RELATIONSHIP BETWEEN LISTENING EFFORT AND REAL-LIFE OUTCOMES IN SCHOOL-GOING CHILDREN WITH COCHLEAR IMPLANTATION

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CERTIFICATE

This is to certify that this dissertation entitled **"Relationship between listening effort and real-life outcomes in school-going children with cochlear implantation"** is the bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student Registration Number: P01II21S0080. This has been carried out under the guidance of the faculty of the institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"Relationship between listening effort and real-life outcomes in school-going children with cochlear implantation"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Relationship between listening effort and real-life outcomes in school-going children with cochlear implantation"** is the result of my study under the guidance of Dr. Geetha C, Associate Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru | Registration No: P01II21S0080

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DEDICATED TO

SAI BABA, MYSELF, AND PARENTS

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Happy Reading…ϑ

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ABSTRACT

The present study evaluated the listening effort and real-life performance outcomes in school-going children with cochlear implantation and aimed to compare the same with the control group. The study included objective (dual-task paradigm) and subjective (SSQ-P10, TEACH) measures. The data were collected from 50 school-going children with an age range of 8-15 years. These 50 participants were further divided into two subgroups. Group I included 25 children with normal hearing sensitivity. Group II included 25 children with bimodal cochlear implantation with bilateral severe to profound hearing loss. Dual-task paradigm and subjective questionnaires were used to assess listening effort. Statistical analyses were performed to compare the findings in group-wise and pair-wise manner. The results revealed that children with normal hearing sensitivity performed significantly better in objective (dual-task paradigm) and subjective (real-life performance) measures than children with CI. Performance was significantly better in quiet than noisy conditions. Further, correlation results revealed a moderate correlation between objective and subjective measures. Hence, the present study suggests that subjective questionnaires could be used as an assessment tool for listening effort. Further, training is required to improve real-life activities, and provides evidence that listening effort needs to be measured in school-going children with cochlear implantation.

Keywords: *dual-task paradigm, SSQ-P10, TEACH, cochlear implant*

CHAPTER I

INTRODUCTION

Hearing loss is a common and serious impairment that hinders students' ability to thrive socially and academically. It has been extensively documented that hearing loss is a serious health issue for school-aged children in poor countries (Olusanya et al., 2000; Phaneendra Rao et al., 2002; Swart et al., 1995). Over 5% (360 million) of the world's population, including thirty-two million children, suffers from hearing loss that is permanently incapacitating (Phaneendra Rao et al., 2002). Cochlear implants (CI) are electronic devices incorporating an electrode inserted into the human cochlea for direct electric stimulation of the auditory nerve (Hussong et al., 2008). It has gained widespread acceptance as a routine treatment for early childhood deafness over the past 20 years (Kral & O'donoghue, 2010). CI helps hearing-impaired people regain some of their auditory abilities. There is evidence that children with cochlear implants had hearing and language development levels comparable to those of typically developing children around ten years after cochlear implantation. The best implant users have word recognition scores of 85% or more (Peixoto et al., 2013). Regarding speech outcomes, profoundly deaf children with implants outperformed those who used traditional hearing aids (Geers et al., 2003). By the time they reach high school, just 5% of implanted children required full-time help and specialized learning environments, with 75% enrolled in conventional classrooms (Geers et al., 2011).

Hence, an increasing number of school-age hard-of-hearing children with CI are attending regular schools rather than special schools (Venail et al., 2010). However, it has been demonstrated over time that classroom noise affects children's performance on various tasks (Shield & Dockrell, 2007).

Hearing-impaired listeners frequently encounter effortful conversation in a less ambient environment; due to the rigorous and dynamic nature of real-life listening settings, including classrooms and group social situations (Hicks & Tharpe, 2002a; Howard et al., 2010; Hughes & Galvin, 2013). The listener has to switch between speakers while processing information and generating appropriate responses in the background noise (Bess et al., 1998; Teele et al., 1990). The increased listening effort could make it harder to simultaneously perform other cognitive tasks involved in learning and maintaining social interaction, leading to fatigue and headaches in school-aged children. Additionally, prolonged listening at a high level of mental fatigue could affect academic performance (Geers et al., 2003; Shield & Dockrell, 2007; Vermeulen et al., 2007), social skills (Bat-Chava et al., 2005), and attention (Damen et al., 2006).

It has been demonstrated that top-down cognitive processes involved in speech perception are taxed when a speech signal undergoes spectral deterioration, such as during CI processing or CI simulations (Başkent, 2012). Listening to CI users could be challenging because understanding the signal needs significant cognitive resources, especially when a CI fitting is unsatisfactory. It is crucial to have a measure that accurately represents listening effort if minimizing listening effort is to be taken into account when fitting CI. Hence, a sensitive and trustworthy measure of listening effort could provide a more thorough evaluation of the children with hearing impairment related to hearing in difficult circumstances. The "dual-task" paradigm, employed in cognitive psychology to test attention allocation (Broadbent, 2013; Kahneman, 1973; Styles & Styles, 2006), is one behavioural technique frequently employed to evaluate listening effort. The dual-task method has solid ecological validity because people frequently must do many cognitive tasks simultaneously, especially in learning environments.

Prodi et al. (2019) used the speech-in-noise test to examine 117 typically developing children in the age range of 5-7 years. The test was done on the entire student group in the classrooms under two listening conditions (quiet with no added noise and a working classroom with a stationary noise) on the number of words that were successfully recognized, and the single-task response time (RT) was thought to be indicative of listening effort. Results found that students' performance decreased when background noise was present, and more RT was needed than under the quiet classroom condition.

Hicks and Tharpe (2002) evaluated the listening effort using a dual-task paradigm in children with NH and mild-moderate or high-frequency hearing loss. The main task was word recognition in quiet and various background noise levels. A response time test was the secondary task, which required participants to press a button as rapidly as possible whenever they noticed a randomly placed light probe. Results showed that children with hearing loss required more effort to complete this task than children with normal hearing (NH), with longer reaction times in all conditions, including quiet.

A review article highlights the studies on measuring listening effort using the dual-task paradigm and subjective self-reports. These measurement techniques capture various aspects of listening effort (Gosselin & Gagné, 2011). According to Feuerstein's distinction between "effort" and "ease" made in 1992, while performance on the secondary tasks denotes effort, a subjective self-report measure denotes ease. Parent reports and some unpublished data collected using an adapted version of the Speech, Spatial, and Qualities of Hearing Scale (Noble & Gatehouse, 2006) for parents and older children reported reduced listening effort may be a subjectively perceived benefit experienced by children using bilateral implants (Galvine et al., 2007).

1.1 NEED FOR THE STUDY

The high levels of accomplishment give children with cochlear implants a chance to enrol in regular classrooms. Studies have demonstrated that early implantation recipients even had reading proficiency levels that were on a level with peers who had normal hearing (Geers et al., 2003; Nevins ME, 1995). Nonetheless, the decreased spectral resolution of CI-assisted hearing leads to increased listening effort (Pals et al., 2013a) under challenging conditions (McCoy et al., 2005; Sarampalis et al., 2009; Zekveld et al., 2011). As regular schools are known to be noisy learning environments, hard-of-hearing children face daily difficulties (Wouters et al., 2015). It takes greater auditory attention, resulting in higher listening effort and fatigue (Zekveld et al., 2011). Hence, there is a need to assess the listening effort in implanted children and compare the findings with the control group in quiet and noisy conditions.

1.1.1 Need to assess listening effort in school-going CI children

Everyday hearing takes place in complex (and frequently noisy) acoustic settings. Children gain crucial cognitive, linguistic, and academic skills in the classroom, in which reported signal-to-noise ratios (SNRs) range from +1 to +11 dB (Larsen & Blair, 2008; Sato & Bradley, 2008). The ability to interpret speech in noisy environments depends on cognitive abilities like working memory and attention, which are still developing in school-aged children (Gomes et al., 2000; Luna et al., 2004).

According to research studies, the sound environment in classrooms can be unsuitable for learning because it can impair children's hearing and understanding of speech (Crandell & Smaldino, 2000; Klatte et al., 2013; Valente et al., 2012). Particularly, it has been demonstrated over time that children's performance on a variety of tasks is impacted by noise, and as a result, their academic achievements may be affected (Shield & Dockrell, 2008).

It can be concluded from the existing research that listening efforts in school-going children can degrade classroom performance, mainly in poor SNR or noisy conditions. Hence, there is a need to measure the effort in school-going implanted children as they find more difficulty understanding the signal and need more cognitive resources.

1.1.2 Need to use dual-task paradigm

CI resulting in best speech perception may not always result in the best listening effort. In a study by Pals et al. (2013), 19 participants with normal hearing completed a dual-task paradigm that included an intelligibility test and a linguistic or non-linguistic visual response time (RT) task to assess intelligibility and listening effort while listening to CI simulations with varying numbers of spectral channels. Additionally, a different self-report scale offered a debatable indicator of listening effort. According to the findings, listening effort diminishes as spectral resolution rises. Furthermore, rather than intelligibility scores or subjective effort assessments, these changes are better reflected in objective measures of listening effort, such as RTs on a secondary task.

McFadden and Pittman (2008) used Dot-to-dot games and word categorization tasks to evaluate children (8–10 years old) with NH or minimal hearing loss (bilateral and unilateral) in quiet and noisy environments. Results showed no appreciable changes in performance on the secondary task across listening conditions or hearing status, even though children with hearing loss did not perform as well on the primary task when noise levels were higher.

Studies have shown that objective measures of listening effort like the dual-task paradigm may be more sensitive to minute changes in listening effort since they are specifically created to represent cognitive demand (Desjardins, 2016; Desjardins & Doherty, 2014). Further, dual-task paradigms have been demonstrated to be sensitive enough to show the impacts of listening effort across a group of participants. As a result, they present a helpful tool that may be applied in research settings. The current study opts for a dual-task paradigm as the child undergoes simultaneous tasks in the classroom, which leads to an increased listening effort.

1.1.2 Need to assess the relationship between dual-task paradigm and real-life outcome measures.

Even though studies assessing listening effort using subjective and objective measures frequently find no statistical relationship between the two (Feuerstein, 1992; Gosselin & Gagné, 2011; Zekveld et al., 2011), they have used measures such as self-reports which may not tap the listening effort difficulties.

SSQ-P10 is a shortened scale based on the original version of the SSQ developed for parents of children (aged five years and over) with impaired hearing by Galvin and Noble (2013). This was developed using statistical methods to identify the items that provided the most information regarding the three aspects of auditory ability, that is speech hearing, spatial hearing, and qualities of hearing. As the number of questions are less, it consumes less time to administered than original SSQ parent version scale. Many studies have shown a poor correlation between SSQ and objective task (Demeester et al., 2012). The same may be observed in SSQ-P10, hence there is a need to see the correlation using SSQ-P10.

In addition, assessment of auditory performance at school is important for school-going children. TEACH questionnaire assesses the classroom performance with cochlear implants, using the responses given by the class teachers. Surprisingly, only a few reports of school-aged children's subjective evaluations of listening efforts have been published. The limited information suggests behavioral listening measures are similar to those used with adults ,and also that listening effort and subjective assessments can differ (McFadden & Pittman, 2008) Hence, it is necessary to analyze perceived listening effort using subjective measures and test its correlation with the objective measures. Although it is simple to administer self-report measures of perceived effort, it is unclear if they accurately reflect the proportional demand on cognitive resources (Wickens, 2002).

If the questionnaires have been found to have a correlation with the dual-task paradigm, listening effort could be estimated even in very young children using those questionnaires. Further, some extraneous factors could affect the results while performing the tests. To clearly identify the relationship between listening effort and real-life outcome performance measures, it was important to recruit a control group. The results in the control group will act as reference scores and consider any practice effects and differences in the measurements from trial to trial.

1.2 AIM OF THE STUDY

The current study aimed to assess the relationship between the listening effort measured using objective tests (dual-task paradigm) and subjective measures (questionnaires) in school-going children with bimodal cochlear implantation, and compare the same with the age-matched normal group.

1.3 OBJECTIVES OF THE STUDY

The objectives of the current study were to -

1. comparing the following measures between the normal hearing and cochlear implanted groups
    a) dual-task paradigm scores
    b) real-life performances using questionnaires
2. compare the listening effort between quiet and noise conditions (+5 dB SNR).
3. assess the relationship between objective (dual-task paradigm) and subjective measures (real-life performance using SSQ-P10 and TEACH).

CHAPTER II

REVIEW OF LITERATURE

Individuals diagnosed with sensorineural hearing loss usually have a poor understanding of information in noisy and reverberant situations (Helfer & Wilber, 1990; Plomp, 1986). In addition, a higher degree of hearing loss does not show significant benefit from hearing aids. Cochlear implantation is done to overcome these difficulties. Children with cochlear implants made significant progress over time and concluded that cochlear implants may effectively improve deaf children's communication and social skill (Bat-Chava et al., 2005; Bat-Chava & Martin, 2002; Christiansen & Leigh, 2002). One of the primary benefits intended for children receiving CIs is improving communication skills. Results such as these concerning cochlear implants led the National Institutes of Health (1995) to conclude that improvements in children's speech perception and speech production are often reported as primary benefits.

Children in the educational setting are frequently required to multitask. They might, for instance, be expected to pay attention to the instructor while taking notes and synthesizing the material that has been given. Additionally, the setting in which students' study is not always conducive to listening. For example, classrooms are usually noisy, and it is widely acknowledged that noise interferes with students' ability to learn and advance academically (Shield & Dockrell, 2007).When conditions are less than ideal, it takes more work for the listener to comprehend the signal. While listening effort in children has typically been examined using a dual-task paradigm, listening ease can also be assessed using self-report ratings. The present study measured the listening effort using objective and subjective measures and compared it with the control group. The relevant literature is reviewed and presented below under the following headings:

2.1 Listening effort in children

Listening effort refers to the cognitive effort the listener exerts to understand the speech signal (Howard et al., 2010a). As Classroom signal-to-noise ratios (SNRs) are frequently close to 0 dB (Arnold & Canning, 1999) and are typically stated to be in the range of - 7 dB to +5 dB (Arnold & Canning, 1999; Crandell & Smaldino, 1995, 2000). Due to the increased listening effort needed in noisy surroundings, multitasking may be difficult. In ideal conditions, where the speech signal is audible, listening is relatively effortless for normal-hearing adults. The dual-task paradigm (Gosselin & Gagné, 2011) is a typical behavioural technique for measuring listening effort in individuals with hearing loss. Studies using dual-task paradigms and other cognitive processing measures have unequivocally demonstrated that hearing loss can increase the cognitive processing demands and listening effort when processing speech (Hällgren et al., 2005; McCoy et al., 2005; Rabbitt, 1991; Zekveld et al., 2011). Many studies are reviewed below, including listening efforts in normal and hearing-impaired children.

The study examined listening efforts in different SNRs. Thirty-one children with normal hearing, in the age range of 9 to 12 years were included in the study sample. Participants practiced sets of five numerals for memory while concurrently repeating monosyllabic words presented against the background of children's chatter (primary task) at SNRs that are thought to represent the school classroom environment (quiet, +4, 0, -4 dB). When multitasking, performance on the listening task was largely maintained; however, performance on the secondary recall task declined, particularly at the more adverse SNRs. This shows that listening at SNRs, typical of a classroom, requires significant listening effort (Howard et al., 2010).

Dual-task paradigms were implemented by Hicks and Tharpe (2002) and McFadden and Pittman (2008) to examine how SNR affected children's listening efforts. In their 2002 study, Hicks and Tharpe (2002) compared children aged 5 to 11 with mild hearing impairment against a group of children with normal hearing. Word recognition was the main objective, presented at 70 dB(A) in quiet and babble at SNRs of +10, +15, and +20 dB. Reaction time (RT) to a light presented randomly in time was the secondary challenge. Children with hearing impairments had longer reaction time (RT) in the dual-task condition, which is consistent with the idea that these children had to work more to listen than kids with normal hearing. However, the elevated RT was comparable throughout. However, the increased RT was similar across the different SNRs, suggesting no effect of SNR on listening effort.

McFadden and Pittman (2008) compared children between 8 and 12 years with mild hearing impairment to a group of children of the same age with normal hearing. The main assignment was to classify terms as either food, animal, or human. The words were spoken at 65 dB SPL at SNRs of 0 and +6 dB in quiet and noise. The secondary task assessed how frequently a dot-to-dot puzzle was finished. When performing both tasks, performance on the secondary task decreased, which was true for both groups. Again, indicating no effect of SNR on listening effort, mean performance was comparable for the two SNRs. Hence, the present study hypothesized a further increase in listening effort in children with bimodal cochlear implantation compared to normal-hearing children.

2.2 Listening effort in children using cochlear implants

Despite recent major advancements in sound processing, the electrical signal produced through CI devices still reflects a spectrally and temporally decreased auditory signal compared to the signal received through the human ear (Reynolds & Gifford, 2019; M. Winn, 2016). Consequently, even for accurately recognized speech, CI users often take longer to recognise speech in noise (McGarrigle et al., 2019). While it may be challenging but manageable for adults to listen in noisy situations, it is more detrimental for children (Hsu et al., 2020). The cochlear implants' distorted hearing input necessitates additional auditory attention, which increases listening effort and fatigue. Language processing may be negatively impacted by listening effort and fatigue, which may assist in explaining the diversity in linguistic and communicative ability. So, measuring an infant's or young child's listening effort and attention to speech might be difficult (Ohlenforst et al., 2017; Saksida et al., 2021; Winn, 2016). Some of the studies that examined listening efforts are discussed below:

Hughes and Galvin (2013) examined the increased listening effort needed when using two implants instead of one in cochlear implants in young adults and adolescents. The participants in the dual-task paradigm included eight people with bilateral cochlear implants and eight people with normal hearing in the age range of 10 to 22 years. The findings demonstrated that participants exhibited equal listening effort when utilizing bilateral implants compared to the normal hearing group when the two groups scored equivalent speech perception ratings. The listening effort was dramatically reduced with unilateral implants.

A study examined listening effort between three CI groups and a control group of people with normal hearing. The four participant groups comprised 12 people with normal hearing, 10 with unilateral CI, 12 with bilateral CI, and 12 with a hybrid short-electrode CI with bilateral residual hearing. The participants underwent a dual-task paradigm with a primary task detecting phrases in noise and a secondary task measuring reaction time on a Stroop test. Speech perception varied significantly amongst the normal-hearing, unilateral, and bilateral CI groups. The hybrid CI and the normal-hearing groups performed the primary task similarly. However, there was no discernible difference in listening effort across the CI groups (Perreau et al., 2017).

This study aimed to demonstrate that listening effort can differ amongst CI processing conditions where speech intelligibility is constant. Nineteen individuals with normal hearing listened to CI simulations with various amounts of spectral channels. The intelligibility and listening effort were tested using a dual-task paradigm that included an intelligibility task and a language or non-linguistic visual response-time (RT) task. The findings imply that listening effort reduces as the spectral resolution is raised. However, only the RT measure of listening effort showed improvement up to 8 channels (Pals et al., 2013).

The above studies concluded that school children with CI also face increased listening efforts at poor SNR conditions, leading to poor academic performances. In noisy environments (i.e., environments with background noises, high reverberation, and multiple interlocutors), the reduced spectral resolution and the elevated degree of spectral smearing cause interference in speech processing and recognition (Fu & Nogaki, 2005). Additionally, hearing in noisy surroundings demands more auditory attention, which raises listening effort (Pichora-Fuller et al., 2016; Zekveld et al., 2011).

2.3 Methods to assess listening effort in children using cochlear implants

Listening effort can be measured in different ways, including objective, subjective, and physiological methods. Most of the studies adopted the dual-task paradigm, single-task paradigm in the case of small children, perceived subjective measures including rating scales, subjective reports, and physiological methods consisting of electroencephalography (Miles et al., 2017), pupillometry (Winn, 2016; Zekveld et al., 2010, 2011), and functional near-infrared spectroscopy (White & Langdon, 2021). As it is non-invasive, compatible with CI devices, and immune to electrical artifacts, functional near-infrared spectroscopy (fNIRS) is a developing technology that aids this population (Saliba et al., 2016).

2.3.1 Physiological methods

The methodological nature, objective or subjective, is why few studies on listening efforts with young children exist. Most research using subjective assessments of perceived effort reveals that increased background noise increases listening effort (Hicks & Tharpe, 2002; Hughes et al., 2018) However, subjective measurements have considerable disadvantages. They are less dependable in connecting with objective data since many environmental factors more easily impact them (Hughes & Galvin, 2013).

In addition, cooperative adults and school-aged children find them useful, whereas small children do not. Psychoacoustic criteria, such as dual-task paradigms, have been developed to assess listening effort across many parallel goals. Again, it is challenging to administer this to extremely young children (Hughes et al., 2018; McGarrigle et al., 2019). Hence, pupillometry fNIRS, and electroencephalography, which has recently emerged as the most popular technique for evaluating listening effort, are three objective physiological techniques that may prove to be applicable in studies with very young (preschool) children and infants with CI in the near future (Saksida et al., 2021).

Pupillometry has been employed in several research (Winn, 2016; Zekveld et al., 2010, 2011) to measure listening effort in relation to hearing abilities, phrase intelligibility, spectral resolution, lexical complexity, semantic context, and fundamental cognitive capacities in the adult population. Even in situations of strong comprehension (Winn & Teece, 2021), demonstrating pupillometry to be a trustworthy instrument for measuring listening effort.

A recent study that evaluated the listening effort in hearing school participants showed a relative relationship between increased loudness and the pupillary response (McGarrigle et al., 2019). Children with bilateral CI showed abilities for binaural fusion in a different investigation. According to the study, binaural fusion is poor without inter-aural level cues and is further complicated by large asymmetries in the bilateral brain-stem pathways, which makes listening harder (Steel et al., 2015)

The near-infrared spectroscopy (NIRS) technology may identify variations in oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hbb) in biological tissue because hemoglobins absorb light at wavelengths between 650 nm and 1000 nm (Jöbsis, 1977). In elderly persons wearing hearing aids, prefrontal brain HbO2 concentrations were likewise favourably correlated with listening effort (Rovetti et al., 2019). According to recent findings from a study of normally hearing people, listening effort depends partly on higher cognitive mechanisms for auditory attention and working memory in the frontal lobe and hierarchical linguistic computation in the brain's left hemisphere (White & Langdon, 2021).

Researchers have employed the Electroencephalogram (EEG), whose main axis is parallel to the cortical surface, to study brain activity for many years. Large groups of pyramidal neurons' synchronised excitatory or inhibitory activity can be picked up by it. Because of the EEG's excellent temporal resolution, it can detect changes in brain activity in fractions of a second. Due to this characteristic and its non-invasiveness and affordability, EEG is particularly advantageous for investigating objective brain correlates of effort and cognitive involvement while listening (Miles et al., 2017).

Compared to listening in quiet environments, listening to noise increased EEG alpha activity, primarily localised in the parietal brain, according to clinical research on paediatric patients with bilateral sensorineural hearing loss (Cartocci et al., 2019). From the studies mentioned above, it can be inferred that none of these techniques is frequently employed in research to measure listening effort since none is likely adequate for a thorough and exhaustive assessment of listening effort on its own (Saksida et al., 2021), requires complex instrumentation, and are majorly used for uncooperative /challenging to test young children.

2.3.2 Dual-task paradigm

Any mental task can only be completed to a certain extent by an individual's cognitive capacity, according to the foundational theory (Kahneman, 1973; Styles & Styles, 2006), where the participants are given two tasks (a "primary" task and a "secondary") to complete simultaneously while using the dual-task paradigm. The primary task in evaluating listening effort often involves listening (for example, speech recognition) in various acoustic environments. Reacting as soon as possible to a visual stimulus presented at random intervals, such as a light or picture, is frequently part of the secondary task (Downs, 1982; Downs & Crum, 1978; Hicks & Tharpe, 2002). This study found that response times in the dual-task condition were 25–50 ms faster than in the secondary task-only condition. This change addressed the extra listening work required when a supplementary visual charge for word or phrase recognition was present.

The present study will quantify listening efforts using behavioural tasks (dual-task paradigm) and subjective self-reports. Studies have shown that the dual-task condition is a better measure (Downs, 1982; Downs & Crum, 1978; Hicks & Tharpe, 2002b) as people frequently manage several cognitive tasks at once, especially in a learning situation (such as paying attention to a teacher's instructions while taking notes); hence the dual-task method has strong ecological validity (Gagné et al., 2017). In the dual-task paradigm, RT tended to rise as auditory signals worsened or as processing went deeper (Ganesh et al., 2011; McGarrigle et al., 2019). Gagné et al. (2017) examined published studies (n = 29) that measured listening effort during speech comprehension in young and old individuals. The research demonstrated that younger and older individuals have successfully employed dual-task paradigms to measure variations in effort under various experimental settings.

The studies use a similar paradigm to examine the effects of age. The first study involved normal hearing (NH) participants aged between 6 and 26. The second study included a group of students between the ages of 5 and 14 who were cochlear implant (CI) users. The listening effort decreases from elementary school through late adolescence (Hsu et al., 2020). It is well known that children under ten typically perform poorly in auditory word recognition tasks, particularly when the input signal is degraded by noise or other variables (Corbin et al., 2016; Eisenberg et al., 2000).

Because children experience significant linguistic and cognitive maturation during elementary school (Cartwright, 2002), the same behavioural paradigm may yield different results between children and adults. However, most published studies on how listening effort changes with age focused on younger versus older adults (Degeest et al., 2015; Ward et al., 2017; Wu et al., 2016). Pals et al. (2013) attempted to demonstrate that listening effort may change depending on the CI processing conditions. Various CI simulations with different numbers of spectral channels were played for 19 subjects with normal hearing. Intelligence and listening effort were investigated using a dual-task paradigm with an intelligibility test with either a language or non-linguistic visual response-time (RT) task. The findings show that listening effort decreases with spectral resolution. Additionally, objective listening effort measures like RTs on a secondary task more accurately measure these modifications.

2.4 Real-life performance in children with cochlear implantation

Apart from the objective behavioural measures, other methods can measure listening effort, such as physiological and subjective (self-report) domains (Klink et al., 2012; McGarrigle et al., 2014; Pichora-Fuller et al., 2016). The dual-task condition is done in a clinical/lab setup. Parents and medical professionals have provided evidence of children decreased listening effort, even when using subjective assessment in real-life settings (Bohnert et al., 2006; Kühn-Inackeret al., 2004; Scherfet al., 2009; Winkler et al., 2002).

2.4.1 Other subjective measures to assess listening effort in Children with Cochlear implants

Perreau et al. (2017) compared listening efforts across three CI groups and a control group of people with normal hearing. The Spatial Hearing Questionnaire (Tyler et al., 2009), and three questions about listening effort from the perceived listening effort scale were used as a subjective measure to assess listening effort. Results showed a significant disparity between the normal hearing and CI groups. The normal-hearing group had a higher reduction in listening effort than the CI users.

This study aimed to demonstrate that listening effort can vary between processing conditions even when speech intelligibility does not. Nineteen individuals with normal hearing took part in CI simulations with various numbers of spectral channels. Different self-report scales were utilised using the dual-task paradigm to provide an arbitrary measurement of listening effort. The NASA Task Load Index (TLX) was used to assess listening effort on a subjective basis. (Hart & Staveland, 1988). The NASA TLX is a multidimensional scale that assesses several factors affecting how much labour is being done, including mental, physical, temporal, performance, effort, and frustration demas (Hart & Staveland, 1988). Changes are best demonstrated in objective measures of listening effort, such as RTs on a secondary task, rather than intelligibility scores or subjective effort evaluations.

Abdel-Latif & Meister conducted a study in 2022, they measured speech recognition and listening effort in cochlear implant (CI) recipients and age-matched normal-hearing listeners using the subjective "Adaptive Categorical Listening Effort Scaling" ("ACALES") (Krueger et al., 2017), and objective test (dual-task paradigm) paradigms. However, while reaching fixed speech intelligibility levels of 50 and 80%, the listening effort did not differ significantly between CI users and listeners with normal hearing. In contrast, both listener groups showed significant inter-individual differences in the subjective scaling and objective dual-task measures of effort.

2.4.2 SSQ-P10

The speech spatial qualities (SSQ), speech spatial qualities -children (SSQ-C), and listening effort pragmatic subscale can gather data regarding CI recipients' experiences that go beyond the capabilities assessed in the sound booth (Lopez et al., 2021). However, SSQ-P10 instead of SSQ will be used in this study as SSQ-P10 is developed to measure outcomes in real-world settings for children. The SSQ-P10 is a validated shortened version of the SSQ-P for use in the clinical management of children with HA/CI (Killan et al., 2020).

In a study to evaluate the impact of CI use on the perceived listening effort of adults and pediatric participants with unilateral hearing loss or asymmetric HL. A clinical trial evaluating the efficacy of cochlear implantation in situations of UHL and AHL involved the subjects who received their CI. SSQ and SSQ-C were administered to the participants preoperatively and at post-activation intervals. Patients with UHL or AHL who use CIs as adults or children report less listening effort than before surgery. In addition to the abilities assessed in the sound booth, the SSQ and SSQ-C Listening Effort pragmatic subscale may offer further insight into the experiences of CI recipients (Lopez et al., 2021). In this study, quality-of-life results for CI patients with UHL are examined. The Speech, Spatial, and Qualities of Hearing Scale (SSQ) was used to measure quality of life during the first year of device use. Cochlear implantation may significantly enhance the quality of life in cases of severe UHL. Subjective gains in speech perception of noise, spatial hearing, and listening effort increase the quality of life (Dillon et al., 2017).

Hornsby (2013) used subjective and objective tests to explore the impact of hearing aid use and advanced hearing aid features on listening effort and mental fatigue in people with SNHL. Additionally, they gathered ratings of attentiveness and fatigue before and after the dual task and subjective rates of listening effort throughout the day. Results from various subjective and empirical tests indicate that people with hearing loss may experience mental fatigue due to prolonged speech processing demands. It is significant to highlight that using hearing aids fitted medically may lessen the listening effort and vulnerability to mental fatigue brought on by prolonged speech-processing demands.

Galvin et al. (2007) assessed, after a 6- to 13-month experience with successive bilateral implants, the additional perceptual benefit given to children by using two cochlear implants instead of one. A questionnaire was used to compare parent ratings of their child's performance in various listening circumstances before and after surgery. Items pertaining to speech perception, spatial hearing, or additional hearing characteristics were included. Scores of postoperative performances for eight patients were generally better than preoperative scores, especially in the section on spatial hearing. Six parents claimed that their children's behaviour has improved in day-to-day life.

Research has examined how subjective tests affect people's perceptions of speech, space, and hearing aid quality. A self-reported questionnaire is the only subjective measure to reveal information about a person's speech, spatial awareness, and perception quality in everyday scenarios. The studies above show that self-report questions help determine the effectiveness of user acceptability, benefit, and satisfaction.

2.4.3 TEACH

Assessing auditory performance at school is essential for school-going children. TEACH questionnaire assesses the classroom performance with a cochlear implant, using the responses given by the class teachers. A research study (Vashist & Chabbra, 2023) has documented the auditory and speech-language development of a late implanted patient with bimodal cochlear implantation. A child with congenitally bilateral sensorineural hearing loss, speech delay, and language delay. She also has severe to profound SNHL in her right ear and profound SNHL in her left ear. After receiving auditory language therapy, a unilateral cochlear implant using the neubio BOLD CI system was placed at the age of 15 years. The results of the cochlear implantation are evaluated using the "Teacher Evaluation Aural/Oral Performance of Children (TEACH)" test. TEACH, administered six months after cochlear implantation, considered the improvement in oral/aural performance in quiet and noisy environments.

Surprisingly, only a few reports of school-aged children's subjective evaluations of listening efforts have been published. The limited information suggests behavioural listening measures are similar to those used with adults and that listening effort and subjective assessments can differ (Hicks & Tharpe, 2002; Gustafson et al., 2014). Hence, it is necessary to analyse perceived listening effort using subjective measures and test its correlation with the objective measure.

In summary, only a handful of studies have reported the effect of cochlear implantation on listening effort and perceived real-life benefits in school-going children in different background conditions (quiet and noise). Less evidence shows the correlation between behavioural and subjective measures of the listening effort in these populations. Therefore, further research is needed to better understand the effects of cochlear implants on listening effort and real-life outcomes in school-going children.

CHAPTER III

METHOD

The present study evaluated the relationship and comparison between listening effort and real-life outcomes in school-going children with cochlear implantation using objective and subjective measures for which quasi experimental research design was used. Purposive sampling would be used to enrol the participants.

3.1 Participants

The study included 50 school-going children in the age range of 8 to 15 years. These 50 participants were further divided into two subgroups. Group I included 25 normal children with a hearing threshold of less than 10 to 15 dB HL served as controls. The mean age of participants in this group was 10.64 (SD = 1.69) Group II included 25 children with bimodal cochlear implantation with bilateral severe to profound hearing loss. The mean age of participants in this group was 10.92 (SD = 2.19).

Group I had a mean PTA of 10.93 dB HL (SD = 2.35) in the right ear and 10.5 (SD = 2.12) in the left ear, and Group II had a mean PTA of 104.69 dB HL (SD = 5.67) in the right ear and 109.19 (SD = 6.22) in the left ear. An attempt was made to match the age, gender, and listening environment between the two groups. The inclusion and exclusion criteria used to select the participants are given below:

3.2 Inclusion criteria

Group I

1. Participants with normal hearing sensitivity were in both ears (≤ 15 dB HL) for both air conduction (0.25 to 8 kHz) and bone conduction thresholds (0.25 Hzto 4 kHz), the air-bone gap is less than 10 dB HL.

2. Participants had speech identification scores of 100%.
3. Children with normal otoscopic findings in both ears were selected as a control group.
4. Participants with age-adequate language skills (based on informal language screening) were included.

Group II

1. Participants with a CI in one ear and a hearing aid in the opposite ear, i.e, bimodal users.
2. Participants had used CI for at least three years.
3. All participants had immittance findings of “A” type or “As” type.
4. Aided speech identification scores were above 80% for all the participants.
5. The implanted ear's aided threshold in the upper range of spectrum for all the participants.
6. Participants with adequate language to perform the tasks were selected. (Informal assessment was done using verbal questions, including reasoning and picture description).

3.3 Exclusion criteria

1. Participants with unilateral hearing loss were not be selected in Group II.
2. Participants with poor word recognition scores were excluded from the study
3. Participate with inadequate language were excluded from the study
4. Participants with scores of screening checklist for auditory processing disorder less than 50% would be considered as at risk of auditory processing disorder.

5. Participants with additional disabilities and anomalies such as middle ear infections, visual impairment, and borderline intellectual disabilities were excluded.

The demographic and audiological details of all the participants are in Table 3.1. and Table 3.2 for two groups. The details about the cochlear implant used are also given in Table 3.2.

Table 3.1.

The demographic and audiological details of the participants with the normal hearing in Group I.

SI.no	Age (years)/ Gender	PTA (dB HL)		SIS (%)
		Right ear	Left Ear	Both ears (R/L)
1.	9/M	12.5	12.5	100
2.	9/F	10	8.75	100
3.	10/M	13.75	12.5	100
4.	10/F	11.25	8.75	100
5.	8/M	5	6.25	100
6.	12/F	12.5	8.75	100
7.	9/M	12.5	13.75	100
8.	12/M	11.25	10.5	100
9.	11/M	8.75	10	100
10.	8/M	12.5	11.25	100
11.	9/M	10.5	12.5	100
12.	13/M	10	8.75	100
13.	13/F	13.75	12.5	100
14.	13/F	8.5	10.5	100
15.	14/F	12.5	12.5	100
16.	11/F	10	8.75	100
17.	14/F	13.75	12.5	100
18.	8/F	11.25	8.75	100
19.	12/F	5	6.25	100
20.	11/M	12.5	8.75	100
21.	11/M	12.5	13.75	100
22.	14/M	11.25	10.5	100
23.	9/M	8.75	10	100
24.	11/M	12.5	11.25	100
25.	8/M	10.5	12.5	100

Note: PTA-Puretone average thresholds at 500 Hz, 1 kHz, 2 kHz, 4 kHz; SIS-speech identification scores.

Table 3.2

The demographic and audiological details of participants with cochlear implants in Group II.

SI. No	Age / gender	PTA (dB HL)		SIS Aided (%)	Model of implant		Model of hearing aid
		Right ear	Left ear		Model of CI	Model of speech processor	
1.	12Y/M	106.5	110	88	Freedom ST	CP802	Phonak Naida P30 UP
2.	8Y/M	110	115	92	Freedom ST	CP802	Beltone boost 695
3.	8Y/M	100	98.75	88	Medel Sonata	Opus 2	Verunio XTM XP BTE
4.	12Y/M	96.25	102.5	84	Freedom	CP 802	Siemens Lotus
5.	9Y/F	113.5	103.5	88	Freedom	CP802	Enzo 598 BTE
6.	9Y/M	97.5	116.2	88	Medel sonata	Opus 2	Logar 598 BTE
7.	9Y/M	100	106.5	88	CI24RE(ST)	CP802	Danavox LG 290
8.	8Y/M	110	113.5	84	CI22	CP1002NFS	Beltone boost
9.	11Y/M	102.5	115	92	CI24RE(ST)	CP802	Danavox logar 598
10.	12Y/F	106.5	110	96	Freedom	CP802	Danavox logar 598
11.	9Y/M	106.5	115	84	Freedom	CP802	Beltone boost 695
12.	11Y/F	100	103.5	92	Medel Sonata	Opus 2	Danavox logar 440
13.	12Y/M	97.5	115	92	Freedom	CP802	Starkey Aries pro
14.	13Y/M	102.5	110	92	Medel Sonata	Opus 2	Beltone boost 695
15.	14Y/M	111.25	117.5	96	Freedom	CP802	Audio service volta HP
16.	11Y/M	106.5	112.5	96	Medel Sonata	Opus 2	Danavox Klar 388 DW SP BTE
17.	9Y/F	100	106.5	92	Medel Sonata	Opus 2	Starkey Aries pro
18.	12Y/F	113.5	115	88	CI24RE(ST)	CP802	Phonak Naida P30 UP
19.	11Y/M	98.75	103.5	92	Freedom	CP802	Rely 395 DW SP BTE
20.	13Y/F	106.5	102.5	92	Freedom	CP802	Audio service volta HP
21.	10Y/F	106.5	102.5	88	Freedom	CP802	Beltone boost 695
22.	11Y/F	113.5	103.5	96	Medel Sonata	Opus 2	Danavox Klar 388 DW SP BTE
23.	10Y/M	115	97.5	96	CI24RE(ST)	CP802	Rely 395 DW SP BTE
24.	12Y/F	100	106.5	92	Medel Sonata	Opus 2	Starkey Aries pro
25.	11Y/F	106.5	103.5	88	Freedom	CP802	Danavox Klar 388 DW SP BTE

Note: PTA- Puretone average thresholds at 500 Hz, 1 kHz, 2 kHz, 4 kHz; SIS- speech identification scores.

3.3 Test environment

Testing occurred in a sound-treated room with ambient noise levels within the specified ranges per ANSI S3.1 (1991). The test room was comfortable enough for the children with reference to temperature and light.

3.4 Ethical consideration

All the testing procedures in the present study were performed using a non-invasive approach. The test procedures were explained to the parents of the participants before the testing, and written informed consent was taken from the parents / caretakers of the participants.

3.5 Instrumentation

- An otoscopic examination was done using a clinical otoscope to rule out tympanic membrane abnormalities and to check for the status of the external ear abnormalities.
- The two-channel calibrated clinical audiometer (Piano plus Inventis) with an option for speech audiometry was used to perform threshold estimation at the octave frequencies and to carry out speech audiometry. The pure tone audiometry for air conduction threshold estimation was obtained using calibrated TDH 39 headphones from 0.25 to 8 kHz at octave frequencies. The output of the audiometer was routed to a loudspeaker, placed 1 meter away from where the child was seated, at 45° Azimuth.
- Calibrated GSI Tympstar Pro Immittance meter was used to perform tympanometry and the acoustic reflex threshold measurements with the probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflexes were measured at 500 Hz, 1 kHz, 2 kHz, and 4 kHz.

- A paradigm software (Perception Research Systems, 2007) was used to create a dual-task paradigm to evaluate listening effort, and MATLAB version 2014 (The Math Works, Natick, USA) was used to generate a speech-shaped noise on a lenovo11th Gen Intel(R) Core (TM) i3-1115G4 laptop computer.

3.6 Stimuli/Material

- Fifty Kannada phonetically balanced (PB) words list developed by Vandana (1998) was used as test stimuli in the dual-task paradigm. Of the 50 items, ten items were considered for trial, and each set with 20 items was presented as the test stimulus in (primary task) both quiet and noise at 5 dB SNR. The same material was used for speech audiometry (SRT and SIS).
- In the dual-task paradigm, squares and triangle shapes were used as visual stimuli for the secondary task.
- SCAP was used to screen for auditory processing disorder, SSQ-P10 and TEACH was used to questionnaires to assess real-life performance.

3.7 Routine hearing evaluation

The present study includes normal and cochlear-implanted children. All the participants underwent a routine audiological evaluation to check their hearing abilities. It included pure-tone audiometry, speech audiometry, and immittance evaluation. Otoscopy was performed to see the tympanic membrane characteristics and exclude the presence of signs such as ear discharge, tympanosclerosis, impacted wax, etc.

All participants initially underwent a standard audiological assessment in a sound-proof room comprising pure-tone audiometry using Modified Hughson &

Westlake method (Carhart & Jerger, 1959) at octave frequencies range from 0.25 to 8 kHz. The participants were instructed to raise their fingers whenever they heard minimal sound via the transducers. For speech audiometry, the participants were instructed to repeat the words they heard. Standardized test materials were used to carry out speech audiometry and to measure both ears' speech identification scores (SIS) presented at 40 dB SL (Ref: SRT level).

The participants were asked not to make movements and swallow frequently. Both tympanometry and acoustic reflex thresholds were measured using Garson Stadler Inc. Tympstar Pro to record the tympanogram and auditory reflex threshold for a probe tone frequency of 226 Hz. To rule out middle ear pathology, both ipsilateral and contralateral acoustic reflexes were measured using 500 Hz, 1 kHz, 2 kHz, and 4 kHz frequencies. The aided performance assessment was conducted for a frequency range (0.25 to 8 kHz) towards the CI side with a behavioural listening check (ling six sound test and/or aided audiogram). The participants were instructed to raise their hand or put the beads inside a box whenever they heard the tones from the loudspeaker. Also instructed to repeat the ling six sounds (/a/, /i/, /u/, /s/, /sh/, /m/), which was repeated by the examiner.

3.8 Procedure for listening effort assessment

The procedure was done in two phases. The first phase included the preparation of stimuli (translation of questionnaires into the Kannada language, the participant's native language) and paradigms. In the second phase, the listening effort task was performed, and administered real-life outcome questionnaires.

3.8.1 Phase 1: Development of stimuli

a) Development of dual-task paradigm

Initially, paradigm software (version 2.5.0.68, perception research systems incorporated, Lawrence, Kansas, united states of America) was used for designing the listening effort experiment. Using MATLAB code (Gnanateja,2016), speech spectrum-shaped noise was generated. A task was created for primary stimulus i,e. speech identification scores in quiet and speech noise at 5 dB SNR. Similarly, triangle and square shapes were created as a stimulus for secondary tasks. All the stimuli were added in the paradigm.

b) Translation of SSQ-P10 and TEACH questionnaire in Kannada

SSQ-P10, a shortened scale, is based on the original version of the SSQ developed for parents of children (aged five years and over) with impaired hearing by Galvin and Noble (2013) and Teacher's Evaluation of Aural/Oral Performance of Children (T.E.A.C.H.), Developed by Teresa Ching & Mandy Hill (2007) in English was taken for translation. These questionnaires were translated into the Kannada language by an experienced audiologist who was a native speaker of Kannada. The translated questionnaire was then reverse-translated to English by two other audiologists to ensure that the meaning conveyed was the same as that of the original questions. The questions that did not convey the original meaning were modified till they convey the same meaning as in the original questionnaire (Beaton et al., 2000). The translated questionnaires in given in Appendix I and II.

3.8.2 Phase 2: Administration of tests on participants

a) Administration of dual-task paradigm

The children were made to sit on a chair 1 meter distance and 45-degree azimuth from the loudspeaker. The laptop was connected to an audiometer, and the stimulus was presented to a loudspeaker at 45 degrees azimuth (towards the cochlear implant side). The level of the stimulus was kept constant at 45 dB HL. Using a dual-task paradigm, listening effort in quiet and noise were evaluated. This was done on both normal hearing and CI groups. During testing CI group participants wore CI and HA which were mapped and programmed by an experienced audiologist. The Kannada PB word list served as a primary task stimuli. In random order, a square or triangle appeared on the monitor simultaneously with each auditory stimulus (PB word) which served as a stimulus for the secondary task. Participants were instructed to repeat the PB words played in the auditory mode for the primary task and to press the keyboard buttons 4 for the triangle shape and 6 for the square shape that appeared on a monitor screen.

The experiment had ten trial items at the beginning of the test for the practice purpose, and 20 PB words were presented as the test stimuli (primary task) in both quiet and noise at +5 dB SNR. The primary task's number of correctly repeated words was considered, and the secondary task's reaction time (in milliseconds) was calculated. To prevent practice effects, a different word list was used for quiet and noise conditions.

b) Administration of questionnaires

Parents rated their children's hearing and listening abilities in everyday situations using the SSQ-P10 questionnaire. The questionnaire included three sub-sections, speech perception, spatial hearing, and qualities of hearing. Each subsection had a rating scale from 0 (not at all) to 10 (perfect). The questionnaire was distributed to the parents of CI children using a structured interview, and they were asked to score each topic on a scale of 1-10. The sum of the total rating score from each domain was divided by the total number of questions rated to calculate the final SSQ score. The maximum possible score was 10.

To assess the efficiency of a child's hearing aids and cochlear implant as well as functional performance in everyday life circumstances, the Teachers' Evaluation of the Aural and Oral Performance of Children (T.E.A.C.H) was used (Ching & Hill, 2007). The questionnaire includes pre rating checklist and 11 questions. The rating scale ranged from 0% (never) to 75%-100% (always). The teachers of CI children were given the questionnaire under three sections: quiet, noise, and overall. The raw score was calculated in percentage by dividing 20 for questions concerning quiet environments and dividing by 16 for questions concerning noisy environments. The maximum possible score was 36.

3.9 Statistical Analysis

The collected data were analysed using Statistical Package for Social Sciences (SPSS for Windows, Statistical Version 26) software. The Shairo-Wilk normality test was carried out to determine the data distribution. Descriptive statistics were performed to summarize the data. Mann-Whitney U tests were conducted to compare the variables across groups and Wilcoxson signed rank test was used for within-group comparison.

Spearman’s correlation was used to determine the correlation between subjective and objective measures.

CHAPTER IV

RESULTS

The present study analyzed the relationship between listening effort and real-life outcomes in school-going children with cochlear implantation. The results of the dual-task paradigm (listening effort), including scores for the primary task (SIS) and the secondary task RT (in msec), were compared between the normal hearing and CI groups in both quiet and noise conditions. In addition, the correlation between listening effort (dual-task paradigm) and real-life outcomes (SSQ-P10 and TEACH) were analyzed. The data were analyzed using SPSS for Windows (version 26) software. The mean, median, SD, and IQR for the two groups are given in Table 4.1 and Table 4.2.

Table 4.1

Mean, median, standard deviation (SD), and inter-quartile range for all the tasks in children with normal hearing (Group I).

Conditions	Mean	SD	median	IQR
		Group I		
LE in quiet (SIS)	19.52	0.653	20.00	1
LE in noise (SIS)	18.04	0.889	18.00	2
LE in quiet (RT in msec)	1766.12	662.23	1444.97	890.64
LE in noise (RT in msec)	2016.13	756.74	1783.88	1144.07
SSQ-P10	9.752	0.2568	9.900	0.5
TEACH	35.64	0.489	36.00	1

Note: LE- listening effort, SIS – speech identification scores, RT- reaction time. The maximum average score for SIS was 20, SSQ-P10 was 10, and TEACH was 36.

Table 4.2

Mean, median, standard deviation (SD), and inter-quartile range for all the tasks in children with cochlear implantation (Group II).

Conditions	Mean	SD	median	IQR
		Group II		
LE in quiet (SIS)	16.88	1.26	17.00	2
LE in noise (SIS)	11.20	1.47	12.00	2
LE in quiet (RT in msec)	3865.25	1859.32	3880.19	2851.38
LE in noise (RT in msec)	5933.71	1265.58	6322.00	1844.32
SSQ-P10	6.800	0.7269	6.700	1.3
TEACH	23.24	3.9	24.00	3.0

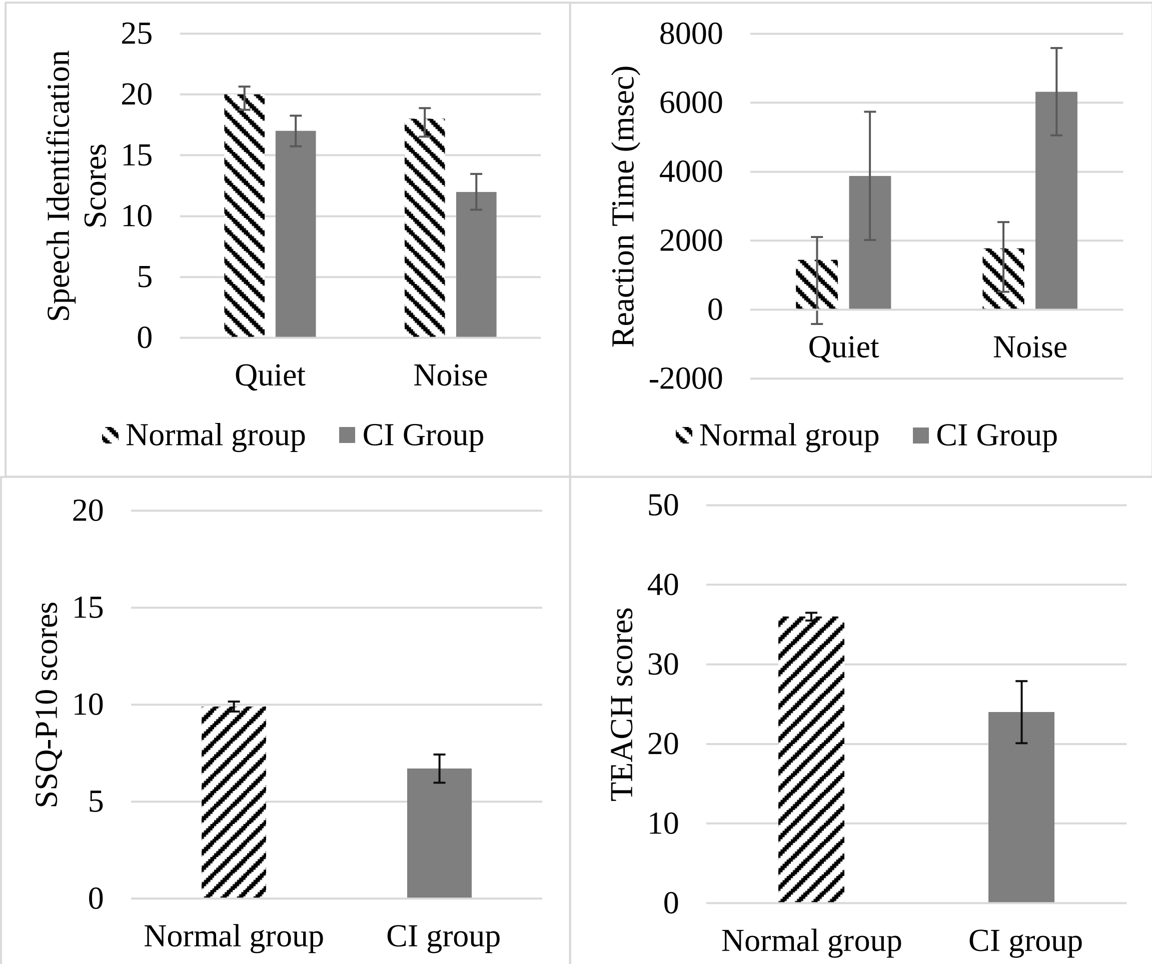
Note: LE- listening effort, SIS – speech identification scores, RT- reaction time. The maximum average score for SIS was 20, SSQ-P10 was 10, and TEACH was 36.

4.1 Comparison of listening effort findings between groups

The Shapiro-Wilk test tested the data's normality. Most parameters were not normally distributed. Hence, non-parametric tests were performed. Descriptive analysis of the two groups' mean, median, and SD revealed that Group I (normal hearing) had higher scores in all the tasks, including dual task (primary and secondary), SSQ-P10, and TEACH responses (represented in Figure 4.1).

Figure 4.1

Bar graph showing (a) listening effort-primary task (in quiet and noise), (b) listening effort-secondary task (in quiet and noise), (c) SSQ-P10, (d) TEACH scores for normal and CI groups.



Note: SSQ-P10- speech, spatial, and quality of hearing scale for parents of children with impaired hearing, TEACH- Teacher's Evaluation of Aural/Oral Performance of Childre, CI group-cochlear implanted group.

The scores of listening efforts between the two groups were analysed using inferential statistics. The Mann-Whitney U test was carried out to determine if any differences existed between the two groups across all the conditions. The results are given in Table 4.3. The results revealed a significant difference between the two groups on all the measures of listening effort, including dual-task paradigm (four conditions) in quiet as well as in noise, and real-life outcome measures.

Table 4.3

Comparison of listening effort between two groups using the Mann-Whitney U test

Measures	|z|	*P* value
LE quiet (SIS)	6.019	0.000
LE noise (SIS)	6.141	0.000
LE quiet (RT msec)	4.201	0.000
LE noise (RT msec)	6.044	0.000
SSQ-P10	6.144	0.000
TEACH	6.192	0.000

Note: $p < 0.01$, LE = listening effort, SIS- speech identification scores, RT- reaction time, SSQ-P10- speech, spatial, and quality of hearing scale for parents of children with impaired hearing, TEACH- Teacher's Evaluation of Aural/Oral Performance of Childre.

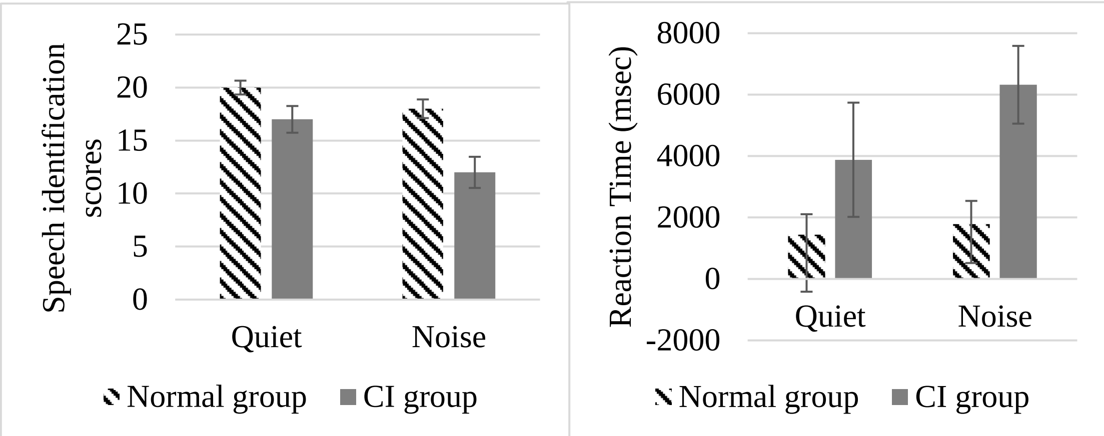
4.2 Comparison of listening effort findings in quiet and noisy conditions within the group

The dual-task paradigm's primary and secondary task findings were compared in two conditions: quiet and noise within each group. The mean and SD of the same are already mentioned in Table 4.1 and 4.2

It can be observed that in both groups, scores were different between quiet and noise conditions. Wilcoxson signed rank test was carried out to see if there were any pairwise differences in both conditions in each group.

Fig 4.2

Bar graph showing(a) listening effort-primary task in a quiet and noisy conditions, (b) listening effort-secondary task within a quiet and noisy conditions in both normal and CI groups.



Note: CI group- cochlear implanted group

The results showed a significant difference between quiet and noise conditions of primary task in normal hearing group (Group I) [$|Z| = 4.202$, $p < 0.01$], and also in secondary task [$|Z| = 2.906$, $p < 0.01$]. Similarly, there was a significant difference between quiet and noise conditions in CI group (Group II) in primary task and secondary tasks [$|Z| = 4.405$, $p < 0.01$], [$|Z| = 4.319$, $p < 0.01$] respectively.

4.3 Correlation between objective measure of listening effort and real-life performance measures

The two questionnaires, SSQ-P10 and TEACH, were administered to parents and teachers of the participants, respectively, and the objective task was done using a dual-task paradigm. Various conditions of the dual-task paradigm were correlated with the questionnaire (subjective measures) findings using Spearman's correlation, as data were not normally distributed on the Shapiro-Wilk normality test.

In CI (Group II), the scores revealed a negative correlation between reaction time (secondary task) in quiet and the SSQ-P10 (ρ = -4.96, p = 0.012), in noisy condition and SSQ-P10 (ρ = -0.623, p = 0.001). Also, there was a negative correlation with TEACH in quiet (ρ = -0.549, p = 0.004) and noisy conditions (ρ = -0.745, p = 0.000) in secondary task. There was no correlation between the primary task and the questionnaires.

CHAPTER V

DISCUSSION

The listening effort and real-life performance findings were measured in two groups of individuals: one had the normal hearing group and the other group individuals who had been using cochlear implantation, using objective method (dual-task paradigm), and real-life outcome measures (SSQ-P10, TEACH) questionnaires. The present study compares the dual-task scores and questionnaire scores between the two groups and between the two conditions (quiet and noise) within each group. In addition, the correlation between dual- task scores and questionnaire scores were also done.

5.1 Comparison of listening effort findings between groups

The results of dual-task in individuals with normal hearing and cochlear implantation revealed a significant difference between the two groups. The individuals with normal hearing scored better in all the conditions when compared to the implanted group. The present results agree with the earlier studies (Hughes & Galvin, 2013; Perreau et al., 2017). As purported by Hughes and Galvin (2013), children using CI would likely have greater listening effort than children with normal hearing, if they had to listen in environments with a low SNR, The reason for increased listening effort in CI children could be because auditory information processing is influenced by linguistic expertise, listening proficiency, and the utilization of contextual signals (Boothroyd, 1999; Hughes & Galvin, 2013) and CI children have reduced cognitive capacity to process the above information in complex situation (Perreau et al., 2017). Further, the reason for the poorer scores by children with cochlear implant in the study may be because of their congenital or extremely early-onset hearing loss and the length of their profound deafness before their first implant, and the CI group is likely to have had impairments in some or all of these categories. Moreover, most of the study's participants were using the CI model without any signal enhancement feature which may also be attributed to poor scores in noisy conditions. Studies that evaluated the speech perception in hearing-impaired individuals who use CI with the noise-reduction algorithm, reveal that noise reduction algorithm improves the speech perception in background noise in the difficult listening condition (Dawson et al., 2011). Also, according to Hersbach et al. (2012), Multimicrophone directionality was also found to be effective in improving speech understanding in spatially separated noisy conditions. This could indirectly reduce the listening effort in CI with advanced technologies

In the present study, the subjective scores of SSQ-P10 and TEACH by participants with normal hearing were higher than those of the individuals with CI. The results of the present study are in agreement with that of Perreau et al. (2017). These findings suggest that CI users exert greater effort than people with normal hearing in everyday listening conditions (Perreau et al., 2017). The findings of subjective measures are similar to that of the dual-task (objective) which implies that both the measures are sensitive to changes in listening effort. Hence, SSQ-P10 and TEACH can be considered sensitive tools in assessing perception in real-life situations.

5.2 Comparison of listening effort findings between quiet and noisy conditions

Another finding of the present shows that, in agreement with other studies, listening effort was more in noisy conditions than in quiet. McGarrigle et al. (2019) demonstrated a clear and unambiguous reduction in secondary task performance as SNR declined, resulting in more listening effort in poor SNR conditions. Howard et al. (2010) employed digit recall as the secondary task and discovered higher listening effort in larger negative SNRs. Hicks and Tharpe (2002) and McGarrigle et al. (2019), showed poorer scores in noisy conditions than the quiet in each group.

The reason could be that the ability of the CI group to process the auditory information is constrained by the poor SNR and reduction in cognitive capacity due to acoustic demands (Damen et al., 2006; McGarrigle et al., 2019). It can be overcome by providing a higher SNR, but it is not always possible to providing high SNR in mainstream settings consistently. Further, Candell and Smaldino (2000) stated that typical classroom SNRs fall between -7 and +5 dB. Children with CI should be predicted to require more listening effort than their NH peers at these low SNRs, leaving less cognitive capacity for other tasks. The findings emphasize the necessity of ongoing support for children with CI in all learning environments. Even when children with CI use language appropriate for their age and perform well academically, parents and teachers must be informed of the frequently demanding nature of mainstream education for these children. Another, suggestion to reduce the increased listening effort can be using bilateral CI, as many studies have reported better outcomes with bilateral CI than unilateral and bimodal CI (Christal, 2012; Dunn et al., 2010; Hughes & Galvin, 2013; Noble & Gatehouse, 2009).

5.3 Correlation between objective measure of listening effort and SSQ-P10

The results showed a moderate negative correlation between reaction time (secondary task) and SSQ-P10 in CI group (Group II) in quiet and noisy conditions. That is RT increases, scores of SSQ-P10 decline, suggesting that children with CI showing increased listening effort may also affect listening in real-life situations. The results of the present study are not in consensus with earlier studies (Downs & Crum, 1978; Feuerstein, 1992; Gosselin & Gagné, 2011; Hicks & Tharpe, 2002; Zekveld et al., 2011). Although listening effort is measured using both subjective and objective measurements, research that combines the two frequently finds no statistical relationship between the two in adults and children (Downs & Crum, 1978; Feuerstein, 1992; Gosselin & Gagné, 2011; Hicks & Tharpe, 2002; Zekveld et al., 2011).which imply that subjective assessments of listening effort and objective measurements of listening effort reflect various facets of listening effort.

However, the present study results showed a moderate negative correlation for a secondary task. SSQ-P10 includes questions related to quiet and noisy conditions and covers the aspects of hearing abilities same as objective tasks. This might have contributed for the correlation. Further, none of the other studies have used the SSQ-P10 questionnaire to correlate with the objective task. This short-form scale was developed using statistical methods to identify the items that provided the most information regarding the three aspects of auditory ability, including speech hearing, spatial hearing, and qualities of hearing.

Johnson et al. (2015) comparing two listening effort measures (self-report and word recall) discovered that the self-report approach was the more sensitive of the two measures, even though both indicated identical changes in listening effort when the SNR increased in the normal-hearing group. In conclusion, subjective and objective measure can be considered sensitive tools to assess listening effort in real-life situations.

5.4 Correlation between objective measure of listening effort and TEACH

The results showed a moderate negative correlation between reaction time (secondary task) and the TEACH questionnaire in CI group in quiet and noisy conditions. i.e., as the reaction time increases, there is a decline in the scores of the TEACH questionnaire. However, there was no correlation between the primary task and the questionnaire. No studies have previously assessed the correlation between objective measures and the TEACH questionnaire. This preliminary study revealed a moderate negative correlation between the objective (secondary task) measure and TEACH. The results shows that children with CI showing increased listening effort in objective tasks may also have difficulties listening in real-life classroom situations.

CHAPTER VI

SUMMARY AND CONCLUSION

The present study analyses the relationship between the listening effort and real-life performance measures in individuals with normal hearing sensitivity in school-going children and cochlear-implanted children. To test the above objectives, twenty-five participants in each group in the age range of 8-15 years underwent objective and subjective testing, including a dual-task paradigm and administration of SSQ-P10 and TEACH questionnaires. In dual-task, primary and secondary task was carried out simultaneously. The findings of objective and subjective measures were tabulated. Descriptive and inferential statistics were used in SPSS software for Windows (v 26). The findings are summarised below:

- ❖ SIS scores of primary tasks show significant differences in quiet and noisy conditions, and normal group scores significantly better than the CI group.
- ❖ Reaction time (msec) of the secondary tasks shows significant differences in quiet and noisy conditions, and the normal group has lesser RT than the CI group.
- ❖ Scores of SSQ-P10 and TEACH between the two groups also showed significant differences.
- ❖ There was a significant difference between quiet and noisy conditions when pair-wise comparison was done within each group.
- ❖ There was a negative correlation between secondary task (RT) and SSQ-P10 in noisy conditions in normal group.
- ❖ There was also a negative correlation between secondary task (RT) and SSQ-P10, TEACH in quiet and noisy conditions in CI group.

- ❖ There was no correlation between the primary task and SSQ-P10, TEACH in any of the conditions in both the groups.

6.1 Conclusions

From the results of the present study, it can be concluded that subjective measures may also assess the listening effort indirectly and objective measures of listening effort can be attributed to subjective and real-life performance measures. Children with normal hearing sensitivity performed better in both objective and subjective (real-life performance) measures. The study’s results also indicate that performance was significantly better in quiet than noise condition which suggests that training is required to improve real-life activities and social and academic achievements.

6.2 Implication of the study

- The study attempted to identify whether listening efforts affect school-going children's school and daily living situations.
- The study findings assist in testing the listening effort that should be helped for mainstreaming.
- The study outcomes help in counselling the benefits of bilateral CI over bimodal CI and unilateral CI. Also, help to understand the importance of listening training in noise which promotes improve real-life activities and social and academic achievements.

6.3 Future direction

- Comparison of listening effort between bilateral CI and bimodal CI in children could be done in future.

- Research can be done to compare the listening effort in users with different models of CI with advanced features like noise reduction algorithm etc.
- Further research needs to be done to see the results after training the children in noise for reducing listening effort.

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Appendix I

ಪ್ರಶ್ನಾವಳಿ

ಭಾಗ 1

ಜನಸಂಖ್ಯಾ ವಿವರಗಳು

1. ಪ್ರಕರಣದ ಹೆಸರು:
2. ಪ್ರಕರಣ ಸಂಖ್ಯೆ:
3. ವಯಸ್ಸು/ಲಿಂಗ:
4. ಹುಟ್ಟಿದ ದಿನ:
5. ವಿಳಾಸ/ಸ್ಥಳ: ನಗರ/ಗ್ರಾಮೀಣ
6. ಸಾಮಾಜಿಕ ಆರ್ಥಿಕ ವರ್ಗ: ಸ್ಲ್ಯಾಬ್ I/ ಸ್ಲ್ಯಾಬ್ II/ಸ್ಲ್ಯಾಬ್ III
7. ಪೋಷಕರ ಶಿಕ್ಷಣ: ತಾಯಿ: ತಂದೆ:

ಭಾಗ 2

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ನಿಮ್ಮ ಮಗು ಸುಮಾರು ಐದು ಜನರ ಗುಂಪಿನಲ್ಲಿ ಕುಳಿತಿದೆ, ಹಾಗೂ ಶಾಂತ ಸ್ಥಳದಲ್ಲಿ ಕುಳಿತಿದೆ. ಮಗು ಗುಂಪಿನಲ್ಲಿರುವ ಎಲ್ಲರ ಮುಖಗಳನ್ನು ನೋಡಬಹುದು. ನಿಮ್ಮ ಮಗು ಅವರ ಮಾತುಕತೆಯನ್ನು ಅನುಸರಿಸುತ್ತದೆಯೇ?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 
ನಿಮ್ಮ ಮಗು ಸುಮಾರು ಐದು ಜನರ ಗುಂಪಿನಲ್ಲಿ ಕುಳಿತಿದೆ, ಹಾಗೂ ದೊಡ್ಡ ಕುಟುಂಬದಂತಹ ಗದ್ದಲದ ಸ್ಥಳದಲ್ಲಿ ಕುಳಿತಿದೆ. ಮಗು ಗುಂಪಿನಲ್ಲಿರುವ ಎಲ್ಲರ ಮುಖಗಳನ್ನು ನೋಡಬಹುದು. ನಿಮ್ಮ ಮಗು ಅವರ ಮಾತುಕತೆಯನ್ನು ಅನುಸರಿಸುತ್ತದೆಯೇ??	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 

ನಿಮ್ಮ ಮಗು ಸುಮಾರು ಐದು ಜನರ ಗುಂಪಿನಲ್ಲಿ ಕುಳಿತಿದೆ, ಹಾಗೂ ದೊಡ್ಡ ಕುಟುಂಬದಂತಹ ಗದ್ದಲದ ಸ್ಥಳದಲ್ಲಿ ಕುಳಿತಿದೆ. ಮಗು ಗುಂಪಿನಲ್ಲಿರುವ ಎಲ್ಲರ ಮುಖಗಳನ್ನು ನೋಡಲಾಗುವುದಿಲ್ಲ. ನಿಮ್ಮ ಮಗು ಅವರ ಮಾತುಕತೆಯನ್ನು ಅನುಸರಿಸುತ್ತದೆಯೇ??	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗುವಿನೊಂದಿಗೆ ನೀವು ಕೋಣೆಯಲ್ಲಿ ಮಾತನಾಡುತ್ತಿದ್ದೀರಿ ಇನ್ನೂ ಅನೇಕ ಜನರು ಮಾತನಾಡುತ್ತಿದ್ದಾರೆ. ನಿಮ್ಮ ಮಗು ಏನ್ ಹೇಳ್ತಾ ಇದ್ದೀರಾ ಎಂಬುದನ್ನುಅನುಸರಿಸುತ್ತದೆಯೇ??	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗುವು ಪರಿಚಯವಿಲ್ಲದ ಸ್ಥಳದಲ್ಲಿ ಹೊರಾಂಗಣದಲ್ಲಿದೆ. ಲಾನ್ ಮೊವರ್ ಅಥವಾ ವಿದ್ಯುತ್ ಉಪಕರಣಗಳಿಂದ ನಿರಂತರ ಶಬ್ದ ಕೇಳಬಹುದು, ಆದರೆ ಶಬ್ದದ ಮೂಲ ಕಾಣಿಸುವುದಿಲ್ಲ, ನಿಮ್ಮ ಮಗು ತಕ್ಷಣವೇ ಶಬ್ದ ಎಲ್ಲಿಂದ ಬರುತ್ತಿದೆ ಎಂದು ಹೇಳಬಹುದೇ?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗು ಹಲವಾರು ಜನರೊಂದಿಗೆ ಮೇಜಿನ ಸುತ್ತಲೂ ಕುಳಿತಿದೆ. ನಿಮ್ಮ ಮಗು ಎಲ್ಲರನ್ನು ನೋಡಲು ಸಾಧ್ಯವಿಲ್ಲ. ನಿಮ್ಮ ಮಗು ಯಾವುದೇ ವ್ಯಕ್ತಿ ಮಾತನಾಡಲು ಪ್ರಾರಂಭಿಸಿದ ತಕ್ಷಣ ಎಲ್ಲಿದ್ದಾರ ಎಂದು ಹೇಳಬಹುದೇ?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗು ಹೊರಗಿದೆ. ನಾಯಿ ಬೊಗಳುವುದು, ಕಾರ್ ಹಾರ್ನ್ ಅಥವಾ ಬಾಗಿಲು ಬಡಿಯುವ ದೊಡ್ಡ ಶಬ್ದ ಸಂಭವಿಸುತ್ತದೆ. ನಿಮ್ಮ ಮಗು ಅದು ಎಲ್ಲಿದೆ ಎಂದು ತಕ್ಷಣವೇ ಹೇಳುತ್ತದೆಯೇ?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗುವು ಕುಟುಂಬದ ಸದಸ್ಯರನ್ನು ಅಥವಾ ಪರಿಚಿತ ಜನರನ್ನು ನೋಡದೆ ಪ್ರತಿಯೊಬ್ಬರ ಧ್ವನಿಯ ಮೂಲಕ ಗುರುತಿಸಬಹುದೇ?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10

ನಿಮ್ಮ ಮಗುವು ಸ್ವಲ್ಪಮಟ್ಟಿಗೆ ಹೋಲುವ ಶಬ್ದಗಳ ನಡುವಿನ ವ್ಯತ್ಯಾಸವನ್ನು ಹೇಳಬಹುದೇ? ಉದಾಹರಣೆಗೆ, ಒಂದು ಕೆಟಲ್ ಕುದಿಯುವ ವಿರುದ್ಧ ವಾಷಿಂಗ್ ಮೆಷಿನ್ಅಥವಾ ಟ್ಯಾಪ್ ರನ್ನಿಂಗ್ ವಿರುದ್ಧ ಟಾಯ್ಲೆಟ್ ಟ್ಯಾಂಕ್ ತುಂಬುವುದು?	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10
ನಿಮ್ಮ ಮಗುವು ಪರಿಚಿತವಿರುವ ವಿವಿಧ ಸಂಗೀತದ ತುಣುಕುಗಳನ್ನು ಗುರುತಿಸಬಹುದೇ? ಸೂಚನೆ: ಪದಗಳು ಅಥವಾ ಚಲನೆಗಳು ಒಂದು ಹಾಡಿಗೆ ಸಂಬಂಧಿಸಿದರೆ ಗುರುತಿಸಬಹುದು.	ಇಲ್ಲ ಸಂಪೂರ್ಣವಾಗಿ 0 1 2 3 4 5 6 7 8 9 10

Appendix II

ಪ್ರಶ್ನಾವಳಿ

ಭಾಗ 1

ಜನಸಂಖ್ಯಾ ವಿವರಗಳು

1. ಪ್ರಕರಣದ ಹೆಸರು:
2. ಪ್ರಕರಣ ಸಂಖ್ಯೆ:
3. ವಯಸ್ಸು/ಲಿಂಗ:
4. ಹುಟ್ಟಿದ ದಿನ:
5. ವಿಳಾಸ/ಸ್ಥಳ: ನಗರ/ಗ್ರಾಮೀಣ
6. ಸಾಮಾಜಿಕ ಆರ್ಥಿಕ ವರ್ಗ: ಸ್ಲ್ಯಾಬ್ I/ ಸ್ಲ್ಯಾಬ್ II/ಸ್ಲ್ಯಾಬ್ III
7. ಪೋಷಕರ ಶಿಕ್ಷಣ: ತಾಯಿ: ತಂದೆ:

ಭಾಗ 2

ಪ್ರಶ್ನೆಗಳು	ಯಾವಾಗಲೂ ಇಲ್ಲ 0%	ವಿರಳವಾಗಿ 1-25%	ಕೆಲವೊಮ್ಮೆ 26-50%	ಆಗಾಗ್ಗೆ 51-75%	ಯಾವಾಗಲೂ 75-100%
ಮಗು ಎಷ್ಟು ಬಾರಿ ಶ್ರವಣ ಸಾಧನಗಳು ಮತ್ತು/ಅಥವಾ ಕಾಕ್ಲಿಯರ್ ಇಂಪ್ಲಾಂಟ್ ಧರಿಸುತ್ತದೆ?					
ಮಗು ಎಷ್ಟು ಬಾರಿ ದೊಡ್ಡ ಶಬ್ದಗಳಿಂದ ದೂರು ನೀಡುತ್ತದೆ .					
ನೀವು ನಿಶಬ್ದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಮಗುವಿನ ಹೆಸರು ಕರೆದಾಗ ಮಗು ಪ್ರತಿಕ್ರಿಯಿಸುತ್ತದೆಯೇ?					
ನೀವು ಮಗುವಿಗೆ ನಿಶಬ್ದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಸೂಚನೆಗಳನ್ನು ಅಥವಾ ಸರಳವಾದ ಕೆಲಸವನ್ನು ಹೇಳಿದಾಗ ಅನುಸರಿಸುತ್ತದೆಯೇ?					

ನೀವು ಮಗುವನ್ನು ಗದ್ದಲದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಕರೆದಾಗ ಪ್ರತಿಕ್ರಿಯಿಸುತ್ತದೆಯೇ? (ಪ್ರತಿಕ್ರಿಯೆಗಳ ಉದಾಹರಣೆಗಳಲ್ಲಿ ನೋಡುವುದು, ತಿರುಗುವುದು, ಮೌಖಿಕವಾಗಿ ಉತ್ತರಿಸುವುದು ಸೇರಿವೆ)					
ನೀವು ಮಗುವಿಗೆ ಗದ್ದಲದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಸೂಚನೆಗಳನ್ನು ಅಥವಾ ಸರಳವಾದ ಕೆಲಸವನ್ನು ಹೇಳಿದಾಗ ಅನುಸರಿಸುತ್ತದೆಯೇ?					
ನೀವು ಶಾಂತವಾದ ಸ್ಥಳದಲ್ಲಿ ಮಗುವಿನ ಜೊತೆ ಓದುತ್ತಿರುವಾಗ ಎಷ್ಟು ಮಟ್ಟಿಗೆ ಮಗು ನೀವು ಏನು ಹೇಳುತ್ತಿದ್ದೀರಿ ಎಂಬುದರ ಗಮನ ಹರಿಸುತ್ತದೆ? ಅಥವಾ ನಿಮ್ಮ ಮಗು ನಿಶಬ್ದ ಸ್ಥಳದಲ್ಲಿ ಟಿವಿಯಲ್ಲಿ ಅಥವಾ ಸಿ.ಡಿ ಕಥೆಗಳು/ಹಾಡುಗಳನ್ನು ಕೇಳುವಾಗ ಎಷ್ಟು ಮಟ್ಟಿಗೆ ಏನು ಬರುತ್ತಿದೆ ಎಂದು ಗಮನ ಕೊಡುತ್ತದೆ?					
ಮಗು ಎಷ್ಟು ಬಾರಿ ನಿಶಬ್ದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಸಂಭಾಷಣೆಯಲ್ಲಿ ಭಾಗವಹಿಸುತ್ತದೆ?					
ಮಗು ಎಷ್ಟು ಬಾರಿ ಗದ್ದಲದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಸಂಭಾಷಣೆಯನ್ನು ಪ್ರಾರಂಭಿಸುತ್ತದೆ/ಭಾಗವಹಿಸುತ್ತದೆ?					
ಮಗು ಎಷ್ಟು ಬಾರಿ ಯಾರೆಂದು ನೋಡದೆ ಜನರ ಧ್ವನಿಯನ್ನು ಮಾತಾಡುವಾಗ ಗುರುತಿಸುತ್ತದೆ?					
ಮಗು ಧ್ವನಿಗಳನ್ನು ಹೊರತುಪಡಿಸಿ ಶಬ್ದಗಳಿಗೆ ಎಷ್ಟು ಬಾರಿ ಪ್ರತಿಕ್ರಿಯಿಸುತ್ತದೆ?					