the research, it is essential to note that certain methodologies, tables, and arguments may overlap; however, each article is designed to stand independently and provides unique contributions to the field.

Ethical Statement

A code of ethics was obtained from the Research Ethics Committees of Azarbaijan Shahid Madani University, and informed written consent was signed and obtained from each participant.

Research Ethics Committees approval ID: IR.AZARUNIV.REC.1403.021

Data Availability

All data are available at: 10.6084/m9.figshare.29562263

References

- Alexieva, B. (1997). A typology of interpreter-mediated events. *The Translator*, 3(2), 153–174. <https://doi.org/10.1080/13556509.1997.10798996>
- Ambrose, N. G., & Yairi, E. (1999). Normative disfluency data for early childhood stuttering. *Journal of Speech, Language, and Hearing Research*, 42(4), 895–909. <https://doi.org/10.1044/jslhr.4204.895>
- Arnaiz, P., & Pérez-Luzardo, J. (2014). Anxiety in Spanish EFL university lessons: Causes, responsibility attribution and coping. *Studia Anglica Posnaniensia*, 49(1), 57–76. <https://doi.org/10.2478/stap-2014-0003>
- Aslan, G., & Eggers, K. (2025). Multilingualism, speech disfluencies, and stuttering: A scoping review. *Journal of speech, language, and hearing research: JSLHR*, 68(8), 3869–3886. https://doi.org/10.1044/2025_JSLHR-24-00479
- Ashouri, M., Bahri, H., & Babaii, E. (2021). The relationship between selective attention and simultaneous interpreting performance in undergraduate students of translation. *Iranian Journal of Applied Linguistics*, 24(1), 67–102. <https://ijal.khu.ac.ir/article-1-3132-en.html>
- Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, 36(3), 189–208. [https://doi.org/10.1016/s0021-9924\(03\)00019-4](https://doi.org/10.1016/s0021-9924(03)00019-4)
- Bayerl, S. P., Gerczuk, M., Batliner, A., Bergler, C., Amiriparian, S., Schuller, B., Nöth, E., & Riedhammer, K. (2023). Classification of stuttering – The ComParE challenge and beyond. *Computer Speech & Language*, 81. <https://doi.org/10.1016/j.csl.2023.101519>
- Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology*, 56(6), 893–897. <https://doi.org/10.1037/0022-006X.56.6.893>
- Bless, H. (2000). The interplay of affect and cognition: The mediating role of general knowledge structures. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 201–222). Cambridge University Press.
- Bock, K., & Levelt, W. J. M. (1994). Language production: Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). Academic Press.

- Boekaerts, M. (1993). Being concerned with well-being and with learning. *Educational Psychologist*, 28(2), 149–167. https://doi.org/10.1207/s15326985ep2802_4
- Brisau, A., Godijns, R., & Meuleman, C. (1994). Towards a psycholinguistic profile of the interpreter. *Meta*, 39(1), 87–94. <https://doi.org/10.7202/002147ar>
- Camayd-Freixas, E. (2011). Cognitive theory of simultaneous interpreting and training. In *Proceedings of the 52nd Conference of the American Translators Association* (pp. 1–10). American Translators Association. https://www.academia.edu/303839/Cognitive_Theory_of_Simultaneous_Interpretation
- Cañas, J. J., Quesada, J. F., Antolí, A., & Fajardo, I. (2003). Cognitive flexibility and adaptability to environmental changes in dynamic complex problem-solving tasks. *Ergonomics*, 46(5), 482–501. <https://doi.org/10.1080/0014013031000061640>
- Cooper, C. L., Davies, R., & Tung, R. L. (1982). Interpreting stress: Sources of job stress among conference interpreters. *Multilingua*, 1(2), 97–107. <https://doi.org/10.1515/mult.1982.1.2.97>
- Craig, A. (1990). An investigation into the relationship between anxiety and stuttering. *Journal of Speech and Hearing Disorders*, 55(2), 290–294. <https://doi.org/10.1044/jshd.5502.290>
- Dalgleish, T., & Power, M. J. (1999). Cognition and emotion: Future directions. In T. Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 799–805). Wiley.
- Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist*, 14(2), 168–176. <https://doi.org/10.1027/1016-9040.14.2.168>
- Dewaele, J.-M., & Furnham, A. (1999). Extraversion: The unloved variable in applied linguistic research. *Language Learning*, 49(3), 509–544. <https://doi.org/10.1111/0023-8333.00098>
- Diriker, E. (2015). Simultaneous interpreting. In F. Pöchhacker (Ed.), *Routledge encyclopedia of interpreting studies* (pp. 382–384). Routledge. <https://doi.org/10.4324/9781315678467>
- Dong, Y., Cai, R., Zhao, N., & Lin, J. (2013). An empirical study on interpreting competence structures in student interpreters. *Foreign Languages*, 36(4), 76–86.
- Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, 7(2), 336–353. <https://doi.org/10.1037/1528-3542.7.2.336>
- Fiedler, K. (2000). Toward an integrative account of affect and cognition phenomena using the BIAS computer algorithm. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 223–252). Cambridge University Press.
- Forgas, J. P. (2000a). Affect and information processing strategies: An interactive relationship. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 253–280). Cambridge University Press.
- Forgas, J. P. (2000b). Feeling and thinking: Summary and integration. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 387–406). Cambridge University Press.
- Forgas, J. P. (2000c). *Feeling and thinking: The role of affect in social cognition*. Cambridge University Press.
- Fromkin, V. A. (Ed.). (1973). *Speech errors as linguistic evidence*. Mouton Publishers. <https://doi.org/10.1515/9783110888423>

- Gile, D. (2009). *Basic concepts and models for interpreter and translator training* (Rev. ed.). John Benjamins. <https://doi.org/10.1075/btl.8>
- Gile, D. (2015). The contributions of cognitive psychology and psycholinguistics to conference interpreting: A critical analysis. In A. Ferreira & J. W. Schwieter (Eds.), *Psycholinguistic and cognitive inquiries into translation and interpreting* (pp. 41–64). John Benjamins. <https://doi.org/10.1075/btl.115>
- Goleman, D. (1995). *Emotional intelligence*. Bantam Books. <https://psycnet.apa.org/record/1995-98387-000>
- Grosjean, F. (1997). The bilingual individual. *Interpreting*, 2(1/2), 163–187. <https://doi.org/10.1075/intp.2.1-2.07gro>
- Grosjean, F. (2001). The bilingual's language modes. In J. Nicol (Ed.), *One mind, two languages: Bilingual language processing* (pp. 1–22). Blackwell. <https://doi.org/10.1017/9781009210409.004>
- Grosjean, F. (2008). *Studying bilinguals*. Oxford University Press. <https://doi.org/10.1017/S0022226709990089>
- Grosjean, F. (2013). Bilingualism: A short introduction. In F. Grosjean & P. Li (Eds.), *The psycholinguistics of bilingualism* (pp. 5–25). John Wiley & Sons. <https://doi.org/10.1111/ijal.12047>
- Headlee, C. (2015). *10 ways to have a better conversation* [Video]. TED Conferences. https://www.ted.com/talks/celeste_headlee_10_ways_to_have_a_better_conversation
- Humphreys, M. S., & Revelle, W. (1984). Personality, motivation and performance: A theory of the relationship between individual differences and information processing. *Psychological Review*, 91(2), 153–184. <https://doi.org/10.1037/0033-295X.91.2.153>
- Ilkowska, M., & Engle, R. W. (2010). Trait and state differences in working memory capacity. In A. Gruszka, G. Matthews, & B. Szymura (Eds.), *Handbook of individual differences in cognition: Attention, memory, and executive control* (pp. 295–320). Springer. https://doi.org/10.1007/978-1-4419-1210-7_18
- Jansson-Verkasalo, E., Silvén, M., Lehtiö, I., & Eggers, K. (2020). Speech disfluencies in typically developing Finnish-speaking children – Preliminary results. *Clinical Linguistics & Phonetics*, 35(8), 707–726. <https://doi.org/10.1080/02699206.2020.1818287>
- John, O. P., & Srivastava, S. (1999). The Big-Five trait taxonomy: History, measurement, and theoretical perspectives. In L. A. Pervin & O. P. John (Eds.), *Handbook of personality: Theory and research* (Vol. 2, pp. 102–138). Guilford Press.
- Lin, Y., Lv, Q., & Liang, J. (2018). Predicting fluency with language proficiency, working memory, and directionality in simultaneous interpreting. *Frontiers in Psychology*, 9. <https://doi.org/10.3389/fpsyg.2018.01543>
- Linnenbrink, E. A., & Pintrich, P. R. (2004). Role of affect in cognitive processing in academic contexts. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 57–87). Routledge. <https://doi.org/10.4324/9781410610515>
- Liu, M., Schallert, D. L., & Carroll, P. J. (2004). Working memory and expertise in simultaneous interpreting. *Interpreting*, 6(1), 19–42. <https://doi.org/10.1075/intp.6.1.04liu>
- Maclay, H., & Osgood, C. E. (1959). Hesitation phenomena in spontaneous English speech. *Word*, 15(1), 19–44. <https://doi.org/10.1080/00437956.1959.11659682>

- Matthews, G. (2008). Personality and information processing: A cognitive-adaptive theory. In G. J. Boyle, G. Matthews, & D. H. Saklofske (Eds.), *Handbook of personality theory and testing: Vol. 1. Personality theories and models* (pp. 56–79). Sage. <https://psycnet.apa.org/doi/10.4135/9781849200462.n3>
- Matthews, G. (2020). Cognitive processes and models. In P. J. Corr & G. Matthews (Eds.), *The Cambridge handbook of personality psychology* (2nd ed., pp. 295–315). Cambridge University Press. <https://doi.org/10.1017/9781108264822>
- McCrae, R. R., & Costa, P. T., Jr. (1999). A five-factor theory of personality. In L. A. Pervin & O. P. John (Eds.), *Handbook of personality: Theory and research* (2nd ed., pp. 139–153). Guilford Press.
- Mead, P. (2002). Exploring hesitation in consecutive interpreting: An empirical study. In G. Garzone & M. Viezzi (Eds.), *Interpreting in the 21st century: Challenges and opportunities* (pp. 73–82). John Benjamins. <https://doi.org/10.1075/btl.43.08mea>
- Menzies, R. G., Onslow, M., & Packman, A. (1999). Anxiety and stuttering: Exploring a complex relationship. *American Journal of Speech-Language Pathology*, 8(1), 3–10. <https://doi.org/10.1044/1058-0360.0801.03>
- Messenger, M., Onslow, M., Packman, A., & Menzies, R. (2004). Social anxiety in stuttering: Measuring negative social expectancies. *Journal of Fluency Disorders*, 29(3), 201–212. <https://doi.org/10.1016/j.jfludis.2004.06.002>
- Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin*, 142(8), 831–864. <https://doi.org/10.1037/bul0000051>
- Moser-Mercer, B. (2000). Simultaneous interpreting: Cognitive potential and limitations. *Interpreting*, 5(2), 83–94. <https://doi.org/10.1075/intp.5.2.03mos>
- Moser-Mercer, B., Künzli, A., & Korac, M. (1998). Prolonged turns in interpreting: Effects on quality, physiological and psychological stress (Pilot study). *Interpreting*, 3(1), 47–64. <https://doi.org/10.1075/intp.3.1.03mos>
- Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. *Journal of Neuroscience Methods*, 222, 250–259. <https://doi.org/10.1016/j.jneumeth.2013.10.024>
- Munoz, E., Sliwinski, M. J., Smyth, J. M., Almeida, D. M., & King, H. A. (2013). Intrusive thoughts mediate the association between neuroticism and cognitive function. *Personality and Individual Differences*, 55(8), 898–903. <https://doi.org/10.1016/j.paid.2013.07.019>
- Natarelli, G. (2018). *Anxiety and stuttering: Filling the research gaps in early adolescence* (Doctoral thesis, Università degli Studi di Padova). <https://www.research.unipd.it/handle/11577/3426700>
- Pöschhacker, F. (2013). The position of interpreting studies. In C. Millán & F. Bartrina (Eds.), *The Routledge handbook of translation studies* (pp. 60–72). Routledge.
- Pöschhacker, F. (2015). Interpreting. In F. Pöschhacker (Ed.), *Routledge encyclopedia of interpreting studies* (pp. 197–199). Routledge. <https://doi.org/10.4324/9781315678467>
- Scherer, K. R. (1999). Appraisal theory. In T. Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 637–663). John Wiley & Sons. <https://doi.org/10.1002/0470013494.ch30>
- Setton, R. (2026). Neurolinguistic and cognitive aspects of interpreting. In C. A. Chapelle (Ed.), *The encyclopedia of applied linguistics*. Wiley. <https://doi.org/10.1002/9781405198431.wbeal0863>

- Saad Merouwe, S., Bertram, R., & Eggers, K. (2024). Speech disfluencies in bilingual Lebanese children who do and do not stutter. *American Journal of Speech-Language Pathology*, 33(5), 2291–2310. https://doi.org/10.1044/2024_AJSLP-23-00311
- Shreve, G. M., Lacruz, I., & Angelone, E. (2011). Sight translation and speech disfluency: Performance analysis as a window to cognitive translation process. In C. Alvstad, A. Hild, & E. Tiselius (Eds.), *Methods and strategies of process research: Integrative approaches in translation studies* (pp. 93–120). John Benjamins. <https://doi.org/10.1075/btl.94.09shr>
- Smith, C. A., & Lazarus, R. S. (1990). Emotion and adaptation. In L. A. Pervin (Ed.), *Handbook of personality: Theory and research* (pp. 609–637). Guilford Press.
- Song, S., & Li, D. (2020). The predicting power of cognitive fluency for the development of utterance fluency in simultaneous interpreting. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.01864>
- Stes, R. (2004). *Vloeïendheidsstoornissen: Rationale eclecticische sociaal-cognitieve gedragstherapeutische benadering – Deel III: Normaal (on)vloeiende spreekcomponenten* [Fluency disorders: Rationale eclectic social-cognitive behavioral therapeutic approach – Part III: Normal (dis)fluent speech components]. Lecture at Postgraduate Stuttering Therapy, Antwerp.
- Timarová, Š. (2015). Working memory. In F. Pöchhacker (Ed.), *Routledge encyclopedia of interpreting studies* (pp. 443–445). Routledge. <https://doi.org/10.4324/9781315678467>
- Timarová, Š., Čenková, I., Meylaerts, R., Hertog, E., Szmalec, A., & Duyck, W. (2014). Simultaneous interpreting and working memory executive control. *Interpreting*, 16(2), 139–168. <https://doi.org/10.1075/intp.16.2.01tim>
- Togato, G., & Macizo, P. (2023). Cognitive flexibility in interpreting. In A. Ferreira & J. W. Schwieter (Eds.), *The Routledge handbook of translation, interpreting and bilingualism* (1st ed., pp. 280–297). Routledge. <https://doi.org/10.4324/9781003109020>
- Tóth, A. (2011). Speech disfluencies in simultaneous interpreting: A mirror on cognitive processes. *SKASE Journal of Translation and Interpretation*, 5(2), 23–31. http://www.skase.sk/Volumes/JTI06/pdf_doc/03.pdf
- Walczyński, M. (2019). *Psycho-affective factors in consecutive interpreting*. Peter Lang. <https://doi.org/10.3726/b15361>
- Walczyński, M. (2020). Polish-English certified interpreter's psycho-affectivity. *Półrocznik Językoznawczy Tertium*, 5(1), 35–53. <https://doi.org/10.7592/tertium2020.5.1.walczynski>
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology & Psychology*, 18(5), 459–482. <https://doi.org/10.1002/cne.920180503>
- Yudes, C., Macizo, P., & Bajo, M. T. (2011). The influence of expertise in simultaneous interpreting on non-verbal executive processes. *Frontiers in Psychology*, 2. <https://doi.org/10.3389/fpsyg.2011.00309>
- Zhao, N. (2022). Speech disfluencies in consecutive interpreting by student interpreters: The role of language proficiency, working memory, and anxiety. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.881778>

Zhao, N., Cai, Z. G., & Dong, Y. (2023). Speech errors in consecutive interpreting: Effects of language proficiency, working memory, and anxiety. *PLOS ONE*, 18(10).
<https://doi.org/10.1371/journal.pone.0292718>