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NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

THE EFFECT OF AUDITORY TRAINING ON SPEECH-IN-NOISE PERFORMANCE BY ELDERLY BILINGUALS IN SINGAPORE

A PILOT STUDY EVALUATING LACE™

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Supervisor: Assistant Professor Chan Hiu Dan Alice

A Final Year Project submitted to the School of Humanities and Social Sciences, Nanyang Technological University, in partial fulfilment of the requirements for the Degree of Bachelor of Arts in Linguistics and Multilingual Studies

2012
Declaration of Authorship

I declare that this assignment is my own original work, unless otherwise referenced, as defined by the NTU policy on plagiarism. I have read the NTU Honour Code and Pledge.

No part of this Final Year Project has been or is being concurrently submitted for any other qualification at any other university.

I certify that the data collected for this project is authentic. I fully understand that falsification of data will result in the failure of the project and/or failure of the course.

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Name                      Signature                  Date
Additional information

- My FYP is an extension of my URECA project.  Yes/No
  If yes, give details:

- My FYP is part of my supervisor’s project.  Yes/No
  If yes, give details:
  My supervisor is the principal investigator for the research on ‘Cultural and Linguistic Constraints in Visual and Auditory Processing’. My FYP involves the effect of auditory training on speech-in-noise processing by elderly bilinguals.

- My FYP is partially supported by my supervisor’s grant.  Yes/No
  FYP is fully supported by supervisor’s grant. Participant cash payment for my FYP comes from the faculty of Communication Sciences & Disorders at Northwestern University in which my supervisor has grant as the lead experimenter for her research.

- Provide details of funding expenditure, (e.g. payment of informant $10/hr funded by supervisor’s grant…)

  Participants were paid $10 per hour for each training session and another $45 upon completion of the training paradigm. Travel or parking fees incurred by them were also reimbursed, with a cap at $3.60.
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Abstract

Auditory training has been found to be an essential compensatory strategy alongside hearing aids for rehabilitating impaired and aged auditory systems. Previous studies have attested to significant improvement in the performance of speech-in-noise processing by monolingual, native English speaking, hearing aid users after training in the Listening and Auditory Comprehension Enhancement (LACE™) programme, designed to improve listening and cognitive skills (Sweetow & Henderson-Sabes 2006; Olson 2010; Song et al. 2012). The LACE programme however has never been validated on non hearing impaired, non-native English speaking elderly bilinguals in a multilingual context like Singapore. In this pilot study, the effectiveness of LACE on a bilingual population is evaluated as four elderly Mandarin-English bilinguals undergo a two-week, computer-based, adaptive LACE programme. Quick speech-in-noise (QuickSIN) test results show overall improvement in speech-in-noise perception and despite within-subject differences in scores, encouraging trends serve as a platform for future research to investigate the long-term benefits of such training, as well as cross-linguistic influences on multilingual populations.
1 INTRODUCTION

Across the globe, the proportion of older people (aged 60 and over) is increasing faster than any other age group, a result of both longer life expectancy and declining fertility rates (World Health Organisation 2012). Perhaps a growing aging population can attest to successful healthcare reforms and better socioeconomic development; however this inadvertently presents new demands a society has to adapt to, such that any functional capacity of older people is not lost. As such, understanding the effect that aging has on communication has become more significant than ever. Highlighted by many renowned audiologists and speech-language pathologists, the importance of studying this topic is built on three premises (Worrall & Hickson 2003):

1. The proportion of older people in the global population is growing
2. There is a prevalence of communication problems among older people
3. Such communication problems can negative impact the quality of life for older people

An inevitable biological phenomenon, aging dulls our sensory functions and they start to lose their accuracy. Losing sharpness in hearing is one of the common ailments that plague older people. The ability to recognise and process speech in adverse acoustic conditions, for example noise, worsens and in order to regain normal functioning in society, one must assimilate various cues such as acoustic, linguistic and environmental ones (Sweetow & Henderson-Sabes 2004). One response in humans to such sensory deficit or deprivation is in the brain’s capacity to undergo plasticity in the auditory cortex by remapping auditory pathways (Irvine, Rajan & Brown 2001; Tremblay, Piskosz & Souza 2003; Bartels, Staal & Albers 2007). Another however, is expressed in the way patients of hearing loss alter their behaviour by relying on poor compensatory strategies, such as ‘tuning out’ or dominating a conversation, to cope with the deterioration of their peripheral hearing and interpretation of a fragmented signal (Sweetow & Henderson-Sabes 2007). While modern hearing aids can provide audibility of sounds, they fail to resolve impaired frequency and temporal resolution in a set of incoming signals which are presumably inferior to that of normal-hearing individuals. Since communication is transactional, relying on amplification alone is rendered inadequate because integrating those cues mentioned previously elicits many skills and processes such as “cognition, auditory memory, auditory closure, auditory learning,
metalinguistics, use of pragmatics, semantics, grammatical shape, localization, visual cues, repair tactics and… effective interactive communication strategies” (pp. 32). Thus with this insight behind how speech-in-noise processing functions, the limitations to using amplification simply as a coping strategy to hearing loss become apparent.

Having fully explored the need for cost-effective, individualistic therapy to rehabilitate an aging auditory system, not provided for by hearing aids alone, leading audiologists, Sweetow and Henderson-Sabes, at the University of California, teamed up with Neurotöne Inc. to develop the Listening and Auditory Communication Enhancement (LACE™) training programme (Sweetow & Henderson-Sabes 2004; 2006). LACE was predominantly birthed for monolingual speakers of American English as an adaptive training stimuli to enhance the listening and comprehension skills of hearing aid wearers in situations with difficult listening conditions. Having tested the effectiveness of LACE on a total of 65 participants at multiple locations, Sweetow and Henderson-Sabes (2006; 2007) found that there were significant improvements on not only LACE training tasks but also on a series of validated measures such as the Quick Speech-In-Noise (QuickSIN), Hearing In Noise Test (HINT), Hearing Handicap Scale for the Elderly (HHIE), and Communication Scale for Older Adults (CSOA). Other studies such as that of Olson (2010), Song, Skoe, Banai and Kraus (2012) and Cheyney (2009) have also administered LACE to either groups or individuals and their results also display a significant increase in understanding and perception of speech-in-noise by users with hearing impairments. According to Neurotöne (www.neurotone.com), this auditory training programme used in independent clinical trials to date has been successful in improving speech-in-noise comprehension and communication capacities by up to 40% in over 80,000 users.

However despite its success, there is a paucity of past research that looks into the use of such auditory training programme for healthy, non-native English speaking elderly bilingual speakers. Additionally, the effect of LACE on speech-in-noise processing has never been tested in multilingual contexts such as Singapore, whereby many official languages may coexist and her people, bilingual.

This study thus focuses on the use of LACE by non hearing impaired, elderly, bilingual English-Mandarin speakers, who are non-native speakers of English. Our goal is to evaluate the effectiveness of LACE in a multilingual setting like Singapore, different from the
environmental setting and audience it was originally produced for (hearing impaired monolinguals). At the same time, this study explores the possibility of extending the use of LACE to pedagogy – specifically, using the method of auditory training for the teaching of English to foreign learners (TEFL) or learners of English as a second language (ESL) – regardless of age group.

The goals and research questions of the study can be summarised as follows:

- To explore the extent of improvement (if any) and relevance of LACE training in a multilingual context like Singapore
- To account for trends observed in the progress of subjects throughout the training programme
- To identify if speech perception in noise by healthy elderly bilingual speakers will improve after LACE training

To investigate these research questions, a handful of non hearing impaired, elderly English-Mandarin bilingual speakers are followed as they go through a series of test phases and other experimental stimuli. By tracking their progress during the LACE training programme, interacting with the subjects and gaining access to their individual language backgrounds, this study attempts to account for any observable trends and present the data in case studies. It is hypothesised that the LACE training, while effective with monolingual English speaking trainees, would be limited in effectiveness when used with elderly bilingual speakers in Singapore who are non-native speakers of English. The ‘complicated’ nature of bilingualism in Singapore presents a unique case whereby there may be a shift in landscape of bilingualism from generation to generation, such that while Mandarin and other Chinese languages used to be the common first languages of the past, many younger Singaporeans, despite being bilingual, have native, if not native-like proficiency in English.

Intertwined between the fields of Communicative Sciences and Disorders and Linguistics, the implications for this study are multifaceted. Recommendations for future research could involve creating a new platform for the exploration of new auditory training programmes tailored for multilingual speakers and societies, regardless of age. Coming full circle, this study also aims to create new interest in the development of rehabilitation programmes in
multilingual gerontology departments around the world. As global aging populations grow, resolving communication problems before they arise should be a necessity to those of multiple tongues.
2 LITERATURE REVIEW

2.1 THE EFFECT OF AGING ON CHANGES IN SPEECH-IN-NOISE PROCESSING

The well-established fact: aging has a pervasive characteristic that causes older adults more trouble in comprehending speech-in-noise as compared to younger people (Schneider, Daneman & Pichora-Fuller 2002). Decades ago however, it was unclear whether auditory or cognitive mechanisms, or both, were responsible for age-related changes in the ability to recognise speech-in-noise (Crandell, Henoch & Dunkerson 1991). From disagreements regarding the specific effect age has on the ability to discriminate speech embedded in a variety of listening conditions, to complaints about inadequate investigation into speech perception problems suffered by aging listeners (Marshall 1981), the process of aging on the auditory system was constantly debated. Different alternative hypotheses regarding age-related declines in speech comprehension were put forth, such as those reported by the Committee on Hearing and Bioacoustics and Biomechanics of the US National Research Council (CHABA 1988; cited in Pichora-Fuller 2003a and Martin & Jerger 2005). Much research was driven by the need to reconcile evolving hypotheses of that time, each supporting different ideologies (Pichora-Fuller 2003a).

Over the years, research into auditory processing by aging listeners has developed tremendously and studies in the new millennia are establishing more evidence to accept both explanations for auditory and cognitive mechanisms on age-related deficits in speech-in-noise processing. Various modern explanations for speech processing problems it seems, point to an interaction of declines in peripheral, central auditory and cognitive processing (Martin & Jerger, 2005; Chioslm, Willott & Lister 2003; Pichora-Fuller 2003a, 2003b), such that “it was necessary to move from a modular site-of-lesion view to an integrated information-processing view” (Pichora-Fuller 2003a, pp. 2S27). What this means is – an interrelation of auditory and cognition contributes to one’s performance in speech-in-noise processing and an age-related deficit of which would thus result in the need for remedy that should target auditory, as well as cognitive-processing mechanisms.

Thus far, the term ‘age-related deficit’ has been left deliberately ambiguous. The reason behind this is that while age undoubtedly produces difficulty for older listeners in challenging
listening conditions, new everyday communication remedies can be implemented regardless of whether these listeners have clinical hearing impairment or significant loss of auditory sensitivity or not (Pichora-Fuller 2003a). In investigating the effect of age on speech understanding in normal hearing listeners, Kim, Frisina and Frisina (2006) sought to determine if the effects of the auditory efferent system and effects of spatial separation for speech perception correlate to contribute to the “cocktail party” effect – the phenomenon of focusing on a particular sound in a midst of sounds. Tasks by the auditory efferent system, located in the brain stem, include detecting speech sounds by modulating active physiological mechanisms. Spatial separation on the other hand is the separation of speech (signal) from the location of the noise (masker), resulting in speech perception or “a binaural release from masker (RFM)”. Their findings for normal hearing listeners of different ages suggest that age-related difficulties in perceiving speech-in-noise are indeed related to age-related declines in both the auditory efferent system and neural mechanisms, thus giving rise to the “cocktail party” effect.

As this research paper takes the approach of seeking effective communication function for healthy older listeners, understanding ‘everyday speech’ or ‘everyday listening’, as it is termed, is important for influencing successful experimental design in auditory rehabilitation (elaborated in later sections). According to Pichora-Fuller (2003a), ‘everyday listening’ crosses beyond the auditory domain to other domains such as that of cognitive, linguistics and socio-emotional. It has been suggested that by looking at these abilities non-discretely, the modern approach tackles performance of speech comprehension in noise differently – that is, measuring a combined ability to execute “naturalistic tasks such as understanding conversation” (pp. 2528) – instead of pursuing frameworks that argue for the value of only one mechanism, as done in the 1960s.

Helfer (1991) studied everyday speech by older listeners with minimal or no hearing loss and found that while these individuals produce more errors than young, normal hearing listeners on nonsense syllable tasks, the errors are similar. This led her to ‘break-down’ factors involved in ‘real-life listening’. Some of the factors include speech rate, message differences, speaker differences, visual information and binaural hearing. From gathering audiological assessment and comparing between different types of subjects, she concluded that should older listeners with minimal or no hearing impairment have difficulties with processing speech-in-noise, the remedy is not so simple as issuing hearing aids to them. Instead,
implementing methods of rehabilitation that expose these listeners to a stimulation of ‘actual communication’ (taking into account all of the factors mentioned above) would be necessary. Such aural rehabilitation methods could potentially educate healthy, older individuals to identify and resolve communication problems in the ‘real world’.

Defined by Boothroyd (2007), aural rehabilitation is the “holistic reduction of hearing-loss induced deficits of function, activity, participation, and quality of life through a combination of sensory management, instruction, perceptual training, and counselling” (pp. 63). Simply put, as Sweetow and Henderson-Sabes (2004) envision it, auditory rehabilitation alongside hearing aids is like therapy for the brain, whereby sensory pathways in the auditory cortex have to be strengthened – very much similar to physical therapy after a hip-replacement – such that psycho-social functions can be restored and quality of life is not diminished.

This then begets the question, what methods of auditory rehabilitation are available and which is the most optimal?

Auditory training for older adults as a rehabilitation method has evolved greatly over the years to now incorporate speech-in-noise instead of teaching the user to simply look out for sound cues (Montano 2007). Training programmes can come in the form of “auditory-alone, auditory-visual, with a focus on speech reading or communication strategies, lab-based, group-based, home-based, in-person or computerized” (Shannon & Extern 2008, pp. 5). With the options aplenty, identifying the two fundamental types of auditory training narrows down the search – analytic (bottom-up), which focuses on understanding the sounds of a speech signal, or synthetic (top-down), which requires a patient to employ contextual cues and his knowledge of language to deduce the semantics of phrases or sentences (Pallarito 2011).

Some of the other auditory training programmes available involve only one of the techniques, while some incorporate both (Pallarito 2011). The programme, Speech Perception Assessment and Training System (SPATS; Communications Disorders Technology, Inc.), administered by clinicians and audiologists, combines both bottom-up and top-down instructions in its regimen for the perception of sentences in noise. With the option of auditory only or auditory-visual training exercises, the Computer-Assisted Speech PERception testing and training at the SENTence level (CASPERSent) programme enables
users to train their lip-reading and/or hearing skills, allowing hearing health professionals to gauge their patient’s progress using the different measures available in the system.

In a systematic review of literature conducted on available individualised auditory training, Sweetow and Palmer’s (2005) preliminary search of two hundred and thirteen articles brought them to single out only six which met the study criteria. Following their analysis, they were convinced that employing synthetic training and including listening strategies in a programme may improve psycho-social functioning. Yet the problem with many of the available training programmes was, as Sweetow and Henderson-Sabes (2006) have pointed out, that not only do they require hearing health professionals to administer them in clinical settings; these professionals consider it time-consuming and costly. Even with group training as a good alternative, many distinct attributes within individual patients tend to be overlooked (Barlow & Hersen 1973, cited in Cheyney 2009; Sweetow & Henderson-Sabes 2006). This led Sweetow to launch LACE™, an easy-to-use, commercially available, home-based programme (CD, DVD, web download) which changed the scene for auditory training. (Pallarito 2011).

Another programme mentioned by Pallarito (2011) and Shannon et al. (2008) is the analytic and synthetic training programme, Seeing and Hearing Speech (SHS; Sensimetric), which trains users in lip reading and listening to speech in noise in four areas: (1) vowels, (2) consonants, (3) stress, intonation and length, and (4) everyday communications. Similar to LACE, this software is computerized and can be used as home-based training. In a bid to determine which software, LACE or SHS, was more effective as a training tool on hearing aid wearers, Shannon et al. (2008) administered the two programmes in random order to 14 older adults (55-75 years old). Each subject was trained in both programmes for a total of about 10 hours and their progress, which was constantly made known to them, was tracked and stored in log files. Although there were similar improvements in the synthetic training exercises for both, participants’ post-training evaluation displayed a tendency for them to rate their improvement in understanding speech in noise after LACE to be higher than that of SHS. Trainees also had more overall positive feedback for LACE than for SHS (Shannon et al. 2008).

With a review of the literature on the comparison between auditory training programmes, this study chose to evaluate LACE because it is easily accessible and well-established in the field.
2.2 **AUDITORY TRAINING WITH LACE™**

Passionate about equipping hearing-aid wearers displaying auditory processing difficulties with ‘therapy’ that aims to enhance hearing aids, Sweetow and Henderson-Sabes (2004; 2006) implemented the ‘Listening and Communication Enhancement’ (LACE) training programme. They believe that in rehabilitation for hearing loss, physiological adaptations (hearing aids) must be accompanied by behavioural strategies (auditory training). Their model (figure 1) demonstrates how proper comprehension and communication can enhance listening skills, while a deficit thereof only exacerbates listening. Driven by that belief that given adverse acoustic conditions (fragmented speech signals), limitations from amplification strategies presented by hearing aids impede the production of desired improvements in speech-in-noise processing. An adaptive auditory training programme, LACE was borne out of certain assumptions, of which one is that to improve communication effectiveness; hearing-aid wearers must assimilate hearing with listening. This means that compensating for peripheral loss can be done with an integration of comprehension and communication skills, made available through home-based auditory training, to manage an imperfect set of speech signals.

![Figure 1. A model of the interaction of elements of communication (Sweetow & Henderson-Sabes 2004)](image)

In a single case study, Cheyney (2009) tested the use of LACE on a 32 year-old patient diagnosed with an auditory processing disorder (APD). With the premise that auditory training for patients with APD should be “plasticity-engaging” (pp. 17) and “targeting of [a] specific stimuli to improve processing in a systematic manner” (pp. 18), LACE’s accessible and adaptive nature provided the right kind of stimuli for her study. Although the subject did not complete the training paradigm, programme statistics indicated a significant improvement in speech in noise related tasks, which resulted in the subject being able to successively hear speech in background noise at a higher volume. This improvement in performance also led to an overall increase in communication capacity in adverse acoustic conditions.
Olson (2010) evaluated the efficacy of LACE’s DVD programme on twenty-six new and experienced hearing aid wearers. The experienced hearing aid users were trained for four weeks with LACE while the new users who received training only at the end of the study, served as controls. While the study did not conclude the contributing factors for improved performance in both types of users, it was found that the new users had a larger training effect due to their lack of familiarity with the communication strategies provided. This study suggests that LACE is an effective training programme for an array of users and perhaps sheds light on the potential effectiveness for users without any hearing impairment.

The first to investigate the effect of speech-in-noise training on human subcortical processing of sound through auditory brainstem response (ABR), Song et al. (2012) decided upon the use of the commercially available LACE programme on sixty normal-hearing young adults. Utilizing a large set of stimuli to mirror real life scenarios and unique to its design, LACE also combines visual feedback after every exercise and promotes higher level cognitive skills which are suggested to enhance perceptual learning and allow for long-term, real-world application. Together with perceptual abilities testing through the Quick Speech-in-Noise test (QuickSIN; Etymotic Research) and the Hearing in Noise Test (HINT), their results have found that LACE takes a top-down, cognitive approach to training sensory processing of noise and is effective even for improving everyday listening by normal hearing listeners. A critical factor of its success, Song et al. evaluates LACE as an important ‘baseline’ indeed for understanding the correlation between biological mechanisms and cortical (neural) plasticity.

Given the results that LACE has been effective in improving speech in noise on hearing and non hearing impaired populations, Cheyney, Olson and Song et al. are optimistic that LACE paves the way for a wider range of populations regardless of age groups or language backgrounds, despite its original intent to act as an alternative compensatory strategy for hearing aid wearers with age-related hearing loss.

2.3 The Effect of Bilingualism on Speech-in-Noise Processing

From adopting the findings of past research on the mechanisms at work in accounting for age-related deficits in processing speech-in-noise, to the rationale behind the need for an adaptive auditory training programme like LACE and most recently the capacity of LACE to
benefit groups of people with different hearing profiles, we now turn our focus to exploring how speaker-related variables, such as one’s language background, can mix with external factors to further fragment speech processing in noise (Rogers, Lister, Febo, Besing & Abrams 2006; Helfer 1991). Of particular importance is the area of bilingualism with regards to age-related speech discrimination in noise. Insight into this factor would be helpful in determining the impact auditory training programmes, like LACE, would have on multilingual contexts and speakers.

For bilinguals, with or without hearing impairments, there are language background variables which, when combined with environmental factors, can affect the way they process speech-in-noise and therein the way auditory training can be suitable. Such language variables may alter the term ‘bilingual’ in the first place and it would be helpful to understand how to define one. At its simplest definition, a bilingual is an individual who has two languages in his or her linguistic repertoire (Baker 1993). This is where the variables come in, to differentiate one bilingual from another. They include age of onset of language acquisition (language history), proficiency in both languages, distribution of use for both languages, language stability (the extent to which proficiency is changing) for both languages, and the domains or contexts of language use in both languages (Rogers et al. 2006).

Many studies in the past on speech-perception abilities by bilingual listeners in noise have focused on that of children (who acquired a second language in adolescence or adulthood) (Crandell & Smaldino 1996) or learners of English as a second language (Nabelek & Donahue 1984). Few have studied the effects of speech in noise by older bilinguals. Rogers et al. (2006) chose to study the speech-perception abilities of early Spanish (L1)-English (L2) bilinguals (aged between 18 and 35 years), with normal hearing, in noise and other acoustic environmental factors like reverberation. This group of bilinguals had proficiency in English deemed by listeners to be native or near native/native-like (exposed before age 6).

When put through different audiological assessments, it was found that the performance of both groups of early bilinguals and monolinguals on word recognition task in quiet were 100%. However when tested with noise and reverberation word recognition tasks, their performance was lower than that of monolingual English speakers. Despite similar self-reported language background and usage patterns for both L1 and L2 and the fact that they were perceived to speak English with minimal or no foreign accent, results suggest that early
bilinguals are still less able than monolingual listeners to withstand acoustic degradations, common in everyday listening environments. This current study thus aims to determine the extent of improvement in performance by non native English speaking bilinguals on processing speech-in-noise after LACE auditory training.

At this junction, it is imperative almost, to consider how this translates to the situation in Singapore. Singapore, being a multiracial and multicultural nation, is undoubtedly multilingual. With four official languages – English, Mandarin, Malay and Tamil – coexisting in her society, it is not surprising that one Singaporean might have a different language profile from another. With linguistic reforms over the last decades promoting the rise of English and Mandarin in a move towards ensuring Singapore’s footing in the global economy (Wee 2003), as well as a call for the eradication of Chinese ‘dialects’ (Rubdy 2001; Tan 2006), the linguistic landscape between generations in Singapore is anything but stagnant.

Therefore with a shifting linguistic landscape and the younger bilingual generation becoming increasingly ‘English-knowing’ (Pakir 1993:73), profiling the language backgrounds of those over the age of 60 is not as simple. Known as the ‘post-war baby boomers’, this group has experienced not only the changes in Singapore’s physical development, but her linguistic changes as well. Native speakers of Mandarin or Chinese ‘dialects’, in a bid to keep up with the times, many elderly have picked up the more fashionable language of today’s time – English – in different degrees, rendering them as non native English speaking, late bilinguals. With non-characteristic language profiles among individuals in this age group, investigating the performance of such bilinguals in discriminating speech-in-noise after auditory training might suggest how one’s degree of bilingualism can affect improvements in the processing of speech-in-noise.
3 MATERIALS AND METHODS

3.1 OVERVIEW

Eligible subjects were sought in the screening phase while the experimental procedure of this qualitative study was divided into three phases, with the first being the ‘pre-training phase’, followed by the ‘post null-training phase’ and lastly the ‘post-training phase’. Over a period of two months, from September to October 2012, these test phases were carried out with each subject in approximately twelve separate sessions, on separate days. For each different phase, careful planning was in place to select a series of test stimuli and materials to be administered to the subjects, including a combination of verbal and non-verbal cognitive tests (results not significant for this current study). Subjects were required to perform the audiometry evaluation in a sound booth at the university, but for the training sessions, this researcher accompanied each subject on consecutive days as they received the LACE training in a quiet room of their homes to simulate the home-based, computerised training programme. An average of 8.5 hours in total was spent with each subject. Each session ranged from half an hour to two hours and subjects were paid $10/h accordingly for their participation and a bonus of S$45 upon completion of the study.

3.2 SEEKING ELIGIBLE SUBJECTS

Prior to the start of the pre-training phase, a detailed two-part screening test was carried out on potential subjects to ensure their eligibility for participation. They had to fill out a questionnaire (refer to Appendix A) and thereafter upon fulfilling eligibility criterions set out for the former, sit for a pure-tone threshold audiometric evaluation.

3.2.1 QUESTIONNAIRE

A residential neighbourhood familiar to this researcher was selected to search for potential subjects, with the chance that finding subjects who fit a set of specific descriptors, in a localised area, would be greater. Upon encountering potential elderly subjects (aged 60 and above), interacting with them and identifying their willingness (verbally) to participate, these
elderly subjects had to fill out the questionnaire on the spot. The questionnaire required information from the participants in the following three sections: (1) personal particulars, (2) language proficiency and use and (3) audiology case history. In order to keep the information garnered from the questionnaire confidential and to prevent a breach of ethics, codenames from this point on were issued to each participant and every document associated with them were hence on codenamed.

In order to evaluate the cognitive and cross-linguistic effects of speech-in-noise processing by English-Mandarin speaking elderly bilinguals, questions in the questionnaire were structured with the aim that the information obtained from the participants would help identify them as firstly, ‘effectively bilingual’ speakers of English and Mandarin Chinese (and/or other languages), and secondly, without any history or medical diagnosis of hearing impairment (known to them). To achieve the first aim, questions included: (i) their education levels, (ii) the languages they speak, (iii) their degree of proficiency of each language (previously stated) in the four basic categories – reading, writing, speaking and listening – (iv) the language(s) they use with their immediate family, as well as (v) their spontaneous language choice in three given scenarios – informal public domain, formal public domain and personal choice private domain. For the purpose of this study, the eligibility criteria for being ‘effectively bilingual’ was set at an average score of 4 and above on a 7-point Likert scale for each language.

To achieve the second aim, potential subjects had to indicate the industries they have worked in and answer questions that probed into their audiology background. However, although subjects had a negative noise history which enabled them to fulfil the eligibility criteria, in order to objectively ensure that they have no hearing impairments, an audiometric evaluation was carried out.

### 3.2.2 Audiometric Evaluation

Pure-tone thresholds at conventional frequencies of 250, 500, 1000, 2000, 4000 and 8000 Hertz (Hz) as well as at intermediate frequencies of 3000 and 6000 Hz were measured with a GSI 18 Grason-Stadler clinical audiometer and equipped with clinical headphones that accompanied the audiometer. Testing was held in a sound booth of the Cognitive and
Neurolinguistics Laboratory in the School of Humanities and Social Sciences at Nanyang Technological University. Starting with the right ear, higher and lower frequencies were tested in a randomised order. At each frequency, a series of tones in decreasing volumes of 10 dB (starting at 80dB) were played until the participant could no longer hear it. The same procedure was repeated for the left ear.

3.3 Subjects

Four elderly males – codenamed for this study as 01M, 02M, 03M and 04M, (mean age = 69.75, standard deviation [SD] = 7.932) – were chosen as subjects in this study. They had met the eligibility criterions for this study and none of them had participated in previous listening experiments using the experimental stimuli. All of the subjects were right-handed bilingual speakers with Mandarin and/or other Chinese languages as their first language(s) and English as second language. Although they rated themselves as being fluent in speaking, writing, reading and listening in both Mandarin and English, they are classified as non-native speakers of English based on their late exposure to English (details of their language background given in section 4.1). All subjects were tested with the Test of Nonverbal Intelligence, fourth edition (TONI-4), to identify their general intelligence quotient (IQ). With a maximum of 41 points, subjects attempted a range of 27 – 36 questions and thus achieved 66.7% - 83.3% accuracy in scores, allowing them to fall into the normal IQ range. The results of the subjects’ audiometry evaluation below also indicate that they have normal hearing patterns for their age group.

Table 1. Pure-tone thresholds of subjects

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Threshold Hearing Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
</tr>
<tr>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>500</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td>25</td>
</tr>
<tr>
<td>2000</td>
<td>30</td>
</tr>
<tr>
<td>3000</td>
<td>20</td>
</tr>
<tr>
<td>4000</td>
<td>30</td>
</tr>
<tr>
<td>6000</td>
<td>30</td>
</tr>
<tr>
<td>8000</td>
<td>45</td>
</tr>
</tbody>
</table>

1 TONI-4 Form B: Item 1 through 19 for ages 6 to 9 years, Item 20 through 60 for ages 10 and older. Every correct response is scored as 1 point and every incorrect response is scored as 0 point. Basal scoring: the highest level at which an individual scores five consecutive correct items. Ceiling score: the third error out of five consecutive responses.
Figure 2. Hearing thresholds for the average of the right and left ears.

3.4 INSTRUMENTS/EXPERIMENTAL STIMULI

3.4.1 SPEECH-IN-NOISE TEST

The Quick Speech-in-Noise Test (QuickSIN; Etymotic Research) (Killion et al. 2004) was used as a test of speech perception in background multitalker noise. It was administered during the pre-training, post null-training and post-training phases. There were 18 standard lists of the QuickSIN and each list consisted of 6 sentences, each with 5 target words. Each sentence had a pre-set signal-to-noise-ratio (SNR) which decreased in 5 dB increments from 25 to 0 dB SNR. The sentences, spoken by a female talker, were embedded in a 4-talker babble (3 women and 1 man). Although the sentences were grammatically correct, they lacked strong semantic or contextual cues (Song et al. 2012; Wilson, McArdle & Smith 2007). In discovering that the 18 standard practice lists were not necessarily balanced in terms of difficulty and familiarity of target words among other factors (Wilson et al. 2007), this researcher and three other listeners made an unbiased assessment of each list, grouping them into 4 levels of difficulty (1 – least difficult; 4 – most difficult). A random combination of 4 lists from each difficulty level were then selected and administered to each participant at each training phase:
Level 1: Lists 1, 3, 5, 9, 17  
Level 2: Lists 4, 8, 12, 13  
Level 3: Lists 2, 6, 10, 14  
Level 4: Lists 7, 11, 16, 15  

The QuickSIN CD was played through this researcher’s personal computer, calibrated to 70 dB HL, and the test sentences were presented via SonicGear headphones. Subjects were instructed to repeat back sentences or key words spoken by the main talker. Annotations including incorrect words were made by this researcher on the response form. In scoring the test, a point was awarded for every key word repeated correctly in each sentence. According to the QuickSIN instruction manual, the SNR loss score for each list was calculated by adding the number of key words repeated correctly, summing across all 6 sentences, and subtracting the total correct from 25.5. A more negative SNR loss was indicative of better performance on the task. The 4 SNR loss scores were averaged to obtain each subject’s final QuickSIN SNR loss score for each test session (Song et al. 2011).

3.4.2 AUDITORY TRAINING

The Listening and Comprehension Enhancement (LACE) programme (Neurotone, Inc., 2005) was used for the training phase. It is an interactive software which allows users to hone their listening, comprehension and cognitive skills through adaptive Degraded Speech tasks. Subjects were led through the degraded speech exercises which included scenarios in difficult listening conditions such as (1) speech in multitalker noise (Speech-in-Noise), (2) time-compressed speech (Rapid Speech) and (3) speech with one competing speaker (Competing Speaker). In each task, the user listens to a signal, is prompted to repeat back what was said and then receives immediate visual feedback on the next screen. If the sentence was comprehended correctly, the following sentence will be of a greater difficulty. Conversely, if it was incorrectly comprehended, the next sentence will be easier. A score (from 1 to 8) is awarded upon completion of each task. This enables subjects to track their progress after every training session. The difficulty level of each training session is based on the user’s scores from the previous session.
The LACE DVD was played through this researcher’s personal computer and the programme stimuli were presented via the same SonicGear headphones (as used for QuickSIN). The sound level was set at a comfortable listening level, as determined by each participant. Subjects manoeuvred the programme independently but compliance with the training regimen was monitored by this researcher. The training was held in 10 consecutive sessions, over the course of 2 weeks. Each session lasted approximately 30 minutes in duration and the subjects were required to complete 5 sessions each week.

3.5 PROCEDURE

In the screening phase, a questionnaire was given to the potential subjects and an audiometry evaluation test was carried out. In the pre-training phase, subjects were tested with 4 lists from QuickSIN. With an interval of two weeks, at the post null-training phase, the subjects were tested again at with 4 lists from QuickSIN and started the first of 10 sessions of the LACE training paradigm. The training ran consecutively for two weeks (except weekends) and on the last day of training, at the post-training phase, subjects were again tested for the third time with another 4 lists of QuickSIN.
4 RESULTS AND DATA ANALYSIS

4.1 QUESTIONNAIRE

Prior to addressing the results to the research question, descriptive analyses of the responses to the questionnaire and additional information about the subjects are presented. Information gathered from the questionnaire would be useful for analysing the following results and trends in greater detail.

Table 2. Summary of responses from questionnaire.

<table>
<thead>
<tr>
<th>Question</th>
<th>n</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your highest level of education?</td>
<td>1</td>
<td>Secondary School</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Pre-University</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>University and above</td>
</tr>
<tr>
<td>What languages do you speak?</td>
<td>4</td>
<td>Mandarin, Chinese languages and English</td>
</tr>
<tr>
<td>What is your (self-rated) speaking proficiency in English?</td>
<td>4</td>
<td>Points 5-7 on Likert scale</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Points 1-4 on Likert scale</td>
</tr>
<tr>
<td>What is your (self-rated) listening proficiency in English?</td>
<td>4</td>
<td>Points 5-7 on Likert scale</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Points 1-4 on Likert scale</td>
</tr>
<tr>
<td>What is your (self-rated) speaking proficiency in Mandarin?</td>
<td>4</td>
<td>Points 5-7 on Likert scale</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Points 1-4 on Likert scale</td>
</tr>
<tr>
<td>What is your (self-rated) listening proficiency in Mandarin?</td>
<td>4</td>
<td>Points 5-7 on Likert scale</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Points 1-4 on Likert scale</td>
</tr>
<tr>
<td>What language(s) do you prefer to use with your parents?</td>
<td>4</td>
<td>Mandarin and/or Chinese languages</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>English</td>
</tr>
<tr>
<td>What language(s) do you prefer to use with your siblings?</td>
<td>3</td>
<td>Mandarin and/or Chinese languages</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>English and/or Chinese languages</td>
</tr>
<tr>
<td>What language(s) do you prefer to use with your children?</td>
<td>2</td>
<td>Mandarin and English</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>English and Chinese languages</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>English only</td>
</tr>
<tr>
<td>What language(s) do you prefer to use with your grandchildren?</td>
<td>1</td>
<td>Mandarin and English</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>English only</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>N.A.</td>
</tr>
<tr>
<td>What language would you choose to use in this given scenario (description given)?</td>
<td>4</td>
<td>Mandarin and/or Chinese languages</td>
</tr>
<tr>
<td>• Informal, public domain (e.g. wet market)</td>
<td>0</td>
<td>English</td>
</tr>
<tr>
<td>• Formal, public domain (e.g. bank)</td>
<td>1</td>
<td>Mandarin and/or English</td>
</tr>
<tr>
<td>• Personal choice, private domain (e.g. reading instruction manual at home)</td>
<td>3</td>
<td>English only</td>
</tr>
<tr>
<td>Do you have a hearing problem?</td>
<td>4</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Data from the questionnaire revealed that all four subjects are native speakers of Mandarin and/or other Chinese language(s) like Hokkien, Cantonese or Foochow, having acquired these languages at birth or as a child and used them in the home with their parents and siblings. English on the other hand was either taught to the subjects in school or picked up in their later years, thus classifying them as late bilinguals.

While they rated themselves relatively proficient (at least 5 on a 7-point Likert scale) in both English and Mandarin for the areas of speaking and listening, the minor discrepancies in their self-rated responses were telling of their degree of bilingualism.

<table>
<thead>
<tr>
<th>Subject (Age)</th>
<th>English Proficiency</th>
<th>Mandarin Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speaking</td>
<td>Listening</td>
</tr>
<tr>
<td>01M (64)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>02M (72)</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>03M (63)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>04M (80)</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

As can be seen in table 3, some subjects were more comfortable than others in one language over the other in the areas for speaking and listening. 03M rated himself equally proficient in both areas for both languages, 01M rated himself less proficient in English than Mandarin for both areas, 02M rated himself better in listening to English and Mandarin than speaking them and 04M rated himself equally proficient in speaking English and Mandarin but felt more confident listening in Mandarin than English.

Most participants reported that they use English most frequently today and it is interesting to note some useful background facts about them: 01M, aged 64 – although he was the only one who went to university (UK), he is most comfortable speaking, reading and listening in Mandarin. Very knowledgeable in Chinese history, he boasts of being able to read Mandarin much faster (in a diagonal fashion) than English. He used to speak to his children only in Mandarin but have since relied on using predominantly English as a result of their replies being only in English. He is retired. 02M, aged 72 – even though he only completed secondary school, he went on to be trained at the Teacher’s Training College (TTC) and was a secondary school English teacher before he retired. 03M, aged 63 – although he was diagnosed with tinnitus (severe ringing in ears) in 2003, he has since fully recovered (naturally) and his pure-tone threshold is the best of the group. Currently still working, he
interacts regularly with American, Australian and European colleagues. 04M, aged 80 — having first been educated in a Chinese-medium school (Hwa Chong School), he was awarded a scholarship to study in an English-medium school later on. He went on to excel in Mandarin and was awarded a prestigious teaching accolade which paved the way for his specialisation as a Mandarin teacher and eventually an English teacher too at the time of his retirement. Today he uses Cantonese and English as frequently.

4.2 LACE TRAINING

With the aim to determine improvement in subjects’ LACE performance over the ten sessions of the training period, trends in each subject’s scores across the three LACE tasks of Degraded Speech – (1) Speech-in-Noise, (2) Rapid Speech, and (3) Competing Speaker – will be presented. The results from tasks in background noise, such as (1) Speech-in-Noise and (3) Competing Speaker, will be displayed first, followed by the task in quiet – (2) Rapid Speech.

4.2.1 TASKS IN BACKGROUND NOISE: GENERAL RESULTS

![Speech-in-Noise graph](image)

**Figure 3.** Speech-in-Noise: graph showing the raw data distribution of scores (vertical axis) awarded to each subject upon completion of task at every session (horizontal axis). The maximum score is 8 and minimum is 1.

As depicted by the average scores in the speech-in-noise task, there is a general improvement in performance of 11.76%, albeit slight, across the four subjects when data points from the first and last training sessions (days 1 and 10) are compared. The fluctuating scores show a
peak in performance at day 5, which failed to maintain thereafter, and a gradual improvement again after day 8. The lowest performance is found at day 2.

**Figure 4.** Competing Speaker: graph showing the raw data distribution of scores awarded to each subject upon completion of task at every session. The maximum score is 8 and minimum is 1.

In this task, the average scores show a large overall improvement of 61.53% in performance between the first and last training sessions. Again, a peak in performance is found at day 5, with scores in the following days falling thereafter. Improvement is seen again after day 8. Among the three tasks, this task had the greatest improvement in performance scores.

### 4.2.2 Task in Quiet: General Results

**Figure 5.** Rapid Speech: graph showing the raw data distribution of scores awarded to each subject upon completion of task at every session. The maximum score is 8 and minimum is 1.
Overall improvement in scores for this task was 53.33%. Similar to the two tasks in background noise, the peak in performance is found around day 4/5, with a steady decrease thereafter. Following a drastic dip in performance at day 8, a sharp improvement is seen after, with the highest score culminating at day 10.

4.2.3 Tasks in Background Noise: Discussion

Both the speech-in-noise and competing speaker tasks were programmed with sentences presented in the presence of background noise, with either multi-talker babble (former) or single-talker babble (latter). Deliberately designed this way to train a user in honing his or her listening and cognitive skills in a compromised acoustic environment, it seems like the effect of such background noise has a different effect on late bilingual listeners than monolinguals.

Although there was no comparison with a monolingual group in this study, the results seem to echo that of past research whereby the perception of speech-in-noise in a non-native language by late bilinguals is significantly lower than that for native speaking monolinguals or early bilinguals (Mayo, Florentine & Buus 1997; Carlo 2008). This is apparent in the form of highly fluctuating scores across the tasks. Despite general improvement between the first and last training sessions, it appears that within subjects there are differences in how each of them reacts to the training material and this might play a part in the results above.

**Figure 6.** (A) Speech-in-noise: scores awarded to each subject at training sessions 1, 5 & 10. (B) Competing speaker: scores awarded to each subject at training sessions 1, 5 & 10.
Figure 6 allows for the comparing and contrasting of trends between the two tasks, formed from scores awarded on days 1, 5 and 10 of the paradigm. Assuming these three data points are representative of the subjects’ progress throughout the training, it is evident that between each task, each subject displays a similar pattern of improvement, but just in varying degrees.

While three out of four of the subjects show an overall improvement in performance between the first and last training sessions, subject 04M failed to exhibit that same pattern of improvement. Instead, his scores either deteriorated (figure 6A) or remained stagnant (6B). According to observations by this researcher, it seems that this can be attributed to certain characteristics of the programme which he was not used to. Some sentences were too long for him to remember and there were a handful of terms and words specific to the modern American context that was difficult to understand, identify and repeat. Being the oldest of the four, his aging auditory system could have probably interfered with his cognitive ability of memory and accuracy of speech discrimination. Coupled with interference from background noise, there were additional imposed demands on his working memory which initiated more than simple speech recognition. At the same time, being the only subject to have reported that he still uses Cantonese as frequently, if not more than, English, perhaps the constant interaction between the two phonetic systems within his active Bilingual brain during speech processing could have resulted in slower processing, and thus, poorer performance.

Another pattern that figure 6 displays is that for the subjects 01M, 02M and 03M, there is a peak at day 5. This could be attributed to a matter of topic presented to the subjects at day 5. In the programme, each training session had sentences played in each task relating to a certain topic. There were a total of 4 topics mentioned - health, money matters, exercise and energy. Health appeared on day 2 and again on day 5. Their familiarity with the topic as well as the great relevance to their personal lives might have provided them with contextual cues to cope with the impaired acoustic signal.

A third pattern worth mentioning is the difference between 01M’s and 03M’s progress pattern. While both subjects had a peak in performance at day 5 (for reasons explained previously), only 03M could maintain that score on the last day while 01M could not. This could be due to their personal abilities to discriminate between accents. While 03M is very accustomed to listening to the American English accent at work, 01M confessed to always having had difficulty listening to American speakers and “catching their words”.

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4.2.4 Task in Quiet: Discussion

It has been shown that bilinguals are able to perform as well as monolinguals in speech recognition of their second language under quiet environmental conditions, even without contextual cues or if they were late bilinguals (Carlo 2008). While the rapid speech task was indeed presented in quiet (without background babble), its time-compressed nature made it an impaired acoustic signal nonetheless. Having to adapt to a fast talker requires quick-thinking, clarity and a more efficient memory to for example, retain the first half of a sentence when a sentence is long. Therefore while subjects showed more than 50% of improvement in this task (figure 5), results demonstrate that they did not achieve consistency in improvement as monolinguals are expected to have.

4.3 QuickSIN Test

Keeping the LACE results in mind, the following results by the QuickSIN test are pivotal to this study as an evaluation of the effectiveness of LACE training on performance by elderly, non-native English speakers in processing degraded speech (in-noise). Average scores from the test, administered twice prior to and once again after the auditory training are compared in the figure below. The significance of the differences is further analysed and discussed.

Figure 7. Comparison of mean Signal-to-Noise Ratio (SNR) losses (vertical axis) averaged from QuickSIN tests administered to all subjects before and after LACE training (horizontal axis). Interval between pre- and post-tests were two weeks for each condition. Error bars indicate the standard error of the mean.
An improvement in performance of speech-in-noise processing is signified by a greater change in SNR loss (from pre- to post-test), in a downward direction. In other words, the more negative the SNR loss score, the better one’s ability to process speech at a certain noise level (in dB) is. It is clear from figure 6 that with the presence of LACE training, the change in SNR loss between pre-and post-tests (51.43%) is much greater than that in the absence of LACE training (3.92%). Interestingly, mean scores for post-test in the absence of training not only show a lack of improvement from the pre-test but a deterioration instead. This demonstrates that any improvement in the test after training was not primed by earlier tests or by a ‘familiarity effect’ of experimental procedure. Rather, it signifies the effectiveness of LACE training on an improvement in performance of processing speech-in-noise, even by elderly, non-native English speakers.

4.3.1 Statistical Analysis

To determine if the improvement in QuickSIN scores as a result of LACE training was statistically significant, pre- and post-test SNR loss scores were compared with the training conditions. Using a two-way repeated measures analysis of variance with test scores (pre vs. post) and training condition (no training vs. LACE training) as within-subject factors, it was found that there was no significant effect for improvement in either factor ($p = 0.138$) nor in an interaction of the two ($p = 0.320$). With a small sample size as in this training paradigm, it can be expected that the response pattern might have missed the threshold for test of significance, resulting in a greater propensity for uncertainty. This however, should by no means disqualify the significance of improvement found in the raw results (figure 6). With these statistical findings, it is preferable to discuss the results descriptively in the next section.

4.3.2 Discussion

Having found a significant improvement in overall speech-in-noise performance scores which can be attributed to the effectiveness of LACE training, this section discusses the individual differences in performance among the four subjects.
Out of all the four elderly, non-native speakers of English who had gone through the pilot training paradigm, three subjects (01M, 02M & 04M) had improved speech-in-noise performance scores. As reflected in figure 8, mean SNR loss scores after LACE training (textured) for all three subjects were significantly lower than that of both pre and post scores prior to training (light & dark grey). Only 03M showed no improvement in QuickSIN scores after LACE training. All of 03M’s three scores however, seem to be consistent and hover around the same point. Using background knowledge of the subjects gathered from the questionnaires and personal interaction with them, this led this researcher to identify some explanations for the results.

The first explanation could be that one’s hearing threshold (pure-tone) could determine their performance. Although none of them have been diagnosed with a hearing impairment and the results from their audiometry evaluation fall within the expected range for their age group, individual differences in hearing can contribute to the individual differences in results. The subjects have been ranked from best to worst in their hearing, based on their frequency threshold.

**Table 4.** Ranking of subjects according to threshold frequencies

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>03M &gt; 02M &gt; 01M &gt; 04M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Freq. (250 – 500 Hz)</td>
<td>03M &gt; 02M &gt; 01M &gt; 04M</td>
</tr>
<tr>
<td>Mid Freq. (1000 – 3000 Hz)</td>
<td>03M &gt; 02M &gt; 01M &gt; 04M</td>
</tr>
<tr>
<td>High Freq. (4000 – 8000 Hz)</td>
<td>03M &gt; 02M &gt; 01M &gt; 04M</td>
</tr>
</tbody>
</table>
In table 4, there is an identical pattern of ranking whereby 03M has the best hearing, followed by 02M, 01M and lastly, 04M. It could be that the better one’s hearing is, the lesser an improvement in performance can be made. With better hearing, it renders the adaptive software slightly redundant because there is little improvement to be made. Therefore 03M did not make any improvement. Comparing the difference between the pre-training test score and that of the post-training, 02M had a lesser improvement, compared to 01M. 04M had the greatest improvement.

The second explanation could be related to the degree of bilingualism in each subject. It seems that the more ‘balanced’ the bilingual is, the lesser an improvement in performance can be made. In other words, if the subject feels the most equally confident and comfortable in his native language(s) as well as the second language (English), the slighter the improvement in his non-native language would be because of a cross-linguistic competition in the bilingual brain further aggravated by degraded listening conditions.

Table 5. Self-rated proficiencies in English and Mandarin & Chinese languages (listening)

<table>
<thead>
<tr>
<th>Subject</th>
<th>English</th>
<th>Mandarin &amp; Chinese languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>03M</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>02M</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>04M</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>01M</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

As seen in table 5, 03M seems the most comfortable between his native and non-native languages, thus it reflects in the lack of improvement. Between 02M and 04M, 02M has a lesser improvement probably due to greater comfort in English, having been an ex-English teacher before his retirement. Although 04M ranked himself only slightly more comfortable in Mandarin and other Chinese languages than English, having been an ex-Mandarin Chinese teacher, his native language probably has a stronger bearing on his speech discrimination performance, therefore his improvement was greater than 01M.

This shows that there is always a danger in taking self-reported data on language proficiency wholesale, without any proper check on a person’s language history, status and frequency of use.
5 GENERAL DISCUSSION

In this study, the effectiveness of LACE was evaluated based on its effect on speech-in-noise perception by elderly bilinguals of English and Mandarin or other Chinese languages. Although previous studies have shown that bilingual listeners, especially those who have acquired their second language at a later age, perform significantly poorer on speech-in-noise tasks than monolingual listeners of their second language, no studies had been done on healthy, elderly bilinguals. Thus a small number of elderly, non-native English speakers were trained for two weeks with LACE and tested with QuickSIN after the training. Their QuickSIN scores were compared with testing done prior to the training.

A language questionnaire was administered to the subjects in order to determine their eligibility as bilinguals, to gain insight into their self-rated proficiency in speaking and listening in their native and non-native languages, as well as to determine the frequency of their language use. On hindsight, although the structure of the questionnaire served its main purpose, the effect of bilingualism on speech-in-noise perception has been a recurring issue in the discussion of the results. As such, a more validated questionnaire could have been used for this research, so as to avoid inconsistencies in the degree of each subject’s bilingualism. A language profile of each subject should entail information on his or her language status, history, competency and use (von Hapsburg & Peña 2002). Thus the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld & Kaushanskaya 2007; cited in Carlo 2008) could have been used. The Peabody Picture Vocabulary Test (PPVT), an effective and well-validated English proficiency test, could have also been used to measure subjects’ listening comprehension and receptive vocabulary, to minimise inaccuracy in self-reported answers.

Although the sample size was suboptimal to produce significant statistical analysis, using the raw data (mean SNR loss) in this pilot study displayed encouraging trends in which further studies can tap on and build upon for larger scaled studies in the future. Yet at the same time, utilizing a case study design on these few subjects allowed close attention to details in behavioural variability, which is critical in a study where the nature of one’s language and audiometric profiles might dictate differences in skill. Future research could include investigating into a cross-linguistic influence that LACE may effect on bilingual participants.
This would require a Chinese version of the QuickSIN test, as well as a monolingual group for comparison. Based on past literature such as that of Song et al. (2012), Olson (2010) and Sweetow et al. (2006), the number of subjects run should be between 20-60, in order to gain statistically significant results. Future research could also tap on the unique linguistic landscape here in Singapore regarding the shift in bilingualism from generation to generation, and whether auditory training on two age groups would result in any differences, due to their type and degree of bilingualism.

A big limitation of the experimental material was in the American English accented speech LACE uses. Often times, the intonation and pronunciation of words and sentences fell unidentified to foreign ears such as these elderly bilingual subjects. This made for comprehension of sentences difficult and could have resulted in an inaccurate diagnostic of a subject’s true ability to perceive speech in noise. Although these bilinguals speak English, it is the British enunciation and pronunciation of words that Singaporeans are more comfortable listening to. It has only recently come to this researcher’s knowledge that a LACE UK edition has been newly-released. Having identified the difficulties that non American English speakers face, Neurotone has worked with PC Werth, a technology company in the UK to produce the UK edition. Perhaps future studies could use this UK edition to determine if a truer evaluation of auditory training on bilinguals can be made. It would also be interesting to test this software on other bilingual Singaporeans of different races to get a more generalised evaluation of the programme in the entire multilingual context.

Lastly, this study was done in the hope of evaluating the idea and technology behind LACE to extend auditory training to the area of pedagogy. More specifically, in the teaching of English as a foreign language (TEFL) to non-native English speakers. Auditory training can come in the form of emphasizing the ability to identify phonemic contrasts (stress, intonation and rhythm) in the presence of noise, or training students to look out for contextual cues when speaking with an interlocutor in a crowded or noisy setting. While LACE has been found effective not just for older, hearing aid users, unfortunately no conclusion can be made as to whether this technology can be extended directly to TEFL. Some questions remain unanswered, such as which variables in the training determines who is most likely to benefit from training, or what are the exact reasons for the improvement in performance.
6 CONCLUSION

Re-exploring the goals of this study, three out of four of the non native English speaking elderly bilinguals who underwent the LACE training demonstrated overall improvements in performance during the training. Assessing individual scores using data revealed in a self-rated questionnaire showed that differences in the degree of one’s bilingualism may be responsible for certain within-subject differences found in response to speech-in-noise training tasks. Significant improvements found in the QuickSIN test by 3 out of four subjects was successful in evaluating LACE as an effective auditory training programme on healthy elderly bilinguals. Discrepancies in scores caused by within-subject factors such as threshold frequencies, degree of bilingualism and comfort in a particular language, have further supported past research that bilinguals will not be able to perform as well as monolinguals in speech-in-noise tasks.

However despite its limitations, LACE has fulfilled its main objectives of enhancing listening and communication skills and getting the user involved in improving his cognitive skills. This pilot study has only been a precursor for future research and one investigating into an effective maintenance of training benefits on LACE users should be conducted. By re-training the same subjects after a 3-month period, the effects of the training would be put to the test. Alternatively, running a ‘vitamin C’ training paradigm on a control group to create a placebo effect and then testing them again 3 months later may be effective in identifying the specific features of LACE which is responsible for improvements in performance.
REFERENCES


APPENDICES

APPENDIX A – QUESTIONNAIRE

PART I. Personal Particulars

Codename: __________________________    Contact no: _____________________

Age range (please select one):
  □ 60 – 65
  □ 65 – 70
  □ 70 – 75
  □ 75 – 80
  □ 80 – 85
  □ 85 – 90
  □ 90 – 95
  □ 95 and above

Highest level of education (please select one):
  □ None
  □ Primary school
  □ Secondary school
  □ Pre-university
  □ University and above

Please select the categories in which you have worked in (you may select more than one):

[Kindly indicate additionally with (*) the industry in which you have worked the longest in]
  □ Architect/Building Construction
  □ Customer Service
  □ Corp. Comms/PR
  □ Education/Training
  □ Engineering
  □ Healthcare/Pharmaceutical
  □ Human Resource
  □ Logistics/Supply Chain
  □ Manufacturing
  □ Maritime
  □ Marketing/Branding
  □ Media/Entertainment
  □ Military
  □ Office Admin
  □ Quality Control/Assurance
  □ Real Estate/Prop Mgmt.
  □ Restaurant/F&B
  □ Retail/Sales
  □ Security
  □ Technician
  □ Trading/Wholesale
  □ Travel/Tourism
  □ Voluntary/Non-Profit
  □ Others – Please specify:

PART II. Language Use & Proficiency

Please state the languages that you can speak and kindly rate your proficiency in it:
(1 – least proficient; 7 – most proficient)

a. ____________________________   Least  1  2  3  4  5  6  Most  7
b. ____________________________   Least  1  2  3  4  5  6  Most  7
c. ____________________________   Least  1  2  3  4  5  6  Most  7
d. ____________________________   Least  1  2  3  4  5  6  Most  7
Degree of proficiency in Language A:
(Kindly rate your proficiency in these areas: 1 – least proficient; 7 – most proficient)

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Degree of proficiency in Language B:
(Kindly rate your proficiency in these areas: 1 – least proficient; 7 – most proficient)

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Degree of proficiency in Language C:
(Kindly rate your proficiency in these areas: 1 – least proficient; 7 – most proficient)

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Degree of proficiency in Language D:
(Kindly rate your proficiency in these areas: 1 – least proficient; 7 – most proficient)

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What languages do you prefer to use when speaking with your family members?

Parents: ____________________________________________________________

Siblings: __________________________________________________________

Children: __________________________________________________________

Great-grand/Grand-children: ________________________________________
Please read each of the following scenarios carefully.

a) You are at the wet market and you would like to order $10 worth of meat from the butcher. The butcher is Singaporean Chinese and is in his fifties.

b) You have recently purchased an electrical appliance and would like to read the instructional manual. The manual contains instructions in English, Mandarin Chinese, Malay, Tamil and other international languages.

c) You are at the bank and you would like to enquire about a new savings plan. The customer service officer is Singapore Chinese and is in his late forties.

In each of the above scenarios, which language would you prefer to use?

a) __________________________

b) __________________________

c) __________________________

When choosing a language to speak to someone, how important would the following factors influence your decision? Kindly rank the factors in order of importance.
(5 – Least important; 1 – Most important)

a. Race of the person

b. Age of the person

c. Friendliness of the person

d. Formality of environment

e. Social status of the person

PART III. Audiology Case History

Do you have a hearing problem? ☐ Yes ☐ No
If yes, how long have you noticed this problem: _____________________________

What do you feel is the cause of your hearing loss: ____________________________

Was the onset gradual or sudden: _________________________________________

In which ear do you hear the best?
☐ Same in both ears
☐ Right ☐ Left

Is your hearing better some days than others? ☐ Yes ☐ No
Are you currently or have you ever been exposed to gunfire, loud machinery or other damaging noises?  
☐ Yes  ☐ No  
If yes, please describe: ________________________________________________________

Does anyone in your family have hearing loss (immediate & extended family) that began before the age of 30?  
☐ Yes  ☐ No  
If so, please specify who: ________________________________________________________

Have you ever had your hearing tested?  
☐ Yes  ☐ No  
If yes, when: _________________________________________________________________  
What were the results: __________________________________________________________

Have you ever undergone radiotherapy or had medical or surgical treatment for your ears?  
☐ Yes  ☐ No

Have you ever experienced severe dizziness, loss of balance, spinning sensations or light-headedness?  
☐ Yes  ☐ No

Do you notice any buzzing or ringing in your ears?  
☐ Yes  ☐ No  
If yes, which ear?  ☐ Same in both ears  ☐ Right  ☐ Left  
Is the buzzing/ringing constant or intermittent?  ☐ Constant  ☐ Intermittent  
Is it bothersome?  ☐ Yes  ☐ No  
Please describe: ________________________________________________________________

Additional comments about your specific hearing situation:  ________________________________________________________________

***End of survey***
Thank you! 😊
### Appendix B — QuickSIN Standard Lists

#### Track 3
**List 1**
1. A white silk jacket goes with any shoes.
2. The child crawled into the dense grass.
3. Footprints showed the path he took up the beach.
4. A vent near the edge brought in fresh air.
5. It is a band of steel three inches wide.
6. The weight of the package was seen on the high scale.

|--------|--------|-------|-------|-------|-------|

#### Track 4
**List 2**
1. Tear a thin sheet from the yellow pad.
2. A cruise in warm waters in a sleek yacht is fun.
3. A streak of color ran down the left edge.
4. It was done before the boy could see it.
5. Crouch before you jump or miss the mark.
6. The square peg will settle in the round hole.

|-------|-------|-------|-------|-------|-------|

#### Track 5
**List 3**
1. Pitch the straw through the door of the stable.
2. The sink is the thing in which we pile dishes.
3. Post no bills on this office wall.
4. Dimes showered down from all sides.
5. Pick a card and slip it under the table.
6. The store was jammed before the sale could start.

|-------|-------|-------|-------|-------|-------|

#### Track 6
**List 4**
1. The sense of smell is better than that of touch.
2. He picked up the dice for a second roll.
3. Drop the ashes on the worn old rug.
4. The couch cover and hall drapes were blue.
5. The stems of the tall glasses cracked and broke.
6. The clean sink deeply into the soft turf.

|-------|-------|-------|-------|-------|-------|

#### Track 7
**List 5**
1. To have is better than to wait and hope.
2. The screen before the fire kept in the sparks.
3. Thick glasses helped him read the print.
4. The chair looked strong but had no bottom.
5. They told wild tales to frighten him.
6. A force equal to that would move the earth.

|-------|-------|-------|-------|-------|-------|

#### Track 8
**List 6**
1. The leaf drifts along with a slow spin.
2. The pencil was cut to be sharp at both ends.
3. Down that road was the way to the grain farmer.
4. The best method is to fix it in place with clips.
5. If you rumble your speech will be lost.
6. A toad and a frog are hard to tell apart.

|-------|-------|-------|-------|-------|-------|

#### Track 9
**List 7**
1. The kite dipped and swayed but stayed aloft.
2. The beetle drooped in the hot June sun.
3. The theft of the pearl pin was kept secret.
4. His wide grin earned many friends.
5. Hurdle the pit with the aid of a long pole.
6. Peep under the tent and see the clown.

|-------|-------|-------|-------|-------|-------|

#### Track 10
**List 8**
1. The sun came up to light the eastern sky.
2. The stale smell of old beer lingers.
3. The desk was firm on the shaky floor.
4. A list of names is carved around the base.
5. The news struck doubt into restless minds.
6. The sand drifts over the sill of the old house.

|-------|-------|-------|-------|-------|-------|

#### Track 11
**List 9**
1. Take shelter in this tent but keep still.
2. The little tales they tell are false.
3. Press the pedal with your left foot.
4. The black trunk fell from the landing.
5. Cheap clothes are flashy but don't last.
6. At night the alarm roused him from a deep sleep.

|-------|-------|-------|-------|-------|-------|

#### Track 12
**List 10**
1. Dots of light betrayed the black cat.
2. Put the chart on the mantel and tuck it down.
3. The steady drip is worse than a drenching rain.
4. A flat pack takes less luggage space.
5. The gloss on top made it unfit to read.
6. Seven seals were stamped on great sheets.

|-------|-------|-------|-------|-------|-------|

#### Track 13
**List 11**
1. The marsh will freeze when cold enough.
2. A gray mare walked before the colt.
4. He wheeled the bike past the winding road.
5. Throw out the used paper cup and plate.
6. The wall phone rang loud and often.

|-------|-------|-------|-------|-------|-------|

#### Track 14
**List 12**
1. The hinge on the door leaked with old.
2. The bright lantern was gay on the dark lawn.
3. He offered proof in the form of a large chart.
4. Their eyelids droop for want of sleep.
5. There are many ways to do these things.
6. We like to see clear weather.

|-------|-------|-------|-------|-------|-------|

#### Track 15
**List 13**
1. The dusty bench stood by the stone wall.
2. We dress to suit the weather of most days.
3. The water in this well is a source of good health.
4. That guy is the writer of a few banned books.
5. The door was barred, locked and bolted as well.
6. A big wet stain was on the round carpet.

|-------|-------|-------|-------|-------|-------|

#### Track 16
**List 14**
1. The team with the best timing looks good.
2. Sit on the perch and tell the others what to do.
3. The early phase of life moves fast.
4. Tea in thin china has a sweet taste.
5. The latch on the back gate needs a nail.
6. A whiff of it will cure the most stubborn cold.

1. Poached eggs and tea must suffice.
2. They sang the same tunes at each party.
3. A gold vase is both rare and costly.
4. Cod is the main business of the north shore.
5. A round mat will cover the dull soot.
6. A good book informs of what we ought to know.

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1. The point of the steel pen was bent and twisted.
2. There is a lag between thought and act.
3. Seed is needed to plant the spring corn.
4. This horse will nose his way to the finish.
5. The dry wax protects the deep scratch.
6. Twist the valve and release hot steam.

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1. The thaw came early and freed the stream.
2. It takes a lot of help to finish these.
3. Roads are paved with sticky tar.
4. It’s a dense crowd in two distinct ways.
5. Raise the sail and steer the ship northwest.
6. Jerk the dart from the cork target.

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1. Read just what the meter says.
2. Clams are small, round, soft, and tasty.
3. The line where the edges join was clean.
4. A round hole was drilled through the thin board.
5. The cloud moved in a stately way and was gone.
6. A plea for funds seems to come again.