# How Hard Can It Be To Listen? Fatigue in School-Age Children with Hearing Loss

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**Teachers and parents have long believed that children with hearing loss (CHL) are at increased risk for fatigue. CHL may be physically and mentally "worn out" as a result of focusing so intently on a teacher's speech and on conversations with other students. Moreover, increased listening effort, stress, and subsequent fatigue could compromise a child's ability to learn in a noisy classroom environment. Only recently, however, have we begun to see empirical studies supporting the notion that some CHL experience more fatigue than children with normal hearing (CNH).**

**The purpose of this paper is to enhance the awareness of fatigue in school-age CHL among educational audiologists. To this end, an overview on the topic of fatigue in CHL is provided including its importance, definitions, consequences, and preliminary findings from a large-scale study at Vanderbilt University. In addition, we discuss the role of the educational audiologist in the identification and management of CHL who are fatigued. Research on fatigue in CHL is lacking and the importance of, and need for, scientific exploration in this area is emphasized.**

**Key Words:**
fatigue
hearing loss
children
salivary cortisol
listening effort
fatigue measures

## Introduction

Fatigue is common in our society and experienced by virtually everyone. Not only is fatigue frequently observed among community-based populations, it is one of the more common complaints noted by persons with disabilities and chronic health illnesses. Hence, the subject of fatigue has received increased attention in the healthcare arena over the past several decades. Fatigue is reported to accompany numerous chronic health conditions, such as multiple sclerosis, cancer, obesity, diabetes, heart disease, systemic lupus erythematosus, and related autoimmune disorders (Daniel, Brumley, & Schwartz, 2013; Eddy & Cruz, 2007; Freal, Kraft & Coryell, 1984; MacAllister, et al., 2009; Varni, Burwinkle, Katz, Meeske, & Dickinson, 2002; Varni, Burwinkle, & Szer, 2004; Varni, Limbers, Bryant & Wilson, 2010; Whitehead, 2009). The effects of fatigue in adults and children are multiple and significant. In adults, the consequences of fatigue are known to impact adversely on work performance and life quality (Hetu, Riverin, Lalande, Getty & St-Cyr, 1988; Kramer, Kapteyn, & Houtgast, 2006). Fatigue in children with chronic illnesses is associated with reduced academic performance, school absences, limited daily activities, increased stress, and negative effects on quality of life (Beebe, 2011; Bess & Hornsby, 2014; McCabe, 2009; Ravid, Afek, Suraiya, Shahar, & Pillar 2009; Stoff, Bacon, & White, 1989). Thus, fatigue appears to be a common problem with significant consequences for individuals with a wide range of chronic health conditions. Despite its ubiquitous nature and potential impact on quality of life, our understanding of fatigue in persons with hearing loss is limited.

The purpose of this publication is to enhance the awareness of fatigue in school-age children with hearing loss (CHL) and to offer an overview of the topic. To this end, we review relevant definitions, concepts, and consequences of fatigue; preliminary findings from fatigue-related research; and the role of educational audiologists when serving fatigued CHL.

### The Concept of Fatigue

Fatigue has been described as “one of the most puzzling enigmas in all of psychology” (Matthews, Desmond, Neubauer, & Hancock, 2012). It is a construct that has been the subject of research for more than 100 years; yet, in many ways, it still remains a mystery. Although we all know how fatigue feels because we have experienced it, we cannot reach a consensus on its definition. Fatigue has been viewed as both a symptom and a disease (Deluca, 2005). As a symptom, it appears in the presence of many medical conditions. As a disease, unexplained fatigue occurs among individuals in the absence of a medical diagnosis. Indeed, our understanding of the basic mechanisms of fatigue is limited. Suffice it to say, fatigue is a complicated and multifaceted construct that is poorly understood by the public and scientists alike.

The definition of fatigue varies somewhat depending on who is describing the construct (e.g., layperson versus psychologist) and the specific area of fatigue in which an individual is interested (e.g., fatigue in patients with cancer versus muscle-fatigue in professional athletes). Thus, it is not surprising that no consensus on the definition of fatigue has been reached among the scientific communities. It is understood, however, that fatigue occurs in both the physical and mental/cognitive domains, and is often described as a mood state—a feeling of tiredness, sleepiness, exhaustion, or lack of energy. Although CHL may also experience physical fatigue, such as body tiredness from prolonged physical exercise, our primary focus is the cognitive fatigue that may result from listening to a teacher’s speech and other children in a noisy environment. Because cognitive fatigue is thought to bring about a general feeling of weariness or tiredness, we often hear teachers of CHL share comments, such as “my students are exhausted at the end of the school day.”

Another factor relevant in the discussion of fatigue is the concept of stress. Anecdotal reports and qualitative research suggest a linkage between demanding speech processing in daily living and a resultant increase in stress and fatigue experienced by persons with hearing loss (Hornsby, Werfel, Camarata & Bess, 2014; Ross, 2012). Like fatigue, stress is difficult to define even though it is a constant factor in our modern lives. Stress can be defined as an internal or external threat that influences an individual’s state of being (Middlebrooks & Audage, 2008). Some stress is normal and is essential for survival. For example, stress helps children develop the skills they need to cope with new and potentially threatening situations. Too much stress, however, can serve as a disruption to performance, which can lead to feelings of fatigue, lack of energy, irritability, demoralization, and hostility (Hockey, 2013; McEwen, 1998). Moreover, prolonged stress is capable of affecting one’s health by causing emotional distress and can lead to a variety of physiological changes (e.g., increased heart rate, elevated blood pressure, variations in stress hormone levels; McEwen, 1998; Middlebrooks & Audage, 2008; Sapolsky, 2004). In sum, fatigue can be viewed as a direct outcome to the presence of sustained stress activity. Recently, fatigue was described as “a stress-related disorder” (Kocalevent, Hinz, Brahler & Klapp, 2011). Hence, the constructs of fatigue and stress are highly associated, and these two entities often overlap (Kocalevent et al., 2011; Magbout-Juratli, Janisse, Schwartz & Arnetz, 2010; Olsen, 2007).

### Hearing Loss, Mental Effort, and Fatigue

The exertion of mental energy needed to attend to and understand a spoken message has been described as listening effort (Bess & Hornsby, 2014; Hicks & Tharpe, 2002; Hornsby, 2013; McGarrigle, et al., 2014). The magnitude of listening effort required in this situation may depend on many factors, including the students’ degrees of hearing loss, their cognitive and attentive capabilities, and the classroom acoustics. Importantly, to offset deficits in audibility due to hearing loss, children and adults with hearing loss must increase their mental effort, more so than persons without hearing loss, when attempting to detect, process, and respond to auditory stimuli (Hicks & Tharpe, 2002; McCoy, et al., 2005). Lewis and colleagues (2014) recently reported that, while CHL showed similar abilities to recognize speech in a noisy classroom environment, they performed poorer than children with normal hearing (CNH) on more challenging tasks of comprehension that required additional cognitive effort. These results suggest that CHL expend greater amounts of listening effort during typical classroom listening and that this increased effort may result in difficulties in higher-order learning tasks.

It is generally assumed that increased listening effort is associated with subjective reports of fatigue in adults with hearing loss in everyday settings (Edwards, 2007; Zekveld, Kramer, & Festen, 2011). Likewise, teachers and parents have long speculated that CHL may also be at increased risk for fatigue. Research related to fatigue in CHL, however, is sparse and consists mainly of pilot studies and anecdotal reports (Bess, Dodd-Murphy, & Parker, 1998; Noon, 2013; Ross, 2012). Only recently have we begun to see scientific evidence in support of these anecdotal beliefs (Bess & Hornsby, 2014; Gustafson, Delong, Werfel & Bess, 2013; Hicks & Tharpe, 2002; Hornsby, 2013; Hornsby et al., 2014; Rentmeester, Shuster, Hornsby & Bess, 2013). One can intuitively reason that CHL could be mentally and physically exhausted as a result of listening intently to the teacher and other children in a noisy classroom environment throughout the school day. The additional attention, concentration, and effort needed to overcome a communication-based deficit while listening and processing speech in noise results in increased reports of stress and fatigue compared to CNH (Bess & Hornsby, 2014; Bess & Hornsby, in press). Moreover, the increased listening effort, stress, and fatigue during school could jeopardize the ability to learn in a noisy classroom, thus increasing the risk for problems in school. Individuals with additional handicapping conditions, as commonly found in CHL, are especially vulnerable to fatigue and its negative consequences (Hardy & Studenski, 2010). Mark Ross, a well-recognized pediatric audiologist with a significant bilateral hearing loss, described his own fatigue in the following way, “I can attest to the fatigue caused by prolonged intensive listening in noise through hearing aids. It seemed like the listening efforts were diverting some of my cognitive resources; so much effort was being devoted to getting the signal, that I sometimes missed part of the message” (Ross, 2012). Such a comment offers anecdotal evidence for an adult with hearing loss experiencing fatigue after sustained difficult listening in a noisy, reverberant environment. No doubt, CHL will also experience fatigue in similar listening situations, even if they are wearing hearing aids.

**A Conceptual Model Linking Hearing Loss to Fatigue and School Performance**

A simplified conceptual model linking CHL to listening effort, stress, fatigue, and school performance is shown in Figure 1. This model posits that CHL experience breakdowns in communication, especially in the area of speech understanding, when listening in noisy, reverberant classroom conditions. The more noise and reverberation in the classroom, the more difficult speech understanding becomes. These difficulties are thought to occur even if CHL are wearing hearing aids, implants, and/or other assistive devices.

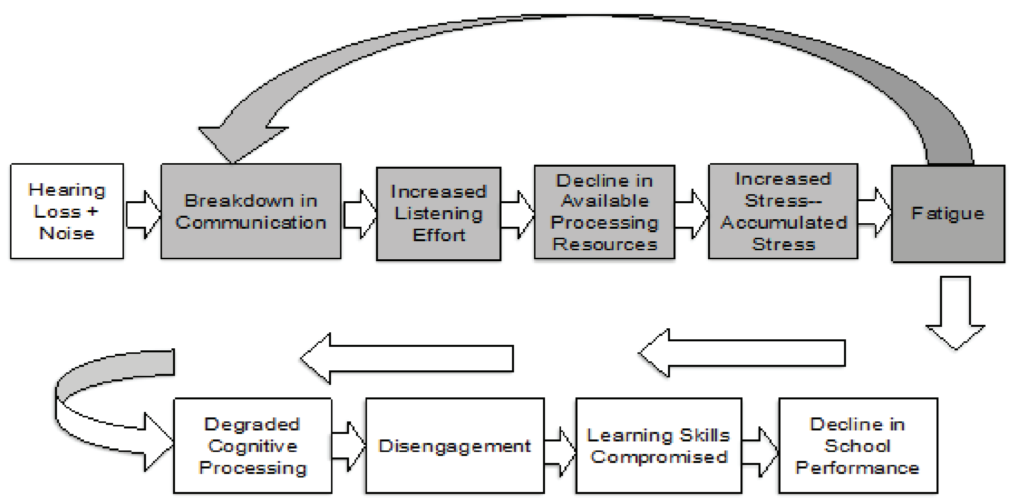


**Figure 1.** Conceptual model linking hearing loss to fatigue and school performance. The shaded areas represent events that occur repeatedly throughout the school day (From Bess & Hornsby, in press).

This breakdown in speech understanding brings about increased listening effort, which in turn results in a reduction in available processing capacity that might otherwise be used for other purposes, such as memory recall. Even if the speech signal is made sufficiently loud and clear to afford correct identification, CHL need to invest more cognitive resources to detect, process, and understand speech than listeners with normal hearing—a concept sometimes referred to as the effortfulness hypothesis (McCoy et al., 2005; Rabbitt, 1966, 1968, 1991). In this conceptual model, the process depicted in the shaded areas of Figure 1 occurs repeatedly throughout the day, resulting in increased listening effort, accumulated stress, and fatigue. Eventually, a point is reached in which the listening effort, accumulated stress, and fatigue are no longer manageable and the child's cognitive processing begins to falter. The continued effort to "keep up" may be replaced by a strategy of low engagement or even disengagement (Hockey, 2013). In other words, the child gives up and the combination of effort, stress, hearing-related fatigue, degraded cognitive processing, and/or disengagement impacts negatively on the behavioral skills essential for learning in school.

We thus find that fatigue is a problematic, somewhat elusive, concept that is frequently observed in both adults and children. Moreover, children with chronic health conditions, including CHL, appear to be at increased risk for fatigue; and such fatigue could impact negatively on learning and academic performance. Interestingly, some of the early research on fatigue in the 1890s took place in the school setting. This research focused on determining the ideal length of a school day—with the goal of ending daily instruction before children developed fatigue-related declines in school performance (Ackerman, 2011). More than 100 years later, we find ourselves revisiting the issues of fatigue in schools, especially as it relates to CHL. What follows is a synopsis of preliminary findings from recent fatigue-related research in CHL and the role of educational audiologists in the management of CHL who are fatigued.

**Review of Studies on Fatigue in CHL**

Much of the information reviewed herein is preliminary data from a large-scale study on listening effort and fatigue in school-age CHL at the Vanderbilt Bill Wilkerson Center. As noted earlier, parents and teachers often report that CHL are at increased risk for fatigue. How do they arrive at such a conclusion? Primarily through anecdotal observation and listening to children describe fatigue in their own words. CHL may express concerns about their tiredness, sleepiness, drowsiness or malaise; and, they may not want to participate in physical activities.

Such subjective reporting of one's mood or feelings represents the primary means to assess fatigue in children and adults. Self-report questionnaires have been developed for both children and adults to assess cognitive and physical fatigue. Comprehensive reviews of subjective measures of fatigue can be found elsewhere and are beyond the scope of this paper (McGarrigle, et al., 2014; Christodoulou, 2007). Briefly, these tests are simple, cost effective, easy to administer, and contain high face validity. Well-standardized fatigue scales typically contain multiple domains that represent such dimensions as physical fatigue, sleep/rest fatigue, and cognitive fatigue. Subjective fatigue scales can be used to identify the presence and severity of fatigue; they can also be used to assess the effectiveness of intervention strategies on fatigue. Many fatigue scales are available for the adult population; however, few such scales exist for children—and, no scales have been developed for fatigue related to hearing loss. Because CHL are at increased risk for fatigue, the need for a fatigue scale designed specifically for this population is paramount. An example of a short, five-item, self-report fatigue scale designed for children is shown in Appendix A. This experimental questionnaire was developed for research purposes to assess hearing-related fatigue following sustained and demanding listening tasks.

One of the early studies to report on fatigue in CHL using subjective self-report measures was that of Bess and co-workers (1998). They assessed functional health status in a group of school-age children with minimal hearing loss and CNH using the COOP Adolescent Chart Method (Nelson, et al., 1987). The COOP is a reliable and valid office-based screening tool for functional health. The tool is based on a five-point scale, with five representing the greatest dysfunction. Bess and coworkers found that children with minimal hearing loss reported significantly more dysfunction than CNH on two subtests of the COOP related to fatigue - stress and energy. In contrast, Hicks and Tharpe (2002) used the same instrument, but did not find any differences between CHL and an age-matched group of CNH. Methodological differences, such as sample size, hearing aid use, and type of hearing loss (unilateral versus bilateral hearing loss), may have accounted for the discrepancies between the two data sets. Another possibility is that the COOP, which is only a screening tool, lacked the required sensitivity for detecting fatigue.

To date, only one study has examined fatigue in school-age CHL using a standardized and validated self-report measure, the PedsQL Multidimensional Fatigue Scale (PedsQL MFS; (Varni et al., 2002; Varni, Burwinkle, & Szer, 2004). The PedsQL MFS consists of three different fatigue domains: cognitive fatigue, sleep/rest fatigue, and general fatigue. A total fatigue score can also be obtained from the three subscales. Hornsby and coworkers (2014) reported that school-age CHL experienced significantly more fatigue across all fatigue domains than an age-matched group of CNH (see Figure 2). Surprisingly, CHL reported more fatigue on the PedsQL MFS than children with other health conditions, such as cancer, rheumatoid arthritis, diabetes, and obesity (Berrin, et al., 2007; Marcus, et al. 2009; Varni et al., 2002; Varni et al., 2010). It is noteworthy that the PedsQL MFS was not developed for CHL; hence, the scale does not include items specific to fatigue associated with hearing related difficulties. A fatigue scale derived from the experiences of CHL and their parents might produce even larger differences between CHL and CNH. Also important to note in work reported by Hornsby and colleagues (2014) is the wide range of fatigue scores reported by CHL. Some children reported scores within the range of scores reported by CNH, while others reported substantially more fatigue. Clearly, additional work is needed to improve our understanding of factors that mediate and modulate fatigue in CHL.

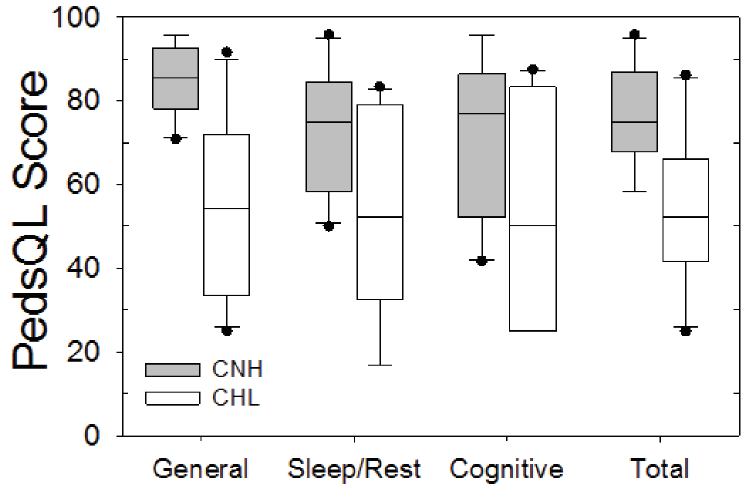


**Figure 2.** PedsQL-MFS ratings from CHL (white boxes) and CNH (grey boxes). Lower values reflect more fatigue. Middle lines represent median fatigue ratings, boxes show 25th to 75th percentile range, whiskers indicate the 10th and 90th percentiles, filled circles represent individual data points above and below the 90th and 10th percentiles (Adapted from Hornsby, B.W.Y., Werfel, K., Camarata, S. & Bess, F.H. (2014). Subjective fatigue in children with hearing loss: Some preliminary findings. *American Journal of Audiology*).

Another method for measuring fatigue is to examine whether cognitively demanding and sustained listening tasks leads to increases in fatigue over time. Rentmeester and colleagues (2013) reported preliminary findings from our Vanderbilt study using this approach. Their preliminary data demonstrated that subjective fatigue increases in CHL and CNH during prolonged and demanding listening tasks (2.5 to 3 hours) that are similar to a classroom environment. CHL show this increase in subjective fatigue whether or not they are using hearing aids during the tasks. To monitor subjective fatigue, the five-item questionnaire discussed above was used (see Appendix A). The fatigue scale was administered six times over the course of the demanding listening tasks. A mean fatigue score was calculated by averaging responses across the five items. Figure 3 (modified from Rentmeester et al., 2013) illustrates mean fatigue scale ratings for CNH and CHL with and without the use of personal hearing aids during the prolonged listening tasks. Average subjective fatigue scales could range from zero, indicating no fatigue, to four, indicating considerable fatigue. The ratings are based on the average rating across the five fatigue questions and are plotted as a function of measurement time point.

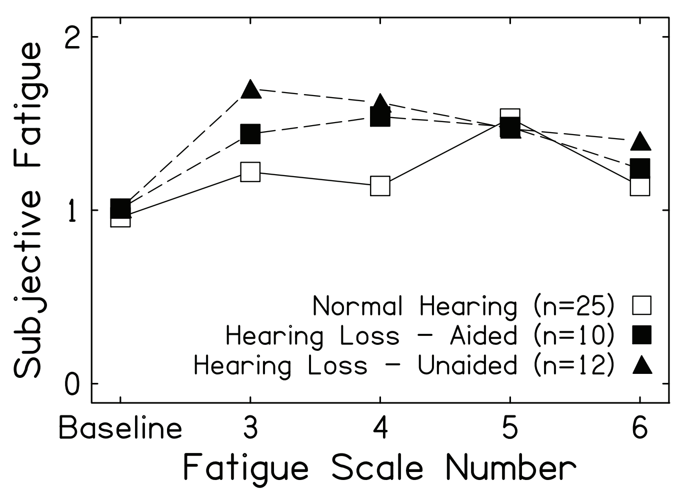


**Figure 3.** Fatigue scale ratings of CHL (with and without hearing aids) and CNH during a series of demanding and prolonged listening tasks as a function of measurement time point. Modified from Rentmeester et al. (2013).

A baseline score was established by averaging ratings of the first and second administration of the fatigue scale, given that the children were not required to complete demanding auditory tasks that involved sustained listening effort until shortly after the second rating scale. At the third administration of the fatigue scale, however, there were clear differences in reported fatigue scores between CNH, CHL wearing hearing aids, and CHL who were not wearing hearing aids. The unaided CHL showed the greatest amount of fatigue at this point, followed by the aided CHL. The CNH reported the least amount of fatigue following the prolonged listening tasks. Interestingly, during the final two fatigue scale administrations near the end of the tasks, the differences between CHL and CNH lessened. Such a finding is consistent with the idea that both CHL and CNH reached a tipping point. That is, the effort required to perform the sustained tasks was likely replaced by a strategy of low engagement (Bess & Hornsby, in press; Hockey, 2013) .

An important limitation of subjective fatigue scales is that they do not provide us with information about the potential mechanisms underlying the fatigue experience. In recent years, several different physiological measures have been proposed to assess cognitive fatigue—some of these measures include event-related potentials (ERP; Murata, Uetake, & Takasawa, 2005), skin conductance (Segerstrom & Nes, 2007), functional magnetic resonance imaging (fMRI; Lim, et al., 2010), and salivary cortisol levels (Hicks & Tharpe, 2002). In the Vanderbilt study on listening effort and fatigue, we have used the biochemical marker cortisol to measure stress and expenditure of energy throughout the school day. Here, we report information on salivary cortisol as a potential physiological index of fatigue. Those readers interested in other physiological methods for measuring fatigue are referred to other resources (Deluca, 2005; Matthews et al., 2012; McGarrigle et al., 2014).

Estimates of cortisol levels in the body can be obtained a variety of ways including samples of hair, urine, blood and saliva. While multiple methods are available, obtaining cortisol estimates via saliva samples offers several advantages (Inder, Dimeskit & Russel, 2012; Turpeinen & Hämäläinen, 2013). Salivary cortisol measures are simple, noninvasive, easy to administer, and can be collected in a naturalistic environment such as a classroom or playground. Hence, this physiologic technique appears to be especially useful for children—even infants and toddlers are able to provide salivary cortisol samples suitable for laboratory analysis (Gunnar, 1992). To collect a saliva sample, cotton pads are rolled in the child's mouth for about 2-3 minutes. Once the pad is saturated, it is coded, refrigerated, and sent to a laboratory for analysis.

The ability to function when fatigued is, in itself, stressful and requires additional energy resources compared to a non-fatigued state. Responding and adapting to stressful events is one of the important roles of the hypothalamic-pituitary-adrenal (HPA) system. When a stressful event occurs the hypothalamus is activated, setting off a chain of physiologic events that leads to the production of cortisol. Under normal conditions, stress leads to an increase in cortisol, which causes the body to prepare for handling the stressful event. Typically, cortisol increases during the night and levels rise sharply soon after awakening – this increase in cortisol level upon wakening is termed the cortisol awakening response (CAR; Fries, Dettenborn, & Kirschbaum, 2009; Wilhelm, Born, Kudielka, Schlotz & 2007). Following the CAR is a steady decline of cortisol levels throughout the day. Alterations in this typical daily profile may occur when individuals experience unusual stress or fatigue (Deluca, 2005; Kumari, et al., 2009; Schlotz, Hellhammer, Schulz & Stone, 2004; Whitehead, Perkins-Porras, Strike, Magid & Steptoe, 2007).

For instance, lower-than-normal cortisol levels have been observed in individuals with chronic fatigue syndrome (Fries, Hesse, Hellhammer, & Hellhammer, 2005; Jerjes, Cleare, Wessely, Wood & Taylor, 2005; Roberts, et al., 2010), a disabling stress-related disease with a primary fatigue symptomatology (Crofford & Demitrack, 1996; Parker, Wessely, & Cleare, 2001). CHL who are stressed and/or fatigued may also show alterations (e.g., lower or higher cortisol levels) in the activity of the HPA system. To explore relationships between hearing loss, stress, and fatigue, Hicks & Tharpe (2002) collected salivary cortisol samples twice a day in ten CHL and ten CNH. The first sample was collected near the beginning of the school day (approximately 9:00 a.m.) and the second sample was taken at the end of the school day (approximately 2:00 p.m.). No significant differences in cortisol values were observed between the two groups at either time point. Several factors may contribute to this finding including the sampling protocol (the small number of samples taken in the day), the small number of children studied, and the potential influence of hearing aids worn by the children. Of course, it is also possible that no differences in salivary cortisol levels exist between these two populations.

The Vanderbilt study on listening effort and fatigue is seeking to further characterize and understand variations of cortisol levels in CHL when compared to those of CNH. Like individuals with chronic fatigue syndrome, CHL who are stressed and/or fatigued might exhibit blunted cortisol values; however, it is also possible that CHL might exhibit elevated levels of salivary cortisol. Preliminary work by Gustafson and coworkers (2013) found that some CHL exhibited higher CARs than CNH, especially at the time point of awakening. Examples of cortisol profiles obtained in a group of CNH and four CHL are shown in Figure 4.

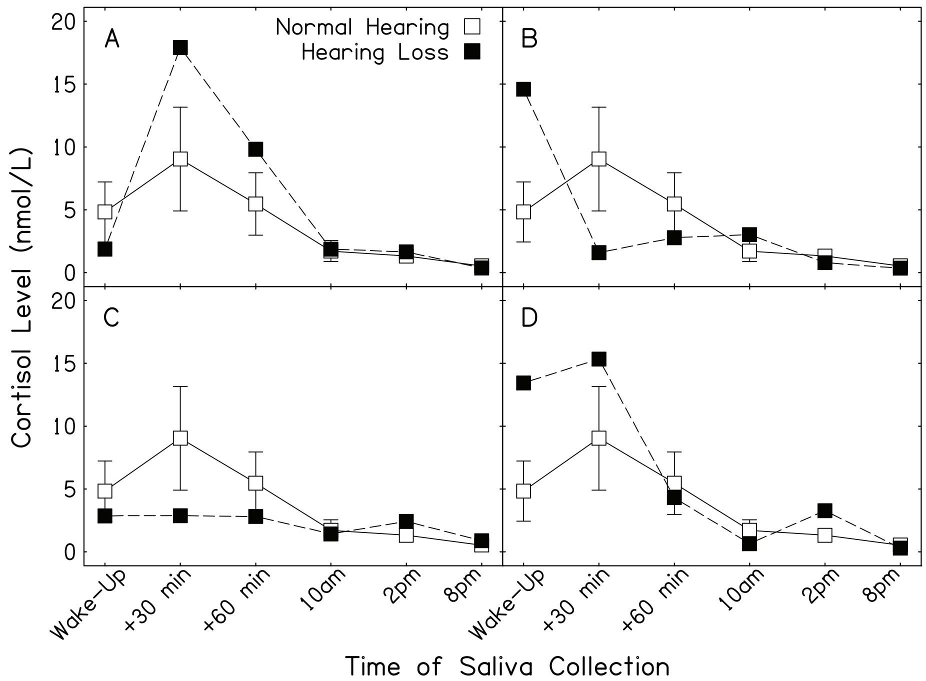


**Figure 4.** Mean cortisol levels (±1 standard deviation) obtained at all times of collection for CNH (open squares) and case examples of CHL (solid squares). Elevated cortisol values at early morning (awakening and 30 min post awakening) are associated with chronic stress, perceived stress, anxiety, and worrying about the burdens of the upcoming day. Blunted values (flat responses) are associated with an inability to mobilize sufficient energy to cope with the challenges of daily life activities.

It can be seen that the CNH (shown by the white squares) exhibit a normal diurnal pattern, with elevations in cortisol levels within the first hour of awakening followed by a decline in cortisol levels throughout the day. The CARs of the four CHL, however, show marked deviations from the profile of CNH. The CHL in panels A, B, and D show variations in elevated CARs, which have been associated with chronic social stress, perceived stress, and worrying about the burdens of the upcoming day (Wust, Federenko, Hellhammer & Kirschbaum, 2000; Wust, et al., 2000). Thus, diurnal cortisol patterns in at least some CHL demonstrate abnormalities consistent with the presence of increased stress levels. Sustained heightened stress levels may put CHL at increased risk for fatigue (Fries et al., 2005; Hellhammer & Wade, 1993). Alternatively, the hearing impaired child depicted in panel C shows blunted cortisol levels similar to those seen by individuals with chronic fatigue syndrome. Blunted values (flat responses) are associated with an inability to mobilize sufficient energy to cope with the challenges of daily life activities (Kudielka, Hellhammer, & Wust, 2009).

Although salivary cortisol appears to have potential for assessing stress and fatigue in school-age children limitations to this approach do exist. Some of the challenges to salivary cortisol measurement include 1) the costs and time required for laboratory analysis; 2) the need to control for multiple factors that can influence cortisol responses (e.g., food or drink, atypical class classroom excitement or stress, medications that might alter HPA axis; 3) the potential for contaminated data if sampling protocols are not strictly followed; and, 4) the need for multiple daily measurements to improve reliability. Despite these limitations, saliva measures provide a reliable estimate of cortisol levels and appear particularly useful for monitoring natural diurnal cortisol patterns in children (Gunnar, 1992; Kirschbaum & Hellhammer, 1999).

**Identification and Management of Fatigue: The Role of Educational Audiology**

CHL appear to be at increased risk for cognitive fatigue. Consequently, educational audiologists will be expected to play an increasingly important role in the identification and management of CHL who exhibit increased listening effort, stress, and subsequent fatigue in school. Perhaps the simplest way to identify children at risk for fatigue is to be alert for symptoms commonly associated with fatigue in children such as tiredness, sleepiness in the morning, inattentiveness, mood changes, and changes in play activity (e.g. decrease in stamina; Bess & Hornsby, 2014; Bess & Hornsby, in press; Hornsby et al., 2014; Rentmeester, Shuster, Key, Hornsby & Bess, 2014). Although empirical evidence is limited, it is believed that certain sub groups of CHL are at greater risk for fatigue and warrant closer surveillance in school. These groups include children with additional handicapping conditions (Bess &

Hornsby, in press; Hardy & Studenski, 2010), children who do not utilize hearing assistive technology (see Figure 3), children who are identified late, and children with moderate to severe degrees of hearing loss. Children suspected of fatigue should be given a subjective fatigue evaluation to confirm the presence of fatigue and to better understand the intensity and characteristics of the symptoms (Hornsby, et al., 2014; Varni, Burwinkle, & Szer, 2004; Hockenberry, et al., 2003; Varni, et al., 2002). Evidence-based intervention strategies are not yet available for CHL identified with fatigue. Until such evidence emerges, a few obvious and sensible steps are suggested—they focus on amplification, classroom strategies, and education of service providers.

**Amplification.** Problems relating to listening effort and fatigue might be minimized through the use of hearing technology such as advanced signal processing and/or the use of hearing assistance technology systems (Hornsby, 2013). Therefore, the identification of those CHL who are at increased risk for fatigue may be useful in the hearing aid selection and/or fitting process. Hearing aid prescription in children typically involves the selection and fitting of hearing aids that will afford the best opportunity for improved speech understanding through increased access to the auditory signal. Advanced signal processing programs such as digital noise reduction and directional microphones are widely available in even entry-level hearing aids, and aim to lessen the negative impacts of background noise on speech understanding and overall listening comfort. While directional microphones have been shown to improve children's speech understanding in noise (Crukley & Scollie, 2014), this technology is not generally appropriate for younger CHL, as the successful use of directional microphones requires the child to appropriately orient their head toward the speaker of interest and away from the prominent noise source (Ching, et al., 2009; Ricketts, Galster, & Tharpe, 2007; Ricketts & Picou, 2013).

Other hearing aid signal processing strategies that are readily activated in children's hearing aids (e.g., digital noise reduction, frequency lowering) have only a minimal effect on speech understanding (McCreery, Venediktov, Coleman & Leech, 2012; Pittman, 2011). However, research has shown that the use of digital noise reduction technology might reduce listening effort in adults (Sarampalis, Kalluri, Edwards & Hafter, 2009) and children (Gustafson, McCreery, Hoover, Kopun & Stelmachowicz, 2014). Thus, in addition to optimizing speech understanding and comfort, an alternative approach to fitting children with hearing aids might include procedures to determine whether a given hearing aid technology minimizes listening effort and hearing-related fatigue under adverse listening conditions.

Finally, although recent evidence suggests that properly fitted hearing aids, in both adults and children, can make a difference by reducing listening effort and cognitive fatigue (Hornsby, 2013; Rentmeester et al., 2014), not all CHL wear their hearing aids and/or use FM systems in the classroom. Gustafson and coworkers (2013) reported that younger CHL (7-10 years) are more likely to be consistent users of hearing aids and FM systems in the school setting than older CHL (11-12 years), irrespective of the severity of hearing loss. Table 1 shows these data in addition to data collected since 2013. For each day observed, we recorded if the child was utilizing hearing assistive technology in the classroom (personal hearing aids, personal FM, or sound field FM) at 10:00 am and 2:00 pm. Shaded boxes indicate device use during the time of observation. Note that device use is reduced in older children and that this pattern is not driven by degree of hearing loss. These observations of device-use in school-age CHL expand on recent data reported for younger CHL (<7 years of age) using data logging technology which show that daily hearing aid use time increases with more severe degrees of hearing loss and for older children (Jones, 2013; Munoz, Preston, & Hicken, 2014; Walker, et al., 2013). Together, this may suggest that CHL show increases in daily device use until early school-age when they are faced with the challenge of listening in noisy classroom environments and increased social awareness at which time device use becomes less consistent (Hornsby, 2004; Jones, 2013). The importance of CHL wearing properly fitted amplification devices throughout the school day cannot be overemphasized; however, further research is needed to better understand the causes and implications of inconsistent device use during various stages of childhood.

**Table 1 .** Observed hearing assistive technology use on two typical school days in children with mild- to- moderate hearing loss.

| Child-Specific Information | | | Day 1 | | | | Day 2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | AM | | PM | | AM | | PM | |
| Study Participant | Age (years) | bPTA (dB HL) | HA | FM | HA | FM | HA | FM | HA | FM |
| HL1 | 6.7 | 18 | | | | | | | | |
| HL2 | 6.9 | 30 | ■ | ■ | ■ | ■ | | | ■ | ■ |
| HL3 | 7.4 | 30 | ■ | ■ | ■ | ■ | ■ | | ■ | |
| HL4 | 7.8 | 53 | ■ | | ■ | | ■ | | ■ | |
| HL5 | 7.8 | 42 | ■ | ■ | ■ | | ■ | ■ | ■ | ■ |
| HL6 | 8.2 | 47 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| HL7 | 9.2 | 10 | | ■ | | ■ | | | | |
| HL8 | 9.3 | 63 | ■ | ■ | ■ | ■ | | | | |
| HL9 | 9.4 | 52 | ■ | | ■ | | ■ | | ■ | |
| HL10 | 10.1 | 47 | ■ | ■ | ■ | | ■ | | ■ | ■ |
| HL11 | 10.2 | 37 | ■ | | ■ | | ■ | | | |
| HL12 | 10.3 | 47 | | | | | | | | |
| HL13 | 10.4 | 35 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| HL14 | 10.5 | 42 | ■ | | ■ | | ■ | | ■ | |
| HL15 | 10.6 | 35 | ■ | | ■ | | ■ | | ■ | |
| HL16 | 10.7 | 41 | ■ | | ■ | | ■ | | ■ | |
| HL17 | 11.3 | 30 | | | | | | | | |
| HL18 | 11.5 | 42 | ■ | ■ | ■ | | ■ | ■ | ■ | |
| HL19 | 11.7 | 28 | | | | | | | | |
| HL20 | 11.8 | 23 | | | | | | | | |
| HL21 | 12.0 | 10 | | ■ | | | ■ | | ■ | |
| HL22 | 12.6 | 30 | | | | | | | | |
| HL23 | 12.7 | 33 | ■ | | | | ■ | | | |
| HL24 | 12.8 | 28 | | | | ■ | | | | |
| HL25 | 12.8 | 10 | | | | | | | | |
| HL26 | 12.9 | 37 | | | | | | | | |

Note. Shaded boxes indicate the use of hearing technology at the time of observation. This table does not distinguish between children using personal or sound field FM systems. HA: hearing aid(s); FM: personal or sound field frequency modulation system; bPTA: better-ear pure-tone average for 0.5, 1, and 2 kHz.

**Classroom strategies.** It is not unreasonable to expect that CHL who are fatigued will be presented with unique listening and learning challenges, especially when attention and concentration are needed to deal with the demands of verbal comprehension in a noisy classroom. Classroom strategies might include recommending preferential seating to minimize environmental distracters, slowing the pace of a lesson to allow for additional processing time, limiting the duration of lessons when the primary content is auditory, and providing small group instruction as often as possible. It is important to note that preferential seating assignments benefiting CHL might not always be at the front of the classroom. Sources of classroom noise (e.g., fish tank pumps, windows, hallway doors) and the location of the primary speaker should be considered when selecting seating assignments for CHL. Of course, the use of a personal FM system partially reduces the difficulties of combating the variable noise sources and speaker locations in a typical classroom. Other strategies might include utilizing breaks as a means to transition between activities, arranging the day so that the most demanding listening tasks occur earlier when children have more resources to cope with these tasks, and scheduling those tasks that require fewer listening resources to occur later in the day. Parents and other family members may also benefit from this knowledge by structuring time away from the classroom to allow for periods of relaxation and rest. Clearly, additional research is needed to systematically examine any potential benefits of these strategies and to provide an evidence-based protocol for minimizing effects of fatigue in CHL.

**Education.** Most general education teachers and health care professionals are unaware that CHL can be at increased risk for fatigue and that such fatigue imposes negative psychosocial and educational consequences. In fact, general education teachers feel ill-prepared to deal with children who have chronic health conditions (Clay, Cortina, Harper, Cocco & Drotar, 2004). Therefore, it would seem beneficial to initiate educational programs designed to target teachers, physicians, and family members regarding fatigue in CHL. Such awareness programs might include information about fatigue and its consequences, symptoms associated with fatigue, and guidelines for identification and management. To be sure, educational programs should emphasize the importance of CHL wearing their prescribed amplification devices in the school setting. Enhanced awareness and knowledge of all professionals who serve CHL should ultimately result in improved services for this population.

Educational audiologists also can play a role in educating the child and family. Recall from the salivary cortisol data (Figure 4) that several CHL may exhibit elevated cortisol levels potentially indicating perceived stress and worrying about the burdens of the upcoming day. Because we understand that stress is an antecedent to fatigue, appropriate health care providers might assist children who are stressed, and their parents, by helping them to learn coping skills, to relax, to avoid high fat diets, and to recognize the beneficial effects of exercise (McEwen, 1998; Ratey, 2008).

## Closing Remarks

Cognitive fatigue has long been the subject of interest to health professionals, scientists, and the public at large. Interestingly, the concept of fatigue in school-age children was one of the very first areas of scientific inquiry, dating back to the 1890s. In the 1920s and '30s, researchers explored fatigue in school-age children with varying levels of intelligence, probed the effects of fatigue on children in the classroom, and examined fatigue associated with such factors as school transportation and general health (Ackerman, 2011; Kefauver, 1928). However, research interest in fatigue waned following the 1930s, and it was not until the 1980s that we began to witness a resurgence of research in this area. The increased interest in fatigue came about as a consequence of the emergence of new models and theories of cognitive processing, attention, and motivation, as well as the development of new behavioral and physiological tools for assessment and inquiry (Ackerman, 2011). Even though fatigue in school-age children appeared to be one of the first areas of inquiry, contemporary research on fatigue in children has lagged behind fatigue research in the adult population. Today, research on fatigue in CHL is almost nonexistent.

The purpose of this overview has been to heighten the awareness and importance of fatigue in school-age CHL among educational audiologists. The topic is complex, but important and deserving of our attention; especially for audiologist's working in the schools. Fatigue is prevalent in CHL and the negative consequences of fatigue are multiple and significant. Indeed, fatigue can place some children at increased risk for learning difficulties in school. The need for additional research is crucial, as we lack information on true prevalence, consequences, mechanisms, identification, and intervention strategies. The creation of a fatigue scale designed specifically for CHL is an important first step in the development of intervention strategies.

The final message then, is that fatigue may be a contributing factor to the longstanding psycho-educational problems associated with hearing loss in children. A consideration of the construct of fatigue is increasingly important in the identification and management of CHL.


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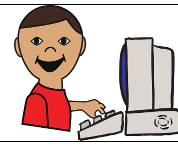
**Appendix A.** A self-report scale for assessing a child's current (right now) level of fatigue.

**How do you feel RIGHT NOW?**

| | | |
|---|---|---|
|  | 1. I feel tired. |  |

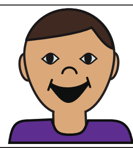
Please circle one for each statement.

| Not at All | A little | Some | Quite a bit | A lot |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |

| | | |
|---|---|---|
|  | 2. It is easy for me to do these things. |  |

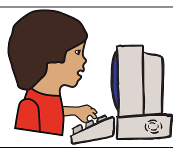
Please circle one for each statement.

| Not at All | A little | Some | Quite a bit | A lot |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |

| | | |
|---|---|---|
|  | 3. My head hurts. |  |

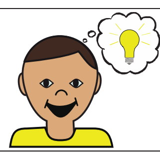
Please circle one for each statement.

| Not at All | A little | Some | Quite a bit | A lot |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |

| | | |
|---|---|---|
|  | 4. It's hard for me to pay attention. |  |

Please circle one for each statement.

| Not at All | A little | Some | Quite a bit | A lot |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |

| | | |
|---|---|---|
|  | 5. I have trouble thinking. |  |

Please circle one for each statement.

| Not at All | A little | Some | Quite a bit | A lot |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |