Review

The Involvement of Listening Effort in Explaining Bilingual Listening Under Adverse Listening Conditions

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Abstract

The current review examines listening effort to uncover how it is implicated in bilingual performance under adverse listening conditions. Various measures of listening effort, including physiological, behavioral, and subjective measures, have been employed to examine listening effort in bilingual children and adults. Adverse listening conditions, stemming from environmental factors, as well as factors related to the speaker or listener, have been examined. The existing literature, although relatively limited to date, points to increased listening effort among bilinguals in their nondominant second language (L2) compared to their dominant first language (L1) and relative to monolinguals. Interestingly, increased effort is often observed even when speech intelligibility remains unaffected. These findings emphasize the importance of considering listening effort alongside speech intelligibility. Building upon the insights gained from the current review, we propose that various factors may modulate the observed effects. These include the particular measure selected to examine listening effort, the characteristics of the adverse condition, as well as factors related to the particular linguistic background of the bilingual speaker. Critically, further research is needed to better understand the impact of these factors on listening effort. The review outlines avenues for future research that would promote a comprehensive understanding of listening effort in bilingual individuals.

Keywords

bilingualism, first language, second language, listening effort, adverse listening conditions

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Introduction

Bilingualism has become the norm in today's global society, with the majority of individuals in the world using more than one language in their daily lives (e.g., Edwards, 2006; Faroqi-Shah et al., 2010; Giussani et al., 2007; Grosjean, 2008, 2010; Grosjean & Li, 2013; Yip, 2021). Whereas early views considered bilinguals as referring to individuals having native-like control in both languages across various skills such as speaking, reading, and writing (e.g., Bloomfield, 1933), current definitions are broader, encompassing individuals who know two languages (e.g., Baker, 1993) or use more than one language in daily life (e.g., Byers-Heinlein & Lew-Williams, 2013; Grosjean, 1989). Critically, there is growing understanding in the field that bilingualism should be viewed as a spectrum of experiences, with multiple sources of variability implicated in bilingual performance (Antoniou et al., 2021; Berthele, 2021; Cowan et al., 2022; DeLuca et al., 2019; Luk, 2023; Luk & Bialystok, 2013; Marian & Hayakawa, 2021; Titone & Tiv, 2023).

The degree to which bilingualism affects cognitive and linguistic functions has gained much interest in the literature (e.g., Bialystok & Craik, 2010, 2022; Degirmenci et al., 2022; Kroll & Bialystok, 2013; Monnier et al., 2021). One area of particular focus is the potential impact of bilingualism on speech perception under adverse listening conditions (e.g., Cowan et al., 2022; Garcia Lecumberri et al., 2010). Adverse listening conditions occur when auditory information is compromised, making it difficult to perceive speech

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accurately (Mattys et al., 2012). These conditions can stem from various factors related to the speaker, the environment, or the listener. Speaker-related degradations can arise from speech disfluencies, as well as the production of accented or conversational speech. Environmental degradations can occur due to the presence of competing signals, high distances from the stimulus source, and reverberant settings, and listener-related degradations can manifest as a result of hearing loss or neurological deficits (Mattys et al., 2012). Although the specific impact of each adverse condition on the perceptual system may vary, they all share a common characteristic, which is creating a mismatch between the perceived speech and its canonical form, ultimately resulting in heightened listening challenges.

Extensive literature on speech perception abilities shows that bilinguals and monolinguals are not functionally equivalent on various speech perception tasks, especially when these are presented in adverse listening conditions, and in bilinguals' second language (L2). In particular, when tested in their L2, bilinguals tend to experience more speech perception difficulties in adverse listening conditions compared to monolinguals (Bidelman & Dexter, 2015; Bradlow & Alexander, 2007; Bsharat-Maalouf & Karawani, 2022a, 2022b; Desjardins et al., 2019; Desouki & Mendel, 2023; Garcia Lecumberri et al., 2010; Mayo et al., 1997; Morini & Newman, 2020, 2021; Náběelek & Donahue, 1984; Neave-DiToro et al., 2017; Rogers et al., 2006; Scharenborg et al., 2018; Scharenborg & van Os, 2019; Shi & Sanchez, 2010; Skoe & Karayanidi, 2019; Tabri et al., 2011; Takata & Náběelek, 1990; Von Hapsburg et al., 2004; Yang et al., 2022), or when compared to performance in their first language (L1) (e.g., Bsharat-Maalouf & Karawani, 2022b; Desjardins et al., 2019; Hurtig et al., 2016; Kilman et al., 2014; Rosenhouse et al., 2006; Weiss & Dempsey, 2008). For example, in a recent study that combined both between- and within-participant comparisons, bilinguals performed poorer in noise compared to monolinguals, and had more speech perception difficulties when tested in their L2 than in their L1 (Bsharat-Maalouf & Karawani, 2022b).

Still, given that bilingualism is a broad term that describes an extremely heterogeneous population, nuances of bilingualism should be considered, as these may play a role in individual's perceptual performance. Cowan et al. (2022) highlight in their recent review how various dimensions related to the bilingual linguistic profile, such as age of language acquisition, language competency, and demand for use, may affect bilinguals' perceptual performance under adverse listening conditions. For example, age of L2 acquisition was suggested to modulate bilinguals' perceptual performance, with better performance for earlier learners of the language compared to late learners (Mayo et al., 1997; Regalado et al., 2019; Rimikis et al., 2013; Shi, 2009, 2012, 2014b; Shi & Sanchez, 2010; Weiss & Dempsey, 2008). Similarly, the level of language competency and demand of use were shown to affect bilinguals' speech perception, with better speech in noise performance among individuals with higher language skills (Kilman et al., 2014; Rimikis et al., 2013; Shi, 2012, 2014b, 2015; Shi & Sanchez, 2010) and higher exposure to the language (Shi, 2012).

Why Does Bilingualism Affect Speech Perception?

Different factors have been postulated to account for bilinguals' speech perception performance in adverse listening conditions. First, it has been suggested that bilinguals may have less accurate stored lexical representations as well as weaker links between different sub-components of these representations (Gollan et al., 2002, 2005, 2008; Schmidtke, 2014, 2016). These less accurate lexical representations and weaker links increase the challenges faced by bilinguals because it may become more challenging to match the input to the canonical stored representation. In addition, the fact that during auditory processing, bilinguals' two languages are activated in parallel, even when only one language is used in the task (Blumenfeld & Marian, 2013; Marian et al., 2008; Marian & Spivey, 2003a, 2003b; Shook & Marian, 2012, 2013; Weber & Cutler, 2004), may lead to increased competition, deteriorating speech perception abilities (Bsharat-Maalouf & Karawani, 2022b). Therefore, these two mechanisms namely, less accurate lexical representations and increase competition may explain why bilinguals experience difficulties in speech perception under adverse listening conditions.

Moreover, bilinguals' speech perception difficulties under adverse listening conditions may be mediated by reduced ability to properly perceive the stimulus. This may be linked to two difficulties that bilinguals may exhibit relative to monolinguals—namely difficulties with "spectral integration" and "dip listening" (Cowan et al., 2022). Specifically, bilinguals, particularly those who are late learners and presented with speech stimuli in their nondominant language, may show difficulties with integrating spectral cues distributed across disparate frequency regions, affecting stimulus perception efficiency (e.g., Calandruccio & Buss, 2017). Also, compared to monolinguals, late bilinguals may show difficulties in catching brief glimpses of the target signal when fluctuating background noise momentarily decreases in its level (Calandruccio et al., 2014; Stuart et al., 2010). Thus, when the stimulus is degraded, bilinguals may be less efficient at catching cues that may assist in restoring the stimulus. Consequently, the difficulties experienced by bilinguals in these areas can decrease the acuity of the received signal, resulting in more challenging listening. Finally, bilinguals' perceptual difficulties in adverse listening conditions have been explained by their inefficient ability to infer missing information when the signal is degraded. For example, some studies suggested that bilinguals are less effective compared to monolinguals in using high linguistic compensatory information, such as contextual cues (Akker & Cutler, 2003; Bradlow & Alexander, 2007; Bsharat-Maalouf & Karawani, 2022b; Clahsen & Felser, 2006; Mayo et al., 1997; Shi, 2010, 2014a; Skoe & Karayanidi, 2019; Yang et al., 2022). Therefore, when more reliance on linguistic compensatory information is needed to support speech perception, as is the case in adverse listening conditions (Skoe & Karayanidi, 2019), bilinguals are expected to face more challenges compared to monolinguals.

Thus, differences in the quality of the lexical representations, increased competition, reduced acuity in target signal perception, and reduced use of high compensatory information have all been suggested to explain bilinguals' increased difficulty in processing speech under adverse listening conditions. Of relevance to the current review, the literature also raises the possibility that *listening effort* can be considered as a mediating factor in explaining bilinguals' perceptual performance under adverse listening conditions (e.g., Borghini & Hazan, 2018, 2020). Therefore, the current paper reviews studies specifically focused on bilinguals' listening effort and its implications for perceptual performance under adverse listening conditions. Despite the limited number of studies available in this area, some consistent findings emerge. Further, this review aims to identify areas within this domain that warrant further investigations and thus guide future research directions.

Listening Effort and the Importance of its Assessment. Effort is defined as the deliberate allocation of cognitive resources to overcome obstacles or challenges when carrying out a task, with *listening effort* applying more specifically when tasks involve listening (Pichora-Fuller et al., 2016). In adverse listening conditions, the received signal is degraded (Mattys et al., 2012), creating a mismatch between the input and stored representations. Thus, to reach lexical access in such adverse conditions, there is a greater need to rely on mental and cognitive processes (Pichora-Fuller et al., 2016; Rönnberg et al., 2008, 2013, 2019). Such involvement is highlighted by the Ease of Language model (ELU), which offers a description of the processes underlying listening effort in language understanding (Rönnberg et al., 2008, 2013, 2019). This model suggests that involvement of mental and cognitive processes during language understanding is associated with an increased level of listening effort.

Maintaining high levels of listening effort may increase stress and fatigue and have long-term consequences for mental and physical health (Alhanbali et al., 2017, 2018; Bess & Hornsby, 2014; Borghini & Hazan, 2018; Hornsby, 2013; Hornsby et al., 2016; Hua et al., 2013; Key et al., 2017; Kramer et al., 2002, 2006; McGarrigle et al., 2017; Pichora-Fuller et al., 2016). As such, uncovering the degree to which listening effort is implicated is important. Further, individual differences in exerted effort can sometimes be observed even when perceptual performance (intelligibility) is comparable or not affected (e.g., Borghini & Hazan, 2018, 2020; Desjardins & Doherty, 2014; Houben et al., 2013; Mackersie & Cones, 2011; Ohlenforst et al., 2018; Sarampalis et al., 2009; Strand et al., 2020; Wendt et al., 2017; Winn et al., 2015; Winn & Teece, 2021). Thus, studying how effort is implicated in bilinguals' difficulties in adverse listening conditions may uncover challenges in speech processing that may not be revealed if just perceptual performance is examined. In what follows, we first discuss the various measures utilized in the literature to examine listening effort and then review studies that have applied these measures to examine listening effort in bilingual populations under adverse listening conditions. Drawing upon the insights gained from this literature, we then propose potential avenues for future studies that will deepen our understanding of listening performance and effort in bilingual individuals.

Listening Effort Measures. Several methods have been used to measure listening effort, broadly classified as physiological, behavioral, and subjective measures. McGarrigle et al. (2014) and Pichora-Fuller et al. (2016) discuss in detail the different measures, and Alhanbali et al. (2019) summarize the advantages and disadvantages of each measure.

Briefly, *physiological measures* refer to the recording of changes in central and/or autonomic nervous system activity during task performance. One of the common physiological measures used to index listening effort is pupillometry. This measure examines task-evoked pupillary responses, where increased mean pupil dilation (average magnitude of pupil size observed during the task) and larger peak pupil size (maximum dilation recorded during the task), are associated with higher processing load, indicating increased effort (e.g., Gómez-Merino et al., 2020; Koelewijn et al., 2012, 2014; Kramer et al., 2016; Paulus et al., 2020; Silcox & Payne, 2021; van der Wel & van Steenbergen, 2018; Van Engen & McLaughlin, 2018; Wendt et al., 2014; Winn et al., 2015, 2018; Zekveld et al., 2018; Zekveld & Kramer, 2014). In addition to pupillometry, various other physiological techniques have been suggested to capture differences in effort. For example, changes in cardiac responses (e.g., Mackersie & Calderon-Moultrie, 2016; Mackersie & Cones, 2011; Seeman & Sims, 2015), hormonal activity (e.g., Jahncke & Halin, 2012), or skin conductance responses (e.g., Mackersie & Calderon-Moultrie, 2016; Mackersie & Cones, 2011; Seeman & Sims, 2015), were attributed to changes in effort. In addition, changes in the synchronization of alpha and theta oscillations during electroencephalogram (EEG) recordings (Deng et al., 2019; Miles et al., 2017; Obleser et al., 2012; Wisniewski, 2017; Wisniewski et al., 2018), changes in the topography, latency, or amplitude of event-related potentials (ERPs) (e.g., Bertoli & Bodmer, 2016; Kyong et al., 2020; Obleser & Kotz, 2011; Ullsperger et al., 1988), or recruitment of additional brain areas in neuroimaging studies (e.g., Eckert et al., 2016; Peelle, 2018; White & Langdon, 2021; Wild et al., 2012) were found to be associated with the difficulty of the task and were interpreted to reflect changes in effort.

Behavioral measures entail performance in dual-task paradigms and reaction time measures (e.g., Fraser et al., 2010; Houben et al., 2013; Pals et al., 2015; Picou & Ricketts, 2014; Sarampalis et al., 2009; Tun et al., 2009; Visentin et al., 2022). In the dual-task paradigm, the listener simultaneously performs two unrelated tasks, a primary and a secondary task (Gagné et al., 2017), and effort is indexed by examining how performance in the secondary task changes as a function of manipulating the difficulty of the primary task (e.g., Gagné et al., 2017; Wu et al., 2016). Such an approach assumes that both tasks rely on the same limited pool of cognitive resources (Kahneman, 1973; Norman & Bobrow, 1975), such that when the primary task becomes more demanding and consumes more cognitive resources, performance in the secondary task will reveal the outcome of the cognitive effort exerted in the primary task (e.g., Fraser et al., 2010; Gagné et al., 2017). In behavioral reaction time measures, the time between the presented stimulus and an individual's reaction time is measured. Studies that have utilized reaction time as a measure of listening effort operate under the assumption that listeners devote more time to complete more effortful and demanding tasks (Gatehouse & Gordon, 1990; Gustafson et al., 2014; Houben et al., 2013; Lam et al., 2018; Meister et al., 2018; Pals et al., 2015; Sarampalis et al., 2009). Although reaction time may also tap processing speed (e.g., Hui & Godfroid, 2021; Kamath & Shastry, 2021; Woods et al., 2015) rather than effort per se, increased reaction time has been taken to indirectly reflect increased effort in several previous studies (e.g., Houben et al., 2013; Lam et al., 2018; Oosthuizen et al., 2020; Pals et al., 2015; Picou et al., 2013; Visentin et al., 2019).

Subjective measures include self-report tools (e.g., Alhanbali et al., 2017, 2018; Mackersie & Cones, 2011; McAuliffe et al., 2012; Panico & Healey, 2009; Picou et al., 2011). With such measures, listeners are instructed to use rating scales and questionnaires to estimate the effort needed for listening in everyday life or research settings (Alhanbali et al., 2017; Johnson et al., 2015; Kilman et al., 2015; Mackersie & Cones, 2011). Thus, these measures rely on listeners' conscious awareness and estimation of the mental effort they exert.

Although listening effort has been assessed using multiple measures (Alhanbali et al., 2019), it is becoming increasingly evident that the different measures grouped under the umbrella of the "listening effort" term may tap into distinct underlying dimensions of the construct and could not be used interchangeably (Alhanbali et al., 2019; Visentin et al., 2022; Wendt et al., 2016). For instance, Alhanbali et al. (2019) showed non-significant or weak correlations between pupillometry, skin conductance, EEG alpha power, and subjective ratings measures, suggesting that these measures may tap into slightly different components of the effort construct. In addition, different effort measures may not be equally sensitive to the demands of a task and to methodological manipulations (Seeman & Sims, 2015; Strand et al., 2018). For instance, Seeman and Sims (2015) showed that the sensitivity to changes in task complexity and signal-to-noise ratios (SNRs) differed across listening effort measures. In their study, physiological heart rate variability was greater for increased task complexity and poorer SNRs, skin conductance measure was elevated for greater task complexity only, and dual-task measure increased for stimuli presented at more challenging SNRs. Moreover, each specific measure assumed to tap into the effort construct may reflect additional, separate, cognitive processes, as is exemplified by the positive correlation found between pupil dilation and subjective experience of tiredness in McGarrigle et al. (2021). Thus, effort should be viewed as a multidimensional construct, composing several overlapping systems (Alhanbali et al., 2019; Francis & Love, 2020; Lemke & Besser, 2016; McGarrigle et al., 2014, 2021; Peelle, 2018; Seifi Ala et al., 2020; Strand et al., 2018; Visentin et al., 2022). With this in mind, the current review takes a comprehensive approach, including bilingual studies that have used these various effort measures. By avoiding a narrow focus on a specific measure, we aim to provide a comprehensive understanding regarding the involvement of listening effort in bilinguals' performance under adverse listening conditions.

Listening Effort in Bilinguals in Adverse Listening Conditions. In the forthcoming sections and in Table 1, we organize the relevant literature based on the type of measure used. It is noteworthy that many of the studies reviewed here were conducted within a framework distinguishing native from non-native speakers. However, for our purposes, we consider non-native listeners as bilinguals operating in their nondominant language (L2). To the best of our knowledge, the existing literature on listening effort in bilinguals under adverse conditions has predominantly utilized physiological, behavioral, and subjective measures in isolation, with only two studies integrating behavioral and subjective measures to assess the listening effort involved. We opted to organize this review based on the type of measure used in the hope of highlighting which of the aforementioned measures is best suited to capture the listening effort involved in bilinguals' performance in adverse listening conditions, and direct future studies based on these insights.

Listening Effort Using Physiological Measures

Examining listening effort using physiological measures has been studied with bilingual adults (Borghini & Hazan, 2018, 2020; Francis et al., 2018; Grant et al., 2022) and bilingual children (Brännström et al., 2021). Specifically, by using *pupillometry*, Borghini and Hazan (2018) examined how the presence of background noise, as a form of environmental

Table 1. Summary of Reviewed Studies.

Effort measure/s		Adverse condition	Study	N	Age	Language/s	L2 background	Stimuli	Listening effort	Variability within bilinguals
Physiological measure	*Pupillometry*	*Noise (level)*	Borghini and Hazan (2018)	50	Adults	English monolinguals & Italian (L1)–English (L2) bilinguals	*Proficiency*—self-reported 4.5 of 6; *Usage*—50%; *Learning*—Environment based	Repeat sentences presented in quiet and in two levels of SNRs	Bilinguals (L2) > monolinguals	N/A
	Pupillometry	*Noise (level & language)*	Francis et al. (2018)	13	Adults	Dutch (L1)–English (L2) bilinguals	*Proficiency*—self-reported as moderate; 9.8 of 12 in proficiency test	Repeat sentences presented in quiet, in L1 or L2 competing speech	L2 > L1 sentences; L1 > L2 competing speech; L2 in L2 > L2 in L1 combination	High > low proficient bilinguals
	Pupillometry	*Noise*	Brännström et al. (2021)	63	Children	Swedish monolinguals & not stated L1–Swedish (L2) bilinguals	*Learning*—environment and classroom based	Speech picture verification task, presented in typical and favorable SNRs	Bilinguals (L2) > monolinguals	N/A
	Pupillometry	*Noise & speaking style*	Borghini and Hazan (2020)	54	Adults	English monolinguals & Italian (L1)–English (L2) bilinguals	*Proficiency*—5–38 of 40 in proficiency test; *Usage*—45%; *Learning*—environment based	Repeat quiet and noisy sentences presented in plain and clear speaking style	Bilinguals (L2) > monolinguals	High = low proficient bilinguals
	EEG (changes in alpha power)	*Noise*	Grant et al. (2022)	49	Adults	English (L1)–French (L2) bilinguals & French (L1)–English (L2) bilinguals	*AoA*—< 15 years; *Proficiency*—self-reported as high; *Usage*—5% to 95%	Repeat final word of high- and low-constraint sentences presented in quiet and in noise	L2 > L1	Late > early bilinguals
Behavioral measure	*Reaction time*	*Noise & reverberation*	Lam et al. (2018)	37	Adults	English monolinguals & various L1s–English (L2) bilinguals	*AoA*—> 3 years; *Proficiency*—self-reported 4.73 of 5; *Learning*—environment and classroom based	Words presented in quiet, in reverberation condition, and in reverberation and noise condition	Bilinguals (L2) > monolinguals	N/A
	Reaction time in single and dual-tasks	*Noise*	Oosthuizen et al. (2020)	60	Children	English monolinguals & not stated L1–English (L2) bilinguals	N/A	Repeat digit triplets in quiet and two SNRs	Monolinguals = bilinguals (L2)	N/A
Subjective measure	*Subjective ratings*	*Noise & listener age*	Desjardins	60	Young adults	English monolinguals & Spanish (L1)–	*AoA*—~ 4 years; *Proficiency*:	Repeat sentences in quiet and noise	Bilinguals (L2) > monolinguals; bilinguals'	N/A

(continued)

Table 1. Continued.

Effort measure/s		Adverse condition	Study	N	Age	Language/s	L2 background	Stimuli	Listening effort	Variability within bilinguals
			et al. (2019)		& older adults	English (L2) bilinguals	self-reported 7.1 or higher of 10; high in proficiency test; *Usage*—50%; *Learning*—environment based		L2 > L1; Young adult = older adults	
	Subjective ratings	*Noise & hearing status*	Kilman et al. (2015)	43	adults	Normal- and impaired hearing Swedish (L1)–English (L2) bilinguals	*Learning*—classroom based	Repeat sentences in four masker conditions	Normal hearing = hearing impaired bilinguals	N/A
Behavioral & Subjective measures	*Reaction time & subjective ratings*	*Noise & distance from stimulus source*	Visentin et al. (2019)	25	Adults	Italian monolinguals & German (L1)–Italian (L2) bilinguals	*AoA*—<8 years; *Proficiency*—self-reported as high; *Learning*—environment and classroom based	Listen to words presented in quiet, stationary, or fluctuating noise, in forward or backward locations of a classroom	Reaction time: bilinguals (L2) > monolinguals; Subjective rating: bilinguals (L2) = monolinguals	N/A
	Dual-task paradigm & subjective ratings	*Noise & reverberation & accented speech*	Peng and Wang (2019)	115	Adults	English monolinguals & Chinese (L1)–English (L2) bilinguals & bilinguals with L1 not Chinese, L2 English	*Proficiency* moderate or higher in proficiency tests; *Learning*—environment and classroom based	Tests presented in three SNRs, and five reverberation time scenarios, in English accent or Mandarin Chinese accent	Subjective rating: Bilinguals (L2) > monolinguals; Dual-task: Bilinguals with L1 not Chinese > monolinguals = Bilinguals with L1 Chinese	Bilinguals with L1 not Chinese > Bilinguals with L1 Chinese

Note. L2 background: Not all studies specified age of acquisition (AoA), proficiency, usage and learning circumstances. L2 proficiency estimates are based on self-reports and/or proficiency test/s. L2 learning/exposure circumstances are categorized as either classroom (learned in school/university) or environment-based (acquired while living in an L2-speaking country or family). N/A, not available. N = total sample size.

degradation, affects the listening effort experienced by young adult native English monolinguals and Italian (L1)–English (L2) bilinguals. Group differences in listening effort were measured while asking participants to listen to and repeat English sentences. Thus, the study compared monolingual processing in their native language to bilinguals' processing of their L2 (English). Sentences were presented in quiet and in the presence of an 8-talker babble noise. In noise, an adaptive procedure was used to estimate for each participant two signal-to-noise ratios (SNRs) that enable low (40%) and high (80%) intelligibility levels. Thus, listening effort was examined in SNRs that allowed similar intelligibility levels across monolingual and bilingual listeners. The findings showed that the SNRs required for achieving 40% or 80% intelligibility were significantly lower for monolinguals than those required by bilinguals, such that to reach a particular intelligibility level, monolinguals were able to deal with more challenging SNRs than bilinguals. With respect to listening effort, differences in pupillometry were observed across the two intelligibility levels. Specifically, for both monolinguals and bilinguals, larger mean and peak pupil dilation, reflecting more listening effort, were observed in the condition that enabled low intelligibility (40%) compared to high intelligibility (80%), confirming that listening effort is sensitive to the level of speech intelligibility. Critically, the results also showed that the mean and peak pupil dilation were greater for bilingual young adults compared to monolingual young adults in all listening conditions, even when intelligibility was near ceiling, as was the case in the quiet condition. This result suggests that greater listening effort is involved in listening to L2 compared to L1, even in the absence of perceptual performance differences.

Francis et al. (2018) similarly used *pupillometry* to assess bilingual young adults' listening effort in the presence of background noise. However, in that study listening effort was examined within a group of bilinguals in each of their two languages: L1 (Dutch) versus L2 (English). Participants were asked to repeat Dutch (L1) and English (L2) sentences in quiet, and in the presence of single talker competing speech presented once in Dutch (L1), and once in English (L2). Here, too, an adaptive procedure was used to estimate the required speech perception threshold that enabled listeners to achieve similar intelligibility performance in L1 and L2. The findings showed poorer perceptual performance and larger pupil dilations when the target sentences were presented in bilinguals' L2 compared to L1, and in the presence of L1 competing speech compared to L2 competing speech, suggesting that a native language might be easier to attend to but harder to ignore. Further, listening to L2 sentences presented in L2 competing speech resulted in larger pupil dilation than L2 sentences presented in L1 competing speech, confirming the target-masker linguistic similarity hypothesis (Brouwer et al., 2012; Brown et al., 2022; Calandruccio et al., 2010; Calandruccio & Zhou, 2014). This hypothesis suggests that the more similar the target and the competing speech are, the harder it is to efficiently segregate the two streams, as this similarity can result in informational masking. While a detailed discussion of the effect of informational masking is beyond the scope of the current work, it is worth noting that unlike energetic masking that interferes with the signal at the level of the auditory periphery, informational masking may create confusion between the signal and masker that originates more centrally in the auditory system (Cooke et al., 2008; Kidd et al., 2008; Mattys et al., 2009). Thus, in the presence of informational masking, performance can be constrained by greater similarity of the target signal and the competing speech, resulting in uncertainty of the listener as to which acoustic elements belong to the target stream versus which belong to the competing speech (masker). Accordingly, the larger pupil dilation, reflecting more listening effort, observed in the L2–L2 combination compared to L2–L1 combination in Francis et al. (2018) can be attributed to the higher similarity in acoustic features, temporal patterns, or prosody of the speech and the competing speech in the L2–L2 combination, which probably required bilinguals to exert increased effort to resolve the confusion between both streams. Francis et al. (2018) also showed that bilinguals' L2 proficiency modulated pupil dilation during listening in the L2–L2 condition, such that bilinguals with higher L2 proficiency showed larger pupil dilation than bilinguals with lower proficiency, suggesting that higher L2 proficiency levels may result in more susceptibility to interference from the L2 competing speech, as it is more understandable and harder to suppress. However, because L2 proficiency also modulated pupil dilation when listeners performed the task in L1 in the presence of L1 competing speech (L1–L1 condition), the authors offered other factors that may underlie these proficiency effects and called future studies to examine how individual differences in terms of language proficiency modulate listening effort.

Pupillometry as a measure of listening effort was also used in bilingual children. Brännström et al. (2021) examined listening effort in the presence of favorable (+10 dB SNR) and typical (0 dB SNR) (i.e., more difficult) levels of noise among primary school monolinguals and bilinguals. The monolingual group consisted of native Swedish speakers, whereas the bilingual group consisted of children who had a later age of acquisition (AoA) of Swedish which could thus be considered the L2 (bilinguals' L1 was not stated). Accuracy and pupil size were examined while listeners performed a Swedish speech-picture verification task, in which they heard a passage and determined whether a pictured object had been mentioned in the passage or not. The findings showed that monolinguals exhibited a slight but nonsignificant decrease in perceptual accuracy in the typical (i.e., more difficult listening condition) compared to the favorable listening condition. However, bilinguals' accuracy in their L2 was significantly lower in the typical compared to the favorable listening condition. Moreover, when comparing pupil size in the two noise levels, larger dilation was observed under the typical noise levels than the favorable condition, and the effect was especially pronounced in bilingual listeners. The findings further showed that among monolinguals, higher accuracy in the task was associated with larger pupil size. Interestingly, this effect was absent for bilinguals, particularly in the typical listening condition, where they instead had greater pupil dilation during trials to which they subsequently provided incorrect answers. These patterns suggest that monolingual listeners effectively exerted increased effort to reach sufficient perceptual performance, whereas bilingual children invested increased effort, without necessarily achieving sufficient listening comprehension. Moreover, the latter finding may be interpreted through the lens of an inverted U-shaped relationship between task difficulty and pupil size. According to this perspective, pupil size is expected to decrease when the individual no longer perceives success as possible or worthwhile (e.g., Wendt et al., 2018; Zekveld & Kramer, 2014). In the context of Brännström et al. (2021) study, it is plausible that monolinguals perceived the typical listening condition as manageable and thus maintained effort to improve their performance, as evidenced by larger pupil dilation during correct trials. In contrast, bilingual participants may have experienced a reduction in their motivation and engagement as the typical (relatively adverse) condition was more demanding and challenging for them to handle.

Borghini and Hazan (2020) expanded the literature to not only test the effect of noise, but rather used *pupillometry* to explore how the combination of noise and speaker degradation influenced listening effort in bilingual individuals. Their study examined how variations in speaking style (speaker degradation) interact with background noise (environmental degradation) to affect the listening effort experienced by English monolingual and Italian (L1)–English (L2) bilingual young adults. Specifically, listeners were asked to repeat English sentences presented in the presence of a babble noise that enabled 50% intelligibility in one of two conditions: Plain speech (produced in conversational style) and clear speech. Conversational speech style may be treated as a speaker degradation insofar as it affects the produced speech. It includes syllable omission, segment elision, segment reduction, and faster speech rate, which reduce intelligibility compared to clear speech (Mattys et al., 2012). With respect to listening effort, the findings of Borghini and Hazan (2020) showed greater effort indexed by greater mean and peak pupil responses in the plain compared to the clear speaking style, and critically, in bilinguals (L2) compared to monolinguals. The increased effort among bilinguals was observed even when intelligibility level was equated across groups, and irrespective of the condition tested. However, unlike the correlation found in Francis et al. (2018), here bilinguals' score on the English proficiency test did not modulate pupil response. Still, as noted by the authors, this finding does not preclude a relation between language proficiency and listening effort, and multiple factors were attributed to the lack of such a correlation, such as presenting the listening task at a less favorable SNR to the more proficient bilinguals compared to the less proficient bilinguals. Therefore, more research is needed to better characterize the relation between bilingual language proficiency and listening effort.

Using a different physiological measure, Grant et al. (2022) examined listening effort among English (L1)–French (L2) and French (L1)–English (L2) bilinguals, by tracking the changes in *alpha oscillation*. During EEG recordings, bilinguals listened to sentences presented in both of their languages (L1 or L2) in quiet and in the presence of multi-talker babble noise. In line with the findings observed in pupillometry studies, the results showed an increase in alpha power, reflecting more listening effort, during the noise condition compared to the quiet condition and during the processing of L2 sentences compared to L1 sentences. In addition, the authors observed a positive correlation of alpha power with L2 AoA (from 0 to 15 years), suggesting that bilinguals who acquired L2 at a later age exhibited higher listening effort compared to earlier learners. Thus, as expected, variability within bilingual populations appears to modulate listening effort.

Together, the studies utilizing physiological measures of effort suggest that bilinguals experience greater listening effort in their L2 compared to L1 and relative to monolinguals, even when perceptual accuracy is similar. This holds particularly when the degradation interferes more with the target signal, such as when listening in more challenging SNRs, or when the degradation is presented in the same language of the signal. In such conditions there is an increase of energetic or informational masking. For example, in Borghini and Hazan (2018) increased effort was observed in the more challenging SNR level which presumably created high energetic masking resulting in poor audibility of the signal. At the same time, in Francis et al. (2018) increased effort was observed in the matched target-masker condition, indicating higher levels of informational masking, as discussed above. However, isolating the unique influence of informational/energetic masking on listening effort relying solely on these studies is not straightforward, as these types of masking often occur simultaneously, and the above studies differed in additional methodological aspects. Thus, future studies should examine the effect of masking components, while trying to isolate their effects (see Brown et al., 2022), and study their relationship to listening effort in bilinguals. Critically, the above findings also highlight that listening effort can be sensitive to factors related to bilinguals' linguistic profile, such as age of language acquisition and level of language proficiency, but more research is needed to elucidate these effects.

Listening Effort Using Behavioral Measures

Lam et al. (2018) and Oosthuizen et al. (2020) employed behavioral measures to investigate bilingual listening effort under adverse listening conditions. In particular, Lam et al. (2018) relied on *reaction times* to measure listening effort among young adult bilingual students in realistic acoustic scenarios. To do so, the authors examined the impact of environmental degradations, including noise and reverberations, on listening effort. Monolingual native speakers of English were compared to bilingual speakers of English as an L2 with various L1s (e.g., Mandarin, Korean, Cantonese, Spanish, Farsi, Bengali, Arabic, Portuguese, or Romanian). Participants were asked to recognize English words in a quiet listening condition, in reverberation dominant listening condition (reverberation time = 1.08 s and negligible level of noise (SNR > + 15 dB)), and in a condition that mixed reverberation and noise (reverberation time = 0.68 s, SNR = + 7.5 dB SNR). The two latter listening conditions were used to mimic classroom acoustics. The findings showed that although monolinguals and bilinguals achieved comparable, close to ceiling perceptual accuracy of English words, bilinguals required more time to provide their answers compared to monolinguals in all acoustic conditions, including in the quiet listening condition. Thus, to the extent that reaction time differences reflect differences in effort rather than other aspects of processing, these findings suggest that even when environmental degradations result in a low energetic masking (as is the case of reverberation dominant listening condition), bilinguals in their L2 tend to exert greater effort compared to monolinguals. In addition, the group differences observed in the quiet condition confirm that effort can be involved in bilinguals' performance even when no specific degradation exists.

Interestingly, in contrast to the findings of Lam et al. (2018), Oosthuizen et al. (2020) did not observe increased listening effort for bilingual listeners in their L2, as measured by behavioral indices. In that study, the speech task contained digit triplets and participants were school-aged children who were native and non-native speakers of English (L1 of the non-native speakers was not stated). During the study, these individuals listened to digit triplets in quiet and at two levels of noise (−10 and −15 dB SNRs) and were required to either only repeat the heard digits (a single task condition), or to simultaneously perform a secondary visual task (touch a shape on the screen). Changes in verbal *reaction time* in a single task and visual reaction time in the *dual-task* were used to measure listening effort. The findings showed that verbal and visual reaction times were affected by noise, such that all children demonstrated slower reaction times with the addition of, or increase in, background noise. Critically, however, native and non-native listeners did not differ in their reaction-time patterns. The authors suggested that the use of universal digit stimuli with low linguistic load, which were highly familiar to both groups, might have influenced the observed listening effort, highlighting the potential role of stimulus complexity and familiarity in affecting listening effort.

Considering that bilinguals' perceptual performance is affected by the linguistic processing demands of a given task (e.g., Akker & Cutler, 2003; Bradlow & Alexander, 2007; Clahsen & Felser, 2006; Kraus & White-Schwoch, 2017; Krizman et al., 2017; Mayo et al., 1997; Shi, 2010; Skoe & Karayanidi, 2019), it is reasonable to postulate that this factor may also affect exertion of listening effort. However, it is also worth noting that the results obtained in Oosthuizen et al. (2020) may be specific to the measures employed or to other methodological factors. For example, it is possible that the behavioral measures used did not fully capture the effort experienced by bilinguals. Furthermore, no information was provided about the multilingual background of the participants, which limits the examination of how variability in language background might have influenced the results. Thus, whereas it is reasonable to suggest that bilinguals may exert increased listening effort when tested with stimuli posing high linguistic demands, more research is needed to elucidate this prediction. Future studies can explore this prediction by manipulating the linguistic demands of tasks while controlling for other methodological factors. Additionally, it would be valuable to employ different measures of listening effort and examine whether these measures can capture any differences.

Listening Effort Using Subjective Ratings

Desjardins et al. (2019) and Kilman et al. (2015) used subjective measures to examine bilingual listening effort under adverse listening conditions that involved environmental and listener-related factors. Specifically, Desjardins et al. (2019) examined the impact of background noise (environmental factor) and age (listener factor) on the listening effort experienced by monolingual and bilingual adults. Perceptual performance in sentences presented in quiet and in a background noise, along with *subjective ratings* of listening effort was examined among young and older adult monolinguals (English) and Spanish (L1)–English (L2) bilinguals. While no significant differences were observed within or between the participant groups in quiet, significant differences emerged in the presence of background noise. Bilinguals performed perceptually poorer when tested in background noise on the L2 sentences compared to the L1 sentences, and their subjective ratings of listening effort were higher for the L2 presentation. Similarly, when comparing monolinguals' L1 to bilinguals' L2 in noise, bilinguals had poorer perceptual performance compared to monolinguals and reported increased listening effort ratings. These findings are consistent with the conclusions raised earlier, that under adverse listening conditions, listening effort tends to be larger in bilinguals' L2 compared to L1 or when it is compared to that of monolinguals. Regarding the effect of age, there was no difference between younger and older participant groups in the subjective rating effort measure, indicating that age may not modulate bilinguals' listening effort. However, to draw a definite conclusion about the effect of age on bilinguals' listening effort, further research incorporating additional measures is warranted because it may be the case that younger and older adults differ in their criteria for reporting and defining their subjective experience of effort.

In the study of Kilman et al. (2015), the impact of a different listener-related factor, specifically hearing status, was examined in conjunction with environmental degradation caused by noise. In particular, during the perception of masked native (L1) and non-native (L2) speech, listening effort, using *subjective ratings*, was examined among normal hearing and hearing-impaired (symmetrical mild-to-severe sensorineural hearing loss) Swedish (L1)–English (L2) bilinguals. Bilinguals were asked to evaluate their perceived effort after listening to sentences presented in Swedish and English under different types of noise (stationary noise, fluctuating noise, babble noise in Swedish (L1) and babble noise in English (L2)). Consistent with Francis et al.'s (2018) findings, the results showed that the level of listening effort varied depending on the similarity between the target speech and the masker. Thus, hearing-impaired bilinguals experienced the Swedish (L1) babble as more effortful than the other three types of maskers, and the Swedish (L1) target-Swedish (L1) babble combination was the most effortful condition for these listeners. Notably, although there was no significant difference in perceived effort between hearing-impaired and normal-hearing bilinguals, a trend was observed ($p = 0.06$), suggesting possible effects that may be revealed with a larger sample. Future studies based on larger cohorts and incorporating objective measures of listening effort may provide a more comprehensive understanding of such differences.

In summary, the findings from Desjardins et al. (2019) and Kilman et al. (2015) suggest that subjective ratings can effectively capture the listening effort experienced by bilinguals in response to environmental degradation. However, when it comes to adverse conditions related to listener factors, such as age and hearing status, it is unclear whether subjective measures alone can fully capture bilinguals' listening effort. The limitation of self-report measures in revealing differences in listening effort under adverse conditions caused by listener factors may be tied to the fact that examining such factors relies on comparing different individuals. Because subjective ratings may differ across individuals and across populations (see for instance Tomoschuk et al., 2019), such measures may be less suitable for comparing listening effort in relation to these factors. Therefore, further research is warranted to gain a deeper understanding of how listener-related factors influence listening effort in bilingual individuals. This research should consider incorporating a broader range of listening effort measures, including both objective and subjective indices, to provide more nuanced insights into the complexities of bilingual listening effort.

Listening Effort Combining Behavioral and Subjective Measures

Studies that incorporate different types of effort measures hold the potential to illuminate whether the observed results are specific to the measures employed. Within the context of bilingual research, Visentin et al. (2019) and Peng and Wang (2019) integrated subjective and behavioral measures to examine bilinguals' listening effort under adverse conditions. In particular, using *reaction time* and *subjective ratings*, Visentin et al. (2019) examined the combined effect of background noise and distance from stimulus source on the listening effort experienced by young adult students who were Italian monolinguals or German (L1)–Italian (L2) bilinguals. In their study, participants were asked to recognize Italian disyllabic words. The listening task took place in a real university classroom in three listening conditions (quiet, stationary noise, and speech-like-fluctuating noise) while grouping the listeners into two locations within the classroom (front vs. back locations). These locations differed mainly in the SNR of the received signal, and in its quality, with signals received under more challenging SNRs and with lower quality in the back location of the classroom compared to the front location. The findings showed that under realistic modifications of the room acoustic conditions, as in the case of the presence of speech-like fluctuating noise and sitting in a back location of the classroom, bilinguals needed longer reaction times to achieve correct responses compared to monolinguals. At the same time, supporting the notion that different measures may tap into different components of the effort construct and cannot be used interchangeably, individuals' reaction times did not correlate with their subjective ratings. Thus, bilinguals reported similar subjective perceived effort to that of monolinguals, even though they responded more slowly. This discrepancy between measures emphasized the necessity of utilizing multiple measures to fully grasp the intricacies of listening effort.

Supporting the same point, Peng and Wang (2019) examined effects of noise, reverberation, and accented speech degradations on the listening effort experienced by college students who were (a) native English, (b) non-native English with L1 Mandarin Chinese, or (c) non-native English with L1 other than Mandarin Chinese (e.g., Hindu, Korean, and Portuguese). Listening effort was examined using a *dual-task* paradigm and *subjective rating* measures during the perception of English speech stimuli presented in different tasks (photograph recognition, single sentence inquiry, comprehension of conversations, and monologues). A total of 15 acoustic conditions were tested: Three noise levels (equivalent to SNRs of +21, +11, and +1) and five reverberation time scenarios (from 0.4 to 1.2 s, with an increment of 0.2 s), as well as the presence of accent was examined by presenting the same English stimuli produced once by a native American English speaker and once by a native Mandarin Chinese speaker (i.e., accented). Significant effects were revealed by the subjective but not dual task measure. Specifically, increased perceived effort was reported under lower SNRs and more challenging reverberation conditions, and participants from the non-native groups reported more perceived listening effort compared to native listeners. Furthermore, listening to accented speech was associated with higher perceived effort, particularly when the accent was unfamiliar to bilingual individuals, highlighting the impact of degradation characteristics on the level of effort experienced. Interestingly, such differences were not observed in the dual-task measure, in that performance on the secondary task did not vary with changing acoustic conditions. In addition, increased effort in this dual-task measure was only observed when comparing the non-native English listeners with L1 other than Mandarin to the two other listener groups.

Hence, the collective findings from Visentin et al. (2019) and Peng and Wang (2019) provide compelling evidence for the complex nature of listening effort and highlight the limitations of relying on a single measure to capture its full complexity. These studies underscore the importance of adopting a multi-dimensional approach to thoroughly assess and explore the listening effort experienced by bilingual individuals and emphasize the need for further research in this area.

Summary and Future Directions. The extant literature reviewed here showed that even when perceptual performance is unaffected, differential listening effort may be involved and may elucidate differences between individuals with different language histories or within bilinguals in their L2 compared to their L1. Studies incorporating different measures of effort, including physiological, behavioral, subjective, or a combination of such measures, showed the same direction of effect, in that if anything, L2 listening was associated with increased effort compared to L1, with no instances found of the opposite direction (L2 entailing reduced effort compared to L1). However, the current body of research examining bilinguals' listening effort remains relatively limited in both number and scope, highlighting the need for further investigation in this domain. Therefore, this review serves as an initial step toward understanding the complex nature of listening effort in bilingual speech perception. The conclusions drawn, while important, should be regarded as a starting point for further investigations, with the goal of substantiating and enhancing the proposed hypotheses.

Along with the overall pattern by which greater listening effort is observed in L2 relative to L1 listening, several factors emerge as potentially influential in the observed effects. The first is the measure chosen to assess effort. Physiological measures, providing precise temporal indications of mental processing (Alhanbali et al., 2019; Gómez-Merino et al., 2020; Schmidtke, 2018), consistently revealed differences between bilinguals' L2 and monolinguals or between bilinguals' two languages. In contrast, behavioral or subjective measures, relying on individuals' overt response, did not consistently find such differences. Still, given the complexity in comparing studies with varying participants, materials, and listening conditions, it is difficult to draw firm conclusions regarding the best measure for tapping into bilingual listening effort. Moreover, although the number of studies utilizing multiple types of measures remains limited, the existing evidence demonstrated that different measures may be uncorrelated, emphasizing the potential differences in sensitivity among different tools (Strand et al., 2018), and the multidimensional nature of the listening effort construct (e.g., Alhanbali et al., 2019). To date, there is no agreement on what the concept of listening effort encompasses, and the dimensions of the effort construct are still under-specified (Alhanbali et al., 2019; Francis & Love, 2020; Strand et al., 2020). Furthermore, there is no consensus regarding the measure that might best express listening effort (Neeman et al., 2022). Thus, until more information is available about the different dimensions of this construct and the overlapping systems it is composed of, it may be advisable to include multiple measures rather than relying on one as a sole indicator (Strand et al., 2020). Such an approach would allow one to systematically compare the measures when all other factors are fully controlled, identify the specific characteristics and limitations of each tool, and more importantly, consider the complex nature of listening effort.

A second factor that seems to modulate effort is individuals' proficiency in the target stimuli. The review suggests that bilinguals exert increased effort when processing speech in their L2. In all studies reviewed here, L2 constituted bilinguals' nondominant and less-proficient language (see Table 1). Although this finding aligns with the perceptual disadvantage bilinguals generally demonstrate in their nondominant language under adverse listening conditions, it is important to note that the current review suggests that increased effort in listening to the nondominant language may exist even when differences do not emerge in the perceptual performance of the individual. Thus, assessing listening effort may uncover challenges in speech processing that may not be evident through perceptual performance alone, highlighting its significance beyond speech intelligibility.

Notably, while increased listening effort among bilinguals in their nondominant language is observed across diverse linguistic backgrounds, proficiency levels, age of acquisition, and learning and exposure circumstances (see Table 1), the presence of such overall trend does not preclude the possibility that variability within the linguistic background and experience of bilingual individuals may still modulate listening effort. In particular, variability within bilingual populations, which has been shown to influence perceptual performance (e.g., Blasingame & Bradlow, 2020; Calandruccio & Zhou, 2014; Miller et al., 2019; Reetzke et al., 2016; Regalado et al., 2019; Shi, 2014b, 2015; Shi & Koenig, 2016; Weiss & Dempsey, 2008), is expected to play an important modulating role in bilinguals' listening effort. Therefore, future studies should aim to examine the contribution of such variability on bilinguals' listening effort. Furthermore, future studies should incorporate information about individuals' educational attainment and socioeconomic status as suggested by Cowan et al. (2022), as well as assess emotional and motivational characteristics (Pichora-Fuller et al., 2016), as these may affect language and cognitive task performance (e.g., Gathercole et al., 2016) and in the context of this review, modulate listening effort.

Furthermore, to gain a deeper understanding of bilingual listening effort, future studies should employ more nuanced research designs. Currently, most studies investigating speech perception and listening effort in bilinguals focus on comparing bilinguals in their L2 to monolinguals. Exclusively conducting such a comparison can be problematic, as it involves the comparison of participants who differ on several characteristics over and above their language status. For example, bilinguals tested in such studies can be immigrants or acculturated in ways that are fundamentally different from monolinguals living in their native culture, differences that may modulate individuals' performance and listening effort. Therefore, to isolate the effect of language status, it may be better to consider conducting studies that incorporate both within- and between-subject comparisons (similar to Bsharat-Maalouf & Karawani, 2022b; Desjardins et al., 2019).

Relatedly, there is evidence to suggest that bilinguals are perceptually affected by adverse listening conditions more strongly than monolinguals even when tested in their dominant, first-acquired language (Bsharat-Maalouf & Karawani, 2022b). However, the role of listening effort in mediating these effects remains unexplored. To address this gap, it is crucial to compare bilinguals' listening effort in their dominant language to that of monolinguals. Unlike monolinguals who spend their time in only one language, bilinguals divide their language use between two languages, leading to reduced frequency of exposure to each language. Consequently, bilinguals may possess representations that are of lower frequency and entail weaker links among their subcomponents, even in their dominant language (Gollan et al., 2008; Gollan et al., 2011). This may make perception more challenging for bilinguals, necessitating increased listening effort. Additionally, language co-activation occurs, with words from both languages receiving activation. Therefore, candidate words from the nondominant language may be activated while processing stimuli in the dominant language (albeit to a lesser extent), just as candidate words from the dominant language are activated while processing stimuli in the nondominant language (Blumenfeld & Marian, 2013; Bobb et al., 2020; Marian et al., 2008; Marian & Spivey, 2003a, 2003b; Shook & Marian, 2012, 2013; Weber & Cutler, 2004). Thus, even in their dominant language, bilinguals face heightened competition and co-activation compared to monolingual listeners, potentially leading to an increased need of effort. Future studies should delve into this area to gain a comprehensive understanding of the role of listening effort across all languages of bilingual listeners.

Finally, from the studies that systematically compared how listening effort changed in different adverse conditions it appears that the familiarity of the individual with the adverse condition, the degree of similarity between the target signal and the adverse condition, and more broadly the characteristics of the adverse condition itself, may modulate the degree of listening effort exerted. For example, the current review shows that when a degradation led to higher interference with the signal, such as in the case of a degradation presented in a higher intensity (e.g., Borghini & Hazan, 2018; Brännström et al., 2021) or in the same language of the signal (e.g., Francis et al., 2018; Kilman et al., 2014), more effort was reported. Still, to generalize these findings, further studies are needed to systematically examine a broader range of adverse conditions and their effect on the degree of effort experienced. Additionally, recent studies on monolinguals indicate that exposure to adverse listening conditions can lead to a rapid decrease in listening effort due to an adaptation process (Brown et al., 2020; Rovetti et al., 2023). Therefore, it is crucial for future studies to investigate whether a similar adaptation process exists among bilingual listeners and to what extent it can compensate for the increased effort observed in their nondominant language. These avenues for future research will contribute to a more comprehensive understanding of bilinguals' listening effort and facilitate the development of effective strategies and interventions to address it.

Conclusion

The literature reviewed here suggests that performance in adverse listening conditions comes at a higher cost for bilinguals in their nondominant language, as reflected in increased listening effort. However, additional research is required to validate and strengthen the generalizability and reliability of these findings, as well as to explore the potential consequences of this heightened effort. By developing a more comprehensive understanding of the effort involved in bilinguals' listening, informed decisions can be made and effective strategies can be implemented to support these individuals in clinical, educational, and workplace settings.

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