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Final dissertation

# The cognitive effects of speech noise on readers' comprehension: a focus on second language learners


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# INTRODUCTION

Noise pollution poses a serious threat on multiple domains of quality of life and well-being. It is omnipresent and continues to evolve at an alarming rate, raising concerns of adverse impacts yet to come. Noise can have different sources and takes on many forms, of which speech noise is the most bothersome.

Speech noise is highly prevalent and tends to be concentrated in bustling areas, such as university campuses. This is problematic as noisy environments are not compatible with educational settings where silence is valued for concentration. To assess the effects of this issue, it is important to evaluate whether there are any implications on cognitive performance on the university students exposed to the noise. By doing so, necessary measures can be put into place to limit potential impairments.

Reading comprehension is a demanding task which involves important executive functions. Hence, testing reading comprehension performance provides insight on which cognitive skills are impaired due to speech noise intrusion. Additionally, eye-tracking techniques can be utilized to assess difficulties in maintaining attention and concentration. To broaden the pre-existing literature on this topic, shifting the focus from monolinguals to bilinguals allows for inclusion of the booming population of second language learners.

This study was designed with the objective of identifying whether speech noise presented in a non-native language has an impact on reading comprehension of second language learners. The expected outcome is that participants would perform poorly in the noisy condition in comparison to the quiet one. The design and the methodology of the present study will be discussed in this thesis work, as well as its limitations and applications.

## CHAPTER 1: Distinction between sound and noise

Since the beginning of time, sound has been an essential component integrated into our lives. From contributing to our survival instincts by keeping us alert to avoid prey, to providing us with entertainment on our daily commute, sound has continuously evolved and adapted with us.

Sound manifests as sound waves in a medium that deliver signals upon reaching listeners' auditory systems (Muzet, 2007). In some cases, the signals may be useful, while in other cases they may be intrusive and unwanted. When sound contains the latter, it is referred to as noise. (Stansfeld & Matheson, 2003) Hence, the distinction between sound and noise is not physical, but rather subjective (Shepherd et al., 2015). The nature of the noise and its social desirability determines its level of acceptance (Jhanwar, 2016). For instance, white noise, which is characterized by a range of frequencies at stable intensity levels (Pickens et al., 2019), tends to benefit individuals by masking background noise that is perceived as bothersome (Pickens et al., 2019). By extension, unwelcome sound in our surroundings is referred to as environmental noise, such as noise generated from industrial sites and equipment, as well as vehicular traffic. (Goines & Hagler, 2007; Jhanwar, 2016).

### 1.1: Noise pollution and its adverse effects

Pollution is an ever-growing issue, raising concerns regarding the detrimental effects that accompany it. Environmental noise pollution, which refers to excessive unwanted noise production in our environment, is of particular concern as it continues to grow exponentially as a consequence of urbanization. It is pervasive in a variety of contexts such as professional, educational, and social settings (Goines & Hagler, 2007; Jhanwar, 2016). Similarly to other

forms of pollution, noise pollution has adverse impacts on health, well-being, and quality of life (Jafari et. al, 2019).

Besides noise induced hearing loss, the physiological effects of noise exposure are numerous (Stansfeld & Matheson, 2003). Individuals exposed to traffic noise have a greater probability of developing Alzheimer's disease, as well as a range of dementia subtypes (Cantuaria et. al, 2021). Noise generates oxidative stress in the brain and contributes to the development of neurodegenerative diseases (Wang et al., 2016). Additionally, cardiovascular disorders and hypertension are also by-products of noise (Basner et al., 2014). A recurring issue in noisy cities is sleep disturbances. Sleep deprivation perpetuates the development of the aforementioned health complications and impairs performance by delaying reactions. In other words, ill-rested individuals are less vigilant (Dalton & Behm, 2007). Studies show that people may grow accustomed to noise over time, however they do not become fully habituated (Stansfeld & Matheson, 2003).

Cognitive vigilance is compromised as well. There is an inverse relationship between noise and cognitive performance: when exposed to distracting noise, cognitive performance decreases, including poor memory and accuracy (Gheewalla et al., 2020).

This is a topic of concern for workplace safety. Furthermore, noise may have negative implications on attention (Jafari et al., 2019). Since the purpose of noise is to deliver signals, noise alerts individuals and hence increases their level of arousal. In some cases, the increased arousal will lead to higher attention. However, despite the heightened level of attention, the span is compromised and consumed by the noise rather than the task at hand. As a result, individuals will suffer with poor attention and concentration (Jafari et al., 2019).

Psychological states are not exempt from the detrimental effects of noise. Due to the aforementioned lack of sleep, it is common for individuals to have a sour mood and poor perceptions of their quality of sleep, thus amounting to dissatisfaction with their quality of life

(Öhrström, 1989). Another recurring side-effect of unwanted noise exposure is noise annoyance (Stansfeld & Matheson, 2003). Noise annoyance triggers the release of stress hormones. This may lead to a chain reaction and exacerbate the formation of additional problems, like a deterioration in mental health. For instance, the risk of developing depression increases in individuals who experience great degrees of noise annoyance. (Gong et al., 2022) Furthermore, stress and anxiety increase when an individual is subjected to distracting noise as a result of its impact on the central nervous system (Jafari et al., 2019). A notable strong association is found between the increased risk of aforementioned cardiovascular diseases and noise-related stress (Steptoe & Kivimäki, 2012). The lack of sleep feeds into this association by generating cardiovascular strain, and creates a cycle (Sforza et al., 2004).

### 1.2: Individual Factors

Noise stems from countless places and takes on various forms. In fact, noise is almost inevitable. The intrusiveness of noise, and the extent to which it acts as a distractor, depend on individual differences of the listeners and characteristics of the noise itself (Gheewalla et al., 2020).

At the individual level, the degree of tolerance to noise is referred to as noise sensitivity (Belojevic et al., 2003; Shepherd et al., 2015). Individuals who are more sensitive to noise tend to experience more annoyance and distress in response to it (Smith, 2003). Additionally, it is more distracting and hampers their cognitive performance (Jafari et al., 2019). Personality traits, specifically extraversion and introversion, have been found to have an influence on individuals' perceptions of noise (Gheewalla et al., 2020). Introverts have higher levels of cortical arousal, making them more prone to overstimulation. Indeed, in the presence of background noise, cortical arousal is amplified, which leads to a decline in cognitive

performance in introverts (Gheewalla et al., 2020). On the other hand, extroverts appear to be more adept in performing in sub-optimal noise conditions. In fact, in some experiments where extroverts were instructed to perform a mundane task, they often requested snippets of noise in order to subside the boredom (Belojevic et al., 2003). Neuroticism is another trait worth mentioning. Individuals who score high on this trait tend to exhibit higher levels of general arousability (Belojevic et al., 2003). As in the case of introverts, a further increase of this arousal is maladaptive to cognitive performance. Furthermore, neurotic individuals tend to struggle with worry and anxiety, and this contributes to their poor coping skills to noise as a stressor (Belojevic et al., 2003). Negative affectivity refers to the degree to which individuals focus on negative aspects of themselves and their surroundings, a trait common in neurotic individuals. There is a notable positive correlation between negative affectivity and noise sensitivity (Smith, 2003).

### 1.3: Types of noise and their characteristics

There are key characteristics of noise that play an essential role in determining the extent of the impact on listeners. The most pronounced feature is noise intensity. As one may expect, the louder a noise is, the more likely it is to be perceived as a stressor (Jafari et al., 2019). Duration and fluctuation of a noise also influence how intrusive it is. If noise exposure is too short, the adverse impact would not have enough time to reach its potential as a disturbance (Jafari et al., 2019). In terms of continuity, intermittent exposure is more detrimental in comparison to continuous exposure (Szalma & Hancock, 2011). This may be attributed to the acclimation listeners may build in response to the prolonged subjection to the noise (Stansfeld & Matheson, 2003). Finally, the nature of a noise and its significance provokes different responses. For instance, noise that is associated with urgency or danger will elicit more of a stressful response

than music would (Gheewalla et al., 2020).

The boom of urbanization has resulted in a plethora of construction sites, highways, and airports. Naturally, traffic and aircraft noise are prevalent under these conditions. Traffic noise is continuous and increases noise annoyance, which acts as a mediator to physical and psychological issues (Stansfeld et al., 2021). Aircraft noise is intermittent and has been shown to impair reading, memory, and academic performance in children (Basner et al., 2017). In busy cities, sirens occur frequently. They are distinguishable from other background noises due to their association with danger and they are curated with the intention of inducing alertness and capturing attention. This is effectively accomplished by their sound design consisting of oscillations and wails. Moreover, individuals lack any control over the occurrence of the noise, and this unpredictability leads to stress (Gheewalla et al., 2020).

Music can be perceived as a distractor, too. Even though individuals tend to have more control over music (i.e., volume level, genre, etc.), music as background noise may still act as a stressor (Hammer et al., 2014). The literature on the effects of music on cognitive performance are complex. In some instances, music increased alertness and improved performance when tasks (like signal detection tasks) called for heightened attention and concentration, because it increased arousal (Dalton & Behm, 2007). On the other hand, it acted as a distractor during tasks that demanded vigilance, such as reading comprehension (Dalton & Behm, 2007). The effects of music are mediated by a multitude of factors including familiarity, task type and complexity, cognitive demand, mood, and tempo (Dalton & Behm, 2007; Gheewalla et al., 2020).

Speech noise is the principal focus of this thesis work. Studies demonstrate that, in comparison to other types of noise, speech noise is the most disruptive (Szalma & Hancock, 2011). More specifically, students undertaking cognitive tasks have reported that meaningful speech noise is more intrusive than non-intelligible speech, also known as babble noise or meaningless

speech (Braat-Eggen et al., 2017). Since there is semantic content in intelligible speech noise, the cognitive process of comprehension has an increased level of interference with the cognitive skills required for the task at hand (Guerra et al., 2020). The opposite assumption can be made; due to the absence of semantic content in babble speech, automatic processing is reduced. Indeed, an overview of the literature demonstrated meaningful speech had prominent effects in a range of tasks including memory, reading, and writing, whereas babble noise had little to no effect (Klatte et al., 2013). This indicates that non-intelligible speech noise remains intrusive, but to a lesser extent. Speech noise can be further classified into task relevant or task irrelevant, with the latter being a primary concern in open-plan workplaces (Di Blasio et al., 2019). Telephone calls and amicable discussions among colleagues are examples of irrelevant speech noise, and employees exposed to them reported a sensation of increased cognitive workload (Di Blasio et al., 2019).

### 1.4: Bilingualism

Individuals that are capable of effectively using two languages are referred to as bilinguals (Dewaele, 2015). There is an array of literature regarding bilingual speakers' speech perception and understanding of their second language, under sub-optimal noise conditions, that depict poorer outcomes relative to native speakers (Alqattan & Turner, 2021; Rogers et al., 2006). This applied to participants that learned their second language at an early age as well (Alqattan & Turner, 2021; Rogers et al., 2006). Additionally, in word recognition tasks under noise exposure, second language learners presented with non-native words struggled with intrusion from their first language (Hintz et al., 2022). Despite these weaknesses, second language learners seem to have an advantage in terms of cognitive function. Particularly, studies on bilingual children revealed that they were better able to exert control over their attention and

inhibition (Bialystok & Majumder, 1988; Bialystok, 2009; Dewaele, 2015). There are several factors that influence second language learners' reading comprehension in general. Naturally, fluent individuals have mastered the language and are not subjected to limitations in comprehension, as opposed to their counterparts with low proficiency (Seabi et al., 2012). Additionally, a limited knowledge of vocabulary and the discomfort of learning in a low proficiency language impairs comprehension (Seabi et al., 2012).

There is a gap in the literature concerning the effects of background speech noise, presented in participants' second language, on their cognitive performance. The purpose of this thesis is to attempt to further bridge the gap and uncover any correlations that may exist between the language the background speech is presented in, and the corresponding impact on cognitive performance. Simultaneously, any findings will be assessed in relation to the existing literature of the impact of background speech noise on cognitive performance, specifically on reading comprehension.

## CHAPTER 2: Factors that determine effects of noise on task performance

The characteristics of the task being carried out, such as cognitive demand and familiarity, influence the level of impact noise may have on performance (Gheewalla et al., 2020). Naturally, they vary from one task to another. Typically, tasks such as reading and writing are more likely to be adversely influenced by noise. This is due to the high cognitive load, and increased need for concentration and attention, among other attentional controls, necessary in order to conduct these tasks (Braat- Eggen et al., 2017).

### 2.1: Executive functions of reading comprehension

In order to understand why speech noise may disrupt reading comprehension, it is helpful to identify the cognitive skills underlying task performance. Reading comprehension is a task that activates a plethora of executive functions. Working memory is a system which maintains information and executes processing functions (Nouwens et al., 2021). It is a crucial component in reading comprehension, as it sustains the activation of relevant information and merges incoming information with pre-existing ones (Butterfuss & Kendeou, 2017; Nouwens et al., 2021). Inhibition is the capability of suppressing instinctual responses (Miyake et al., 2000). It facilitates this process by screening information and restricting access to working memory by only permeating relevant information (Butterfuss & Kendeou, 2017). Shifting is the ability to alternate attention distribution between concurrent operations and tasks (Miyake et al., 2000). While reading, shifting handles the components of language by fusing semantic and phonological information, and localizes attention (Butterfuss & Kendeou, 2017). Planning is a higher-level executive function that coordinates these cognitive skills and curates effective reading strategies (Butterfuss & Kendeou, 2017; Nouwens et al., 2021).

## 2.2: Impact of speech noise on reading comprehension

Speech sound has implications on reading comprehension due to interfering with the associated cognitive functions. Studies have found that readers exposed to speech noise, especially intelligible speech noise, have poorer reading comprehension (Guerra et al., 2020). The explanation for this lies within the immediate semantic processing that occurs upon hearing the noise. This theory is known as interference-by-process, and states that the semantic processing may override the other cognitive processes aimed at comprehension, such as updating working memory (Guerra et al., 2020). This theory identifies speech noise to be more detrimental than other types of noise (Halin, 2016). Intelligible speech noise exposure led to more re-reading fixations, which further highlights issues in semantic processing. When participants were not permitted to re-read the text, intelligible speech noise led to a deterioration in reading comprehension (Vasilev et al., 2018).

There are a multitude of ways to measure difficulties. Text memory and self-reported measures of fatigue are common instruments in assessing challenges. Text memory is usually evaluated by participants' responses to comprehension questions, in order to assess how much of the text was committed to memory, whereas self-assessed fatigue levels were administered via questionnaires to assess the subjective difficulty associated with the task in different conditions (Halin, 2016; Vasilev et al., 2018). The amount of time taken to read a text is another useful measure. Longer reading times are indicators of increased difficulty in maintaining attention (Guerra et al., 2020; Vasilev et al., 2018). Furthermore, eye-tracking studies utilize eye-tracking techniques to measure challenges encountered while reading under noise exposure (Cauchard et al., 2012). More specifically, first- pass fixations, which refer to fixations that occur when reading a text for the first time, and second-pass fixations, which refer to back-

tracking to a previous sentence are useful measures (Hyönä & Ekholm, 2016). However, the perceived effects may vary according to several factors. To begin with, the amount of inhibitory control an individual possesses alters the amount of disruption. Individuals who exhibit more inhibitory control are more adept at filtering out acoustic distractions, including speech sound (Guerra et al., 2020). Additionally, the genre of the text may have an influence on comprehension (Wu et al., 2020). A study assessing reading comprehension demonstrated that in general, even in the absence of noise, expository texts were more difficult than narrative texts and required a distinctive cognitive skill set (Wu et al., 2020). Therefore, this may act as a third variable as individuals may be slow due to the perceived difficulty or unfamiliarity of the text, rather than the noise interference (Braat- Eggen et al., 2021). On the other hand, increased speech intensity and volume were mildly correlated to longer reading times. The longer reading time may be due to the interference of noise at the perceptual level, resulting in individuals resorting to re-reading as an attempt to cope with the interference (Guerra et al., 2020). Another way to counter noise disruption involves altering the cognitive demand associated with the reading task. For instance, a study conducted on students aimed at assessing whether increasing cognitive demand mitigated the distraction of background speech noise. Students were required to read texts with easy or hard to read fonts (Halin, 2016). The results demonstrated that intelligible background speech, administered through headphones at true speech intensity of approximately 60dB, had more negative implications on text memory than the other types of noise (traffic and aircraft noise), only in the easy-to-read font condition (Halin, 2016). Additionally, this alteration did not result in an increase of mental fatigue reports. This outcome is attributed to the localization of attention and diminished processing of background noise (Halin, 2016).

To summarize, there is a vast array of literature depicting background speech as the most disruptive background noise with negative impacts on executive and cognitive functions.

However, there is also a plethora of literature on the possible mediating, confounding, or third variables that may exacerbate negative impacts on cognitive performance than speech noise would be able to exert on its own. Additionally, just as there are some inducing factors, there are also mitigating factors that may counter implications on performance. Oftentimes, studies investigating noise effects on reading are complex and may be confounding (Vasilev et al., 2018). The goal of this thesis work is to evaluate whether there are any negative implications of speech noise in participants' second language on reading comprehension. The findings, if any, may aid the increasing population of second language learners in identifying any limitations in their study strategies, such as the places they opt to study in, and amending them in order to maximize their potential.

## CHAPTER 3: Experimental Procedure and Results

The aim of this study is to determine whether speech noise presented in a non-native language would compromise second language learners' reading comprehension performance in their secondary language. The hypothesis is that speech presented in a L2 language would moderately impair second language learners' performance. The experiment consists of a within-subject design. A within subject design is ideal to maximize thoroughness, limit third variables, and accommodate for a shorter experiment duration. Additionally, it maintains efficiency in the case of having a smaller sample size. The sample recruited consists of second language university students who carry out their academic career in their non-native language, which is English. Despite English being their second language, the average level of proficiency is level B2 according to the Common European Framework of Reference for languages (CEFR), which indicates an upper intermediate English level. This was a criterion upon admission to their university.

### 3.1: Tools

A range of tools are implemented to control for confounding variables. Prior to their arrival, participants are asked to compile the informed consent module. This form details the nature and purpose of the experiment and provides participants with information regarding the confidentiality of data. The module also consists of an additional linguistic background questionnaire, which requires participants to fill in information about the languages they speak and their self-reported level of proficiency. Additionally, participants are asked to fill in a reading habits questionnaire to assess the extent of leisurely reading participants do in both their native and non-native language (Crawford Camiciottoli, 2001). This is beneficial as

frequent readers may have advanced reading proficiency, which may amount to individual differences in the data. The questionnaire was extracted from a study conducted to assess reading habits in a group of Italian students (Crawford Camiciottoli, 2001). It was revised to suit the allocated sample and purpose of the experiment. Participants are instructed to bring the completed forms with them on the testing day.

Upon their arrival to the lab, participants are administered an English proficiency test. The purpose of this test is to check for any discrepancies between the perceived level of proficiency reported in the linguistic background questionnaire, and the actual reading proficiency score obtained from the test. This facilitates the future analysis of subjective reports of increased cognitive workload sensations. The English proficiency test that is utilized is the 'General English Assessment' extracted from the Cambridge English website (Cambridge University Press & Assessment, n.d.). Lastly, to account for any reading difficulties, the Vinegrad's Adult Dyslexia Checklist (Vinegrad,1994) is administered to participants.

### 3.2: Eye tracker

The eye tracker selected for this experiment is Tobii Pro X3-120 (Tobii Pro, 2016). It is a screen-based eye tracker and has a frame rate of 120 Hz. It follows participants' gaze to determine where they are looking and indicates where first-pass or second-pass fixations may occur. Additionally, it tracks saccades i.e., fast eye movements from one point to another.

### 3.3: Texts

Participants will read texts in two acoustical conditions (quiet and noise). In order to counterbalance the two conditions, two different texts have been selected. The texts were

extracted from the World Health Organization (WHO) documentation (WHO, 2022; 2023). Both texts are informative and have been modified to ensure consistency in same text length and corresponding reading times. Text 1 consists of 446 words, 18 sentences, an average of 24.8 words per sentence, and an average of 1.8 syllables per word. Text 2 consists of 445 words, 26 sentences, an average of 17.1 words per sentence, and an average of 1.9 syllables per word. This data permits the calculation of readability, which refers to the ease with which a text can be read and understood. Three measures of readability were implemented. First, the readability of both texts was measured by the Flesch- Kincaid Grade Level (FKGL) (Kincaid et al., 1975). This measure estimates the grade level of education required for text comprehension (Kher et al., 2017). It is a 100-point scale, and the lower the score of a text, the more skilled an individual needs to be to understand it. The score attributed to text 1 was 15.3, and the score for text 2 was 13.5. The second measure of readability was the Flesh Reading Ease (FRE) (Flesch, 1948). Again, it is a 100-point scale, with lower scores indicating less readability (Kher et al., 2017). The score for text 1 was 29.4, and the score for text 2 was 28.7. The results of both readability tests (FKGL and FRE) indicate that the reading level necessary to understand both texts is equated to that of a college graduate i.e., it is very difficult. Lastly, the final measure of readability consisted of peer assessment. The peers who reviewed the readability and difficulty of the texts are excluded from the sample of participants.

### 3.4: Methodology

Participants are required to read two informative texts displayed on a monitor in two different noise conditions (quiet and noise), then respond to comprehension questions. During the reading assessment, participants gaze will be recorded by means of the eye tracker. The noise condition consists of background noise which entailed unintelligible multi-talker babble noise,

transitory noise, as well as an intelligible English voiceover. It is administered via headphones at an intensity of 65 dBA. In both conditions, participants are only permitted to read through the text once. Re-reading is restricted as participants can only access one page at a time and do not have the ability to return to a previous page. After each condition, participants are instructed to respond to 8 closed-ended comprehension questions. Four of the questions are direct, and the answers are explicitly stated in the texts. These questions are aimed at assessing the effects of background speech noise on text memory in reading comprehension. On the other hand, the remaining four questions are inferential, so that it will be possible to also assess the ability to manipulate acquired information. Participants are not allowed to go back and search through the text in order to answer the comprehension questions in either condition.

## CHAPTER 4: Discussion and conclusions

To summarize, the objective of this thesis is to identify whether speech noise presented in second language learners' non-native language would have an impact on reading comprehension. This was carried out by a critical analysis of the literature followed by the curation of an experimental methodology in attempt to bridge the gaps in data.

### 4.1: Framework of expectations

Overall, the literature on this topic is inconclusive (Vasilev et al., 2018). However, some effects of speech noise on reading comprehension have been illustrated. Out of all the noises one could be exposed to, speech noise is deemed as the most detrimental (Halin, 2016; Szalma & Hancock, 2011). The effects of particular concern for this experiment are the mental effects, specifically cognitive performance. Speech noise is broken down into intelligible or babble noise. Both categories have negative implications on cognitive performance, however intelligible speech noise is found to be more detrimental (Braat-Eggen et al., 2017; Klatte et al., 2013). This discrepancy is attributed to the interference-by-process theory, which states that instinctual processing of semantic information of intelligible speech noise (that is absent in babble noise) overshadows the cognitive processes required for text comprehension (Guerra et al., 2020). The primary executive functions underlying reading comprehension are working memory, inhibition, shifting, and planning (Butterfuss & Kendeou, 2017; Miyake et al., 2000; Nouwens et al., 2021). When semantic processing takes place, inhibition attempts to filter out the acoustic distraction (Butterfuss & Kendeou, 2017; Guerra et al., 2020). However, the cognitive cost associated with that involves low levels of attention and concentration, which impairs shifting. Therefore, the noise intrusion disrupts the system of cognitive skills involved

in the task, and reading comprehension is impaired as a result (Guerra et al., 2020). Based on this data, it is presumable that the outcome of the experiment would replicate these findings, and impairment in reading comprehension would be found. However, literature analysis uncovered a range of confounding variables that may interfere with this expectation. All the confounding factors discussed in the literature review play a role and are accounted for as much as possible in the methodology of the experiment. However, since there is an emphasis on second language learners, the impact of bilingualism as a mediating factor is of particular concern.

### 4.2: Expected results

After incorporating the confounding variables, the expectations of the experiment shift to anticipate little-to-no effect on performance. A multitude of reasons contribute to this change. To begin with, despite being second language learners, the participants have good English proficiency levels. The obstacle of having limited vocabulary and a reduced scope of understanding is unlikely to apply to these participants (Seabi et al., 2012). Additionally, the literature demonstrated that bilinguals have more control over their attention distribution and inhibition (Bialystok & Majumder, 1988; Bialystok, 2009; Dewaele, 2015). Since these cognitive skills play key roles in reading comprehension, one may assume that increased control over them would enhance their function and benefit bilinguals by mitigating noise intrusion. Moreover, noisy conditions impair speech perception of bilinguals' second language (Alqattan & Turner, 2021; Rogers et al., 2006). Since the noise implemented in this experiment included a monologue overlapping with a noisy background, participants may encounter difficulties perceiving the speech. Consequently, less semantic content is associated with the speech, rendering it to blend in with the babble noise, and thus its degree of intrusion is limited.

Finally, the difficulty of the texts required an increase in cognitive demand, which corresponds to heightened attention and concentration on the task, countering the noise intrusion (Halin, 2016).

### 4.3: Potential Contributions

Despite a negligible finding, this experiment is beneficial to the rapidly increasing populations of second language learners. For instance, in deciding where to study, students can evaluate the type of task they are aiming to work on coupled with the noise exposure in their options. By doing so, they can select the best suited environment to optimize study performance. On the other hand, professors of second language learners may utilize this finding to adjust the features of the tasks they assign to students, such as the difficulty to increase associated cognitive demand, to accommodate for the inevitable speech noise on school or campus grounds. Additionally, they do not risk invoking higher degrees of fatigue in their pupils (Halin, 2016). These characteristics are valuable in significant occasions, such as testing sessions, to eliminate or counter possible acoustic stressors.

### 4.4: Limitations and further research

This study presents a few limitations such as the lack of diversity in participants' English proficiency, as they all range from an advanced intermediate level to a fluent level. Incorporating less proficient individuals in the sample could yield interesting results with a wider scope of application. Additionally, the high complexity of the texts utilized plays an important role in participants' successful performance. Implementing this study with texts of moderate difficulty could uncover a greater impact of speech noise on participants' performance. Furthermore, in this study, the restriction on re-reading may pose a challenge on

the participants as it has been shown to hinder reading comprehension (Vasilev et al., 2018). However, if participants are informed of this restriction beforehand, it is probable that they will account for it by further increasing their level of attention. The experiment has a variety of possible future directions. Primarily, it requires piloting and testing. Additionally, examining senior bilinguals in these conditions could uncover added dimensions of age and experience to the results.

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