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THE RELATIONSHIP BETWEEN HEARING AND ATTENTION IN HEARING IMPAIRED INDIVIDUALS WITH ADHD COMORBIDITY AND THE EFFECT OF HEARING AIDS ON THE DEVELOPMENT OF ATTENTION: A COMPILATION OF RESEARCH

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ABSTRACT: In children's physical, psychological, social, academic, and particularly language development, hearing is a crucial sense. If early and adequate care is not provided, children with hearing loss may experience retardation in the aforementioned areas. The use of cochlear implants in children with hearing loss at the earliest possible age enables the child to develop in many areas in parallel with their peers. Children with hearing impairment often also have attention deficit and hyperactivity disorder (ADHD), which is diagnosed by psychiatric examination and progresses with psychosocial and academic deficiencies. Comorbid ADHD in a hearing-impaired individual causes a significant disruption in the general development of a child. Therefore, early recognition of both hearing loss and accompanying ADHD, and necessary interventions and treatment are required. In this review, the relationship between hearing and attention functions, how attention is affected in hearing impaired people, the effects of early intervention and cochlear implant use on the child's attention functions and the course of possible attention deficit and hyperactivity disorder are summarized by compiling the literature.
Keywords: Hearing impairment, attention, language development, attention deficit and hyperactivity disorder, cochlear implant

DEHB KOMORBİDİTESİ OLAN İŞİTME ENGELLİLERDE İŞİTME VE DİKKAT İLİŞKİSİ VE İŞİTME CİHAZLARININ DİKKAT GELİŞİMİNE ETKİSİ: BİR ARAŞTIRMA DERLEMESİ

ÖZ: İşitme, çocukların fiziksel, psikolojik, sosyal, akademik ve özellikle dil gelişimlerinde belirleyici bir duyudur. İşitme kaybı olan çocuklarda, erken ve uygun müdahale yapılmadığında bahsi geçen alanlarda gerilikler olabilir. İşitme kaybı olan çocukların mümkün en erken yaşta koklear implant kullanılması, çocuğun birçok alanda yaşıtlarıyla paralel ilerlemesini sağlar. Psikososyal ve akademik alanlarda yetersizliklerle seyreden ve psikiyatrik değerlendirme ile tanı konulan Dikkat Eksikliği ve Hiperaktivite Bozukluğu, işitme engelli çocuklara sıklıkla eşlik etmektedir. İşitme engelli bir bireyde eş tanı DEHB olması, çocuğun genel gelişiminin belirgin olarak aksamasına neden olur. Bu nedenle hem işitme kaybının hem de eşlik eden DEHB'nin erken fark edilmesi, gerekli müdahalelerin ve tedavinin yapılması gerekir. Bu derlemede, işitme engeline erken müdahalenin ve koklear implant kullanımının çocuğun dikkat işlevlerine ve olası dikkat eksikliği ve hiperaktivite bozukluğunun seyrine etkisi literatür bilgilerinden derlenerek özetlenmiştir.
Anahtar Kelimeler: İşitme engeli, koklear implant, dil gelişimi, dikkat eksikliği ve hiperaktivite bozukluğu

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1. INTRODUCTION

The fact that human beings are social beings makes it easier for them to use complicated language more effectively. Communication is facilitated by effective language use. Communication is the verbal or nonverbal expression of feelings and thoughts to another person (Aksan, 1980; Owens, 1990). In order to communicate verbally, first, it is required to hear, then understand, and then be able to use the language. Although the terms "language" and "speak" are frequently used interchangeably, they are two distinct concepts (Kretschmer and Kretschmer, 1979). Language is a system with its own rules and symbols that permits communication between individuals speaking the same language with shared coding, through sharing experience and transmitting thought (Bloom and Lahey, 1978; Topbaş, 2001). Speaking is the process by which verbal language is converted into sound (Konrot, 1991). From a young age, language and speech help people build and sustain social connections as well as developing their cognitive, academic, and neurophysiological abilities (Tüfekçiolu, 2003). Priority for language and speech must be hearing, when a child's hearing is absent or inadequate, their overall development, particularly their language skills, is negatively affected. Therefore, ensuring that the child can hear by using a hearing aid or cochlear implant (CI) as soon as possible to address the hearing issue prevents the child's language abilities and cognitive development from being interrupted. The hearing supplied by the devices and the subsequent acquisition of language and speech have a positive impact on the child's capacity for concentration and maintaining attention.

According to the research, children with hearing loss are more likely to experience attention deficit and hyperactivity disorder (ADHD). ADHD is seen in 3% to 5% of the general childhood population and 6.6% of children with hearing loss (Barkley, 1998; Baş, 2008; Schum, 2004). In the treatment of ADHD, pharmacotherapy takes the first place. However, in children with hearing impairment, early recognition of hearing impairment and appropriate intervention contributes to the improvement of attention functions (Blazer and Tucci, 2019).

Neurodevelopmental disorders such as ADHD, which can accompany hearing loss, should be considered together in order to ensure the best possible cognitive, social and academic development of the child. In this review, it is aimed to discuss the effect of early intervention on hearing loss on cognitive development and accompanying ADHD in children with hearing impairment and using CI, with reference to national and international literature (Akmeşe et al., 2020; Akmeşe and Küçük, 2022; Doğan and Hasanoğlu, 2016; Ogut et al., 2020).

2. LITERATURE REVİEW

The sound that emerges as a result of the vibrations of objects turning into energy exerts a pressure to the air molecules, and this vibration spreads rapidly among the molecules and advances through the air. Thus, the sound is produced, transmitted, and heard. The human ear can detect a sound if its properties are within the range of its sensitivity (Akçamete, 2003; Tucker and Nolan, 1984). When the sound waves hit the eardrum, this vibration is transmitted to the hammer, anvil and stirrup bones in the middle ear. This movement presses the oval window in the stirrup, thereby changing the pressure of the fluid in the cochlea. The corti, the hearing organ, moves its outer and inner hair cells in response to the pressure change. The inner hair cells carry this message to the nuclei in the central auditory system and from there to the auditory cortex in the temporal lobe via the eighth cranial nerve (vestibulocochlear). Sound is consequently heard. To put it another way, hearing starts with the stimulation of neurons, and individual sounds are heard and discriminated by stimulating particular sections. According to studies, a baby inside its mother's womb may hear sounds as early as five months old (Carlson, 2013).

The term "hearing loss" refers to sensory loss that results from a damage to the sense of hearing or to the hearing nerves together with the senses (Tüfekçiolu, 2003). Despite the fact that there are numerous definitions and classification schemes, the two main categories of hearing impairment are "deafness" and "severe/profound hearing impairment". The typical hearing range is thought to be between 0 and 15 dB. Accordingly, hearing loss of more than 70 dB is regarded as deafness. Classifications are made based on the type of loss and the age at which it occurs, in addition to the degree of hearing impairment (Akçamete, 2003; Kaplan, 1996). For over 50% of children with hearing loss, the etiologic reason is unknown. It is well acknowledged that genetics play the biggest role. Other factors include infections, early birth, maternal

exposure to harmful substances while pregnant, and substance abuse (Bailey, 2007). Congenital or pre-linguistic hearing loss can negatively affect the language development of the child, causing him to differ from his peers with normal hearing in all areas of life. Early detection of the hearing loss and initiation of the child's education and training can greatly reduce the negative effects on the child's language and psychosocial development, allowing for normal receptive and expressive language development (Akmeşe, 2015).

Hearing aids are divided into two groups as sound amplifying devices and cochlear implants (CI). As a first step, sound amplifying devices are tried. Depending on the cause of the hearing loss, behind-the-ear and in-ear devices are used. Sound amplification gadgets don't require any surgical procedures. These gadgets help hearing by amplifying mechanical sound energy that enters the ear through the microphone and transmitting it as acoustic sound energy to the inner ear. Every child diagnosed with hearing loss should have a device fitted immediately. For children with hearing loss who are unable to understand speech sounds with hearing aids, CI has become increasingly popular worldwide and in Turkey during the past 25 years. CI is an electronic device that converts mechanical sound energy into electrical signals and transfers it directly to the cochlea, enabling the perception of sounds. In this system, electrodes are placed in the cochlea by surgical intervention. In this way, the damaged part of the outer ear and inner ear is passed and a direct message is sent to the auditory nerve. The speech processing is externally located (microphone and transmitter). The external connecting cable and the round coil are connected to each other with the help of a magnet system placed under the skin on the temporal bone. The speech processor detects external sounds, converts them to electronic information, signals reach the electrodes in the cochlea, and from there, information goes to the auditory nerve and cortex, where it turns into meaningful words (Carlson, 2013; Robbins and Robbins, 2004; Timur, 2016). CI deactivates the hair cells in the inner ear and directly stimulates the surviving neurons in the auditory nerve, thus providing the sense of hearing (Wilson et al., 2001). The ability to distinguish spoken words and speech production in children with CI vary greatly from child to child. These variables include the child's age, the number of electrodes implanted, the education received, the family's cooperation and active involvement in education, the etiology of hearing loss, whether there is an additional barrier to the hearing loss, and language and communication skills (Can et al., 2016; Chute and Nevins, 2003; McKinley and Warren, 2000; Turan, 2000). However, the age at the time of CI insertion is made is reported as the most important factor affecting language development performance (Fryauf-Bertschy et al., 1997; Girgin, 2006; O'Donoghue et al., 2000). The child must regularly wear hearing aids and be exposed to appropriate auditory stimulation whenever he is awake. The child won't be able to develop language and speech that are adequate for the developmental stage if they are not exposed to auditory stimuli (Aykut and Çınar, 2018).

Although attention has been defined differently for a long time (Moray, 1970; Pashler and Taylor, 1998; Posner and Boies, 1971), it is typically defined as "concentrating mental effort on sensory or mental events" (Solso et al., 2005). Donald Broadbent (2013), who pioneered the studies on attention, stated that attention emerges as a result of the fact that people who are exposed to too many stimuli can focus on some of these stimuli. When we look at the neurobiology of attention, it has been observed that substances that provide communication between neurons, especially dopamine and noradrenaline, are associated with attention functions (Waxman, 2020). Executive functions are used as an umbrella term covering many different mental processes such as keeping information in mind, concentrating, reasoning, developing strategies, bringing together information/stimuli, planning, and problem solving. Executive functions are responsible for maintaining, directing and controlling attention, as well as maintaining automatic behaviors (Blair, 2016, 2017; Miller and Cohen, 2001). Studies have indicated that the areas in the brain associated with executive function processes are in the prefrontal cortex, and there are studies showing that the temporal lobe may also be effective in these functions (Clark et al., 2008; Rolls and Grabenhorst, 2008). Studies have shown that different pathologies, especially Attention Deficit and Hyperactivity Disorder, may occur as a result of impairments in executive functions (Alvarez and Emory, 2006; Castellanos and Tannock, 2002; Lezak et al., 2004). ADHD, which is characterized by impaired executive functions, is one of the most common neurodevelopmental disorders in children (Vantalon, 2014). According to the diagnostic and statistical manual of mental disorders (DSM-5), ADHD is defined as difficulty in focusing, hyperactivity and impulsive behaviors (Edition, 2013).

It has been observed that children with hearing loss have difficulty in focusing and maintaining their attention, and may have difficulty in concentrating due to their efforts to seek and make sense of the visual

stimuli and signs around them (Marschark and Wauters, 2008; Morgan and Vernon, 1994; Ashman and Elkins, 2002; Richards et al., 1990; Tarnowski et al., 1986; Westwood, 1997). It has been reported that approximately 40-50% of children with hearing loss are accompanied by a developmental disability such as mental retardation, autism, attention deficit and hyperactivity disorder, cerebral palsy, visual impairment and developmental delay (Mesallam et al., 2019). The most common among them is ADHD (Dopheide and Pliszka, 2009; Stevenson et al., 2015; Theunissen et al., 2014).

It has been reported that school success develops positively in children with normal intelligence and who use devices at an early age and benefit from it. As a result of a study comparing the gap-filling skills of students with CI and students with normal hearing, it was reported that the types of errors in filling in the gaps of students with CI and students with hearing were similar. According to research, students who wore devices at an early age, received intensive education and underwent CI at an early age show similarity regarding number of mistakes with their hearing peers in filling the gaps (Akçamete, 2003; Karasu et al., 2013). Another study found that, when children who got CI before 13 months of age were compared with children who got CI between 16-23 months, it was observed that there was a significant difference in vocabulary learning skills and that CI at an early age facilitated vocabulary learning (Houston et al., 2012; Houston and Miyamoto, 2010). Cruz et al. (2012), on the other hand, reported that CI would be beneficial for their language development in their study they carried out with hearing-impaired children with developmental disabilities. All this information shows that in children who benefit from early diagnosis, education and CI application, language development and academic development can catch up with their peers (Girgin, 2006).

Due to the rough acoustic information provided by CI, CI users have significant difficulty in recognizing speech, especially in noisy environments. Therefore, CI users rely more on visual cues to increase and facilitate recognition than individuals with normal hearing. According to psychophysical research, the lip-reading thresholds for the two groups are often comparable, as would be predicted, while the listening thresholds for people with normal hearing are consistently better. The role of attention in this multisensory speech is one of the important research areas. Studies show that CI users benefit from multi-sensory integration in situations requiring split attention where visual and auditory stimuli are separated, and therefore listening is more difficult for them than individuals with normal hearing. In other words, while individuals with normal hearing can focus heavily on auditory and visual cues, CI users need to divide attentional resources among modalities to improve multisensory speech recognition. This situation may lead to deterioration in speech recognition (Baş, 2008; Bozkurt, 2019; Surowiecki et al., 2002). In some studies, it has been found that children using CI have significant deficits in areas such as memory, short-term memory capacity and concentration compared to their peers who do not have hearing loss (Kronenberger et al., 2013). In addition to these data, many studies show that CI contributes positively to the developmental areas, memory and attention skills of the child. In the study conducted by Dikderi (2020), it was aimed to evaluate the effects of the age of onset of using CI in children with bilateral or unilateral CI and the effects of binaural hearing on cognitive skills such as language development, verbal working memory and selective attention, and compare these cognitive skills in children with CI. In this study, a total of 58 participants were involved between the ages of 6 and 8 years 11 months; 21 children with unilateral early implants, 18 children with unilateral late implants, and 19 children with bilateral implants. The results of the study reveal that there is a significant difference between individuals with unilateral early and unilateral late implants in terms of language, working memory and attention skills. As the age of CI insertion decreases, it has been observed that speech perception performance, central auditory processing, language, memory and auditory attention skills approach their peers with normal hearing (Boons et al., 2012; Markman et al., 2011; Pisoni et al., 2016; Sharma et al., 2002; Tuz, 2014). As a result of the study by Akbarzadeh, Lee and Tan (2020), in which the effect of sound level on auditory attention was examined, it was observed that the auditory attention of individuals with normal hearing was better than those individuals with CI, but increasing the volume level improved selective auditory attention. In this study, it was concluded that loudness control is necessary for the ease of participation in the conversation in CI users. In a study with conducted with 20 children using CIs and 20 children with normal hearing, De Giacomo et al. (2013) found that while children using CIs were more negatively affected in emotional and social interactions than children who did not use CIs, there was no difference in attention, hyperactivity, or communication. This study demonstrates how the use of CI can have a positive effect on attention. In the

study conducted by Jeddi, Doosti, and Hashemi (2020), children using CI with ADHD diagnosis and children using CI without any diagnosis were compared in terms of auditory, receptive and expressive language, speech and cognition skills. The findings reveal that children without ADHD and who use CI are developmentally more successful in auditory, receptive and expressive language, speech and cognition skills than children with CI who are diagnosed with ADHD. In children using CIs, the additional diagnosis of ADHD may result in a delay in language and speech development compared to children without ADHD (Akçakaya, 2015).

3. RESULT AND SUGGESTIONS

In order to prevent delays in the cognitive, psychosocial development, school life, family, and social interactions of children with hearing loss, early detection of hearing loss and proper intervention are crucial (Mitchell and Quittner, 1996; O'Connell and Casale, 2004). Children with hearing loss are more likely to have ADHD. It is widely recognized in the studies conducted on the quality of life of children with ADHD and their families, that emotional, cognitive and academic impairments have a negative effect on their quality of life (Barkley et al., 1985; Dey et al., 2019; Lee et al., 2016). For this reason, concentrating just on finding a solution for hearing for children with hearing loss is insufficient. It is very important to evaluate the attention functions together, to examine possible ADHD and to treat it, if necessary, in terms of the child's general development so that the child can catch up with his peers. Perhaps the most important factor here is to ensure that the hearing-impaired child can hear with a hearing aid at the earliest possible age. Following that, it's critical to assess each hearing-impaired child's executive functions and provide any necessary treatment if he has any problems. Further research is required on the detailed evaluation and follow-up of attention and learning skills in children with hearing aids, the effect of CI use on cognitive skills, and the development of executive functions in these children.

Ethics Statement: All ethical rules were followed in the preparation of this review.

Author Contributions: All authors contributed to the literature review and summarization. Merve Gülçin Tutlu followed the process, combined and compiled the sections. The idea of the subject belongs to Mehmet Ertan Başgül. Canahmet Boz provided support in English translation. Contribution rates are 35% for the 1st author, 25% for the second author, 20% for the third author and 15% for the fourth author.

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