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## Commentary: Listening Can Be Exhausting—Fatigue in Children and Adults With Hearing Loss

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### Abstract

Anecdotal reports of fatigue after sustained speech-processing demands are common among adults with hearing loss; however, systematic research examining hearing loss–related fatigue is limited, particularly with regard to fatigue among children with hearing loss (CHL). Many audiologists, educators, and parents have long suspected that CHL experience stress and fatigue as a result of the difficult listening demands they encounter throughout the day at school. Recent research in this area provides support for these intuitive suggestions. In this article, the authors provide a framework for understanding the construct of fatigue and its relation to hearing loss, particularly in children. Although empirical evidence is limited, preliminary data from recent studies suggest that some CHL experience significant fatigue—and such fatigue has the potential to compromise a child’s performance in the classroom. In this commentary, the authors discuss several aspects of fatigue including its importance, definitions, prevalence, consequences, and potential linkage to increased listening effort in persons with hearing loss. The authors also provide a brief synopsis of subjective and objective methods to quantify listening effort and fatigue. Finally, the authors suggest a common-sense approach for identification of fatigue in CHL; and, the authors briefly comment on the use of amplification as a management strategy for reducing hearing-related fatigue.

### Keywords

Amplification; Cognition; Fatigue; Hearing aids; Hearing loss; Listening effort; Pediatric; Quality of life; Stress

### INTRODUCTION

“I went to a great conference today. It was riveting and I was hooked on pretty much every word. And then I got home and collapsed on the sofa. I’m not just tired, I’m shattered. I’ve had to turn my ears off to rest in silence and my eyes are burning... When I was younger, I was a little embarrassed to be so tired all the time.

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I would force myself to go out and be busy...all I wanted to do was crawl under the sofa and nap...”

(Noon 2013).

These comments, proffered by a profoundly deaf adult, provide compelling insight into the fatigue a person with hearing loss may experience after sustained speech-processing demands in a noisy environment. Mark Ross, a well-known pediatric audiologist with a significant bilateral hearing loss made this judicious comment about his own fatigue “...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). Is it really that difficult for hearing-impaired persons to listen? Anecdotal reports such as these highlight the importance of fatigue resulting from sustained listening demands for working adults with hearing loss. Fatigue not only compromises work performance in adults with hearing loss it can negatively affect quality of life (Kramer et al. 2006; Nachtegaal et al. 2009).

While anecdotal reports and limited empirical research provide some insight into the problem of fatigue in adults with hearing loss, we know far less about fatigue in children with hearing loss (CHL). Many audiologists, educators, and parents have long suspected that CHL experience stress and fatigue as a result of the difficult listening demands encountered throughout a day in school. This belief is supported by anecdotal reports and pilot studies (Ross 1992; Bess et al. 1998; Hicks & Tharpe 2002), but systematic research on hearing-related fatigue in CHL is essentially nonexistent.

Although empirical evidence is lacking, one could easily speculate that toward the end of a school day, CHL may be physically and mentally spent as a result of focusing so intently on a teacher’s speech, as well as the conversations of other children. The excessive noise levels known to occur in classrooms exacerbate the listening demands experienced by CHL (Crandell & Smaldino 2000; Walinder et al. 2007). Hence, in addition to the inherent disadvantage of reduced auditory information resulting from hearing loss, sustained difficult listening throughout the day in noisy classrooms could be expected to increase stress and fatigue.

To be sure, the possibility that CHL are at increased risk for fatigue has important implications. Increases in listening effort, stress, and fatigue in CHL could jeopardize their ability to learn in a noisy classroom thus increasing the risk for problems in school. A large body of evidence clearly shows that fatigue impairs human performance in both adults and school-age children (Dinges et al. 1997; Hockenberry-Eaton et al. 1999; Gaba & Howard 2002; Kramer et al. 2006; Ravid et al. 2009a, 2009b). Interviews and survey data reveal that adults with hearing loss experience more stress and fatigue in the workplace than normal hearing workers—and such stress and fatigue negatively impacts work performance (Morata et al. 2005; Kramer et al. 2006). Fatigue has been studied in children with other chronic health conditions, such as cancer, sleep deprivation, cerebral palsy, rheumatic diseases, and chronic fatigue syndrome (CFS). Results uniformly show that fatigue is associated with reduced academic performance, increased school absences, an inability to engage in usual

daily activities, sleep disturbances, changes in social relationships, and a negative change in life quality (Stoff et al. 1989; Garralda & Rangel 2002; Berrin et al. 2007; McCabe 2009; Ravid et al. 2009a, 2009b; Beebe 2011).

If indeed, listening effort and fatigue are contributing factors to poor learning skills and subsequent educational difficulties in CHL, improved understanding of these foundational issues would serve to assist educators (general and special educators) and clinicians (audiologists, psychologists, speech-language pathologists) in the development of more effective intervention strategies for this population. Clearly, a need exists for the audiology community to develop a better understanding of listening effort, stress, hearing-related fatigue, and how they impact academic performance among school-age CHL.

Here we provide a framework for understanding the construct of fatigue in pediatric hearing loss. Although empirical evidence is limited, preliminary data from recent studies suggest that some CHL experience significant fatigue—and such fatigue has the potential to compromise a child’s performance in the classroom. In this commentary, we discuss several aspects of fatigue including its importance, definitions, prevalence, consequences, and potential linkage to increased listening effort in persons with hearing loss. We also provide a brief synopsis of subjective and objective methods to quantify listening effort and fatigue. Finally, we suggest a common-sense approach for identification of fatigue in CHL; and, we briefly comment on the use of amplification as a management strategy for reducing hearing-related fatigue.

## WHAT IS FATIGUE?

Fatigue is a multifaceted construct that occurs in the physical and mental/cognitive domains. Definitions of fatigue vary, in part, based on the discipline of the person describing the construct (e.g., layperson, physiologist, cognitive psychologist, physician) and the focus of their study (e.g., muscle fatigue in athletes, cognitive fatigue in multiple sclerosis). In fact, a universally accepted or standardized definition of fatigue does not exist. Physical fatigue refers to a reduced ability or desire to perform some physical task (Chalder et al. 1993; Dimeo et al. 1997) and has attracted the most attention from scientists and clinicians but cognitive fatigue is a common experience. Relatively less research has been directed toward cognitive fatigue, especially as it relates to hearing loss. Mental/cognitive fatigue may be defined subjectively as a mood—a feeling of tiredness, exhaustion or lack of energy due to cognitive or emotional, as opposed to physical, demands. In some cases, the subjective experience of fatigue may be accompanied by a decrease in physical or cognitive processing abilities. Thus, cognitive fatigue can also be described as a state of decreased optimal performance due to sustained cognitive demands (cf. Ackerman 2011). Cognitive fatigue is characterized by difficulties in concentration, increased distractibility, feelings of anxiety, reduced attentiveness, alertness, and decreases in mental energy or efficiency (Lieberman 2007; Boksem & Tops 2008).

Fatigue is a common public health problem in the United States. In the general population, fatigued adults in the workplace are less productive and more prone to accidents (Ricci et al. 2007). Prevalence rates vary depending on how fatigue is defined and the characteristics of

the group assessed (e.g., age, gender, ethnicity, and health status [chronic health conditions versus healthy populations]). For a community-based population, it is estimated that fatigue affects 18 to 38% of adults (Wessely et al. 1998); in another community-based survey, approximately 4% of children and adolescents (5 to 17 years) reported fatigue (Jordan et al. 2000; Kocalevent et al. 2011). Once puberty is reached, however, the prevalence rate among young people rises markedly. Internationally, community-based surveys suggest that school-age children report experiencing fatigue or tiredness at “worrying rates” (McCabe 2009). Fatigue is more common in females and in lower socio-economic groups (Wessely et al. 1998). In populations defined by chronic health conditions, the frequency and severity of fatigue among adults and children is more common than that experienced by community-based populations (e.g., pediatric cancer: >50% [Bottomley et al. 1995]; type 1 diabetes: 40% [Goedendorp et al. 2013]; multiple sclerosis: 78% [Freal et al. 1984]; systemic lupus erythematosus >80% [Hastings et al. 1986]).

Individuals who are fatigued usually experience stress. Stress is defined as the body’s reaction to a change that requires a physical, mental, or emotional adjustment or response. Stress is part of our everyday lives—some stress is good for us because it enables us to focus and concentrate on the task at hand. Too much stress (chronic or repeated stress), however, can act as a source of threat or disruption to performance which in turn leads to feelings of fatigue, a lack of energy, irritability, demoralization, and hostility (McEwen 1998; Hockey 2013). Hence, fatigue can be viewed as a direct outcome to the presence of sustained stress activity. Recently, Kocalevent et al. (2011) described fatigue as “a stress-related disorder.” We thus find that the concepts of fatigue and stress are highly associated; and, these two entities often overlap (Olson 2007; Magbout-Juratli et al. 2010; Kocalevent et al. 2011).

## **LISTENING EFFORT: MEASUREMENT AND RELATIONSHIP TO FATIGUE**

Listening effort may be described as the allocation of attentional and cognitive resources toward auditory tasks, such as detecting, decoding, processing, and responding to speech. In a more practical sense, listening effort can be thought of as a specific type of mental effort—that effort, needed to attend to, and understand, spoken messages or other auditory signals (Hicks & Tharpe 2002; Picou et al. 2013; McGarrigle et al. 2014). There is no “gold standard” for measuring the mental effort applied to a task (auditory or otherwise). However, test paradigms are generally categorized as subjective (or self-report), behavioral (task performance based), or physiologic in nature. A variety of measurement options are available within each category and the specific paradigm used will depend on the goals of the research. A brief description of some common approaches used to assess listening effort (and mental effort in general) is provided later in this article (see Gosselin and Gagne 2010 or McGarrigle et al. 2014 for more detailed discussion).

Subjective methods provide a quick, easy way to assess an individual’s perception of mental effort and have high face validity. A common approach for assessing mental effort, particularly in laboratory investigations, is the use of visual analogue scales. These scales may have descriptive (e.g., no effort/maximum possible effort) and/or numeric (e.g., 0 to 100) anchors (Hart & Staveland 1988; Zijlstra 1993; Rudner et al. 2012; van Esch et al. 2013). Respondents rate the effort applied on a given task or situation by marking along the

scale. Such scales are commonly used in laboratory experiments to assess the mental effort required/utilized in a given experimental condition. Alternatively, the scale could be designed to have respondents rate the mental effort required in typical everyday situations as opposed to a specific laboratory condition (e.g., Gatehouse & Noble 2004).

In contrast with the direct estimate of perceived mental effort provided by subjective ratings, the mental effort applied during a task can be indirectly estimated via behavioral measures. For example, dual-task paradigms have been used extensively in recent years to assess the effects of hearing loss, hearing aids and signal processing algorithms on listening effort (Sarampalis et al. 2009; Hornsby 2013; Picou et al. 2013; Desjardins & Doherty 2014; Neher et al. 2014; Picou & Ricketts, 2014; Wu et al. 2014). Dual-task paradigms consist of a primary and secondary task, performed simultaneously. In relation to hearing loss and speech processing the primary task is typically an auditory, or auditory-visual, speech recognition task. Secondary tasks vary—examples include visual reaction time (RT) measures, tactile pattern recognition, and recall of auditory or visual stimuli (Downs 1982; Hallgren et al. 2005; McCoy et al. 2005; Gosselin and Gagne 2011).

The utility of dual-tasks for assessing listening effort is based on an assumption that the cognitive resources required for understanding speech are limited (e.g., Kahneman 1973; Baddeley 1986). To complete a dual-task these limited resources must be shared between the primary (speech) and secondary tasks. If more cognitive resources (listening effort) are applied to the primary task, as might be expected in people with hearing loss listening to speech, the assumption is that there will be fewer resources available for completing the secondary task—leading to poorer secondary task performance. For example, Downs (1982) used a dual-task paradigm to examine the effects of hearing aid use on listening effort. The primary task was word recognition, tested unaided and aided. The secondary task was a visual RT measure—pressing a button whenever a light flashed. Results showed word recognition and visual RTs improved when listening with hearing aids. The improvement in visual RTs was taken as evidence of reduced listening effort when wearing hearing aids.

Behavioral methods of assessing effort like dual-task paradigms also have shortcomings (McGarrigle et al. 2014). This approach is time consuming, often complicated, expensive, and must typically be carried out in a laboratory setting. It is important to note that, drawing firm conclusions based on the outcomes of dual-task paradigms can be difficult. One issue is the underlying assumption that cognitive resources are allocated to optimize performance on the primary task and remaining resources are utilized completing the secondary task. This assumption is difficult to confirm and likely not accurate in all cases especially with children. Choi et al. (2008) found that during a dual-task, which combined speech recognition and memory recall, young children gave priority to the speech task rather than the memory task regardless of which task was assigned as the primary task.

Several investigators have suggested vocal/verbal response times can provide an estimate of the mental effort required during a speech processing task particularly when recognition in a given condition is high (Gatehouse & Gordon 1990; Mackersie et al. 1999; Houben et al. 2013; Gustafson et al. 2014). In difficult listening situations (e.g., poor signal-to-noise ratios [SNRs]) participants take longer to process and repeat back the speech they hear (Hecker et

al. 1966; Mackersie et al. 1999). However, even in conditions where speech recognition is similar, response times may differ—potentially indicating differences in mental effort between conditions (Pratt 1981; Gatehouse & Gordon 1990; Houben et al. 2013).

Compared with dual-task paradigms, this approach has the advantage of not requiring participants to consciously allocate cognitive resources to different tasks. Utilizing verbal response time as an indication of mental effort, however, also has limitations. It is important to note that the relationship between changes in mental effort and response times may vary with condition. For example, it is assumed that in more challenging conditions participants must apply more mental effort, which would result in slower verbal response times. It is also possible that the mental effort applied on a task may increase as task difficulty increases potentially resulting in similar, or faster, response times in more challenging conditions.

Physiologic methods provide a third option for assessing mental effort during cognitive tasks, such as speech processing. Not surprisingly, physiologic changes often accompany subjective and behavioral indications of increased listening effort. Thus physiologic measures can provide insight into the underlying mechanisms responsible for variations in mental effort between conditions or groups. Physiologic measures have several advantages over subjective and behavioral measures of effort. They do not require overt behavioral responses—as in dual-task paradigms and are able to be recorded continuously, unlike subjective measures. The continuous recording offers some opportunity to detect rapid changes in mental effort in real-time (Kramer 1991).

Depending on the task and its demands, physiologic changes may reflect variations in central or autonomic nervous system activity. A variety of physiologic responses have been used as markers of mental effort, including brain wave activity (assessed via electroencephalography, evoked response potentials, magnetoencephalography), brain metabolism and blood flow (assessed via fMRI and positron emission tomography), cardiac activity (assessed via heart rate and heart rate variability), ocular activity (assessed via eye blinks, eye scanning and pupil diameter), skin conductance, and hormone levels (e.g., adrenaline, noradrenaline, and cortisol) among others. There is a large literature in this area and a detailed discussion of these methods is beyond the scope of this commentary. For a general review of physiologic methods for assessing mental workload, of which mental effort is a component, see Kramer (1991) or de Waard (1996). For a more focused overview of physiologic methods used in recent studies specifically to assess listening effort see McGarrigle et al (2014).

It is well known that, across a wide range of listening conditions, adults and CHL exert greater listening effort while processing speech than listeners with normal hearing (Downs 1982; Hicks & Tharpe 2002; McCoy et al. 2005; Zekveld et al. 2011; Hornsby 2013; Desjardins & Doherty 2014). This increased effort, and the resultant reduction in cognitive resources available for other tasks, is required for persons with hearing loss to overcome their auditory deficits and optimize speech understanding. Despite potential benefits in terms of speech comprehension, research suggests that sustained and effortful listening may also have negative consequences for persons with hearing loss.

An obvious example is the potential negative effect on school-based learning in CHL. If substantial cognitive resources must be allocated to the process of detecting, decoding, and processing speech, then fewer resources may be available to aid in the learning process. Recent work showing that CHL have more difficulty learning novel words and greater difficulty multi-tasking than children without hearing loss supports this hypothesis (Pittman 2011a, 2011b). In addition to potential learning difficulties in CHL, it is generally assumed that increased listening effort is associated with subjective reports of fatigue in persons with hearing loss in everyday settings (e.g., Edwards 2007; Zekveld et al. 2011). Anecdotal reports from persons with hearing loss suggest a linkage between sustained listening demands in everyday settings and feelings of stress and fatigue. These subjective reports are consistent with qualitative research suggesting persons with hearing loss may cope with auditory processing difficulties by increasing listening effort; which in turn can lead to increases in stress, tension, and fatigue—negatively impacting quality of life (Hetu et al. 1988; Kramer et al. 2006; Nachtegaal et al. 2009). Although the link between increased listening effort in persons with hearing loss and fatigue is intuitive, there is limited systematic, empirical work examining this issue (Hornsby 2013). Thus, the relationship between hearing loss, listening effort, and fatigue in everyday settings remains unclear.

## FATIGUE MEASURES AND OUTCOMES

Similar to the assessment of mental effort, there is no “gold standard” for measuring fatigue. Likewise, existing methods for assessing fatigue can be categorized as subjective, behavioral, or physiologic in nature. Again, a variety of options are available and the specific paradigm used depends on the goals of the research. A brief description of some common measures and approaches is provided later in this article.

### Subjective Measures for Assessing Fatigue

Regardless of the cause, fatigue is largely a subjective experience and thus commonly measured using self-report instruments. Subjective measures are simple, easy to administer, readily available, and cost effective. They can be used to assess the nature and extent of fatigue as well as to monitor fatigue during and after intervention. Some scales are designed for healthy asymptomatic community-based populations; others include items that are weighted for fatigue experiences unique to chronic health conditions; and others include subscales that target specific information related to severity, duration, and distress. The scales may be multidimensional (e.g., physical, emotional, and cognitive), unidimensional (e.g., sleep/rest), or a separate module within a larger health-related life quality instrument. Many scales assess the feelings of fatigue and the perceived effect of fatigue on life quality (for reviews see Dittner et al. 2004; Hjollund et al. 2007; Whitehead 2009).

Although numerous fatigue scales exist for the adult population, there are very few, well-standardized instruments for children and adolescents (Hockenberry et al. 2003). Most existing scales for children focus on chronic illnesses—to our knowledge, no fatigue scale has been developed specifically for CHL. Examples of well-designed standardized fatigue scales for children and adolescents include the Childhood Fatigue Scale (Hockenberry et al.

2003), the Fatigue Scale-Adolescent (Hinds et al. 2007), and the PedsQL Multidimensional Fatigue Scale (PedsQL MFS) (Varni et al. 2002).

The PedsQL is a comprehensive and well-designed scale that has been validated for use with children between the ages of 5 to 18 years (Varni et al. 2002; Varni et al. 2004). The PedsQL MFS is comprised three subscales, each containing six items: (1) General Fatigue (e.g., “I feel tired”); (2) Sleep/Rest Fatigue (e.g., “I rest a lot”); and (3) Cognitive Fatigue (e.g., “It is hard for me to think quickly”). A Total (composite) Fatigue score is also calculated from the subscales. The children are asked how much of a problem each item has been over the past month. Test items are reverse-scored and linearly transformed to a 0 to 100 scale so that *higher scores indicate less fatigue*. Preliminary data for school-age CHL and children with normal hearing (CNH) using the PedsQL are shown in Figure 1. Note that CHL reported greater fatigue (lower scores) than the age-matched CNH across all dimensions. Surprisingly, CHL report more fatigue as measured on the PedsQL than children suffering from such chronic illnesses as cancer, rheumatoid arthritis, diabetes, and obesity (Varni et al. 2002, 2004, 2009, 2010).

It is important to note that subjective measures alone do not provide a complete picture of the fatigue experience. That is, subjective measures do not give insight into the underlying variables responsible for the fatigue ratings nor do they inform us as to the physiologic mechanisms of hearing-related fatigue. Accordingly, more objective (i.e., physiologic and behavioral) measures have been used to complement subjective ratings. Subjective ratings of fatigue are often not, or only weakly, correlated with objective measures suggesting they may be assessing different aspects of the fatigue experience (DeLuca 2005).

### **Physiologic Measures for Assessing Fatigue**

A wide variety of techniques have been used to measure the physiological manifestations of cognitive fatigue, including event-related potentials (ERP) (Murata et al. 2005), skin conductance (Segerstrom & Nes 2007), functional magnetic resonance imaging (fMRI; Lim et al. 2010), and salivary cortisol levels (Hicks & Tharpe 2002). A complete description of these methods in relation to measurement of fatigue is, again, beyond the scope of this commentary. Salivary cortisol is the only physiologic metric, to date, that has been used to examine fatigue in persons with hearing loss and is thus the focus in the next section.

Measuring cortisol levels is a useful approach given its sensitivity to stress, energy expenditure and associated fatigue. Salivary cortisol sampling is simple, quick, noninvasive, and can be collected in a naturalistic setting such as the home, classroom or playground. Cortisol is a hormone secreted by the adrenal gland. It is a part of the body’s response to stress and is regulated by the hypothalamic–pituitary–adrenal (HPA) axis; and cortisol is considered a valid indicator of this reactivity (Hennessey & Levine 1979; Herman & Cullinan 1997). When a stressful event occurs, the hypothalamus is activated producing a chain of events that eventually results in the release of cortisol. Cortisol is a glucocorticoid (steroids that reduce inflammation throughout the body) that increases the sugars available in the blood stream resulting in a sense of energy—energy resources that are required to respond to a stress experience. In normal situations, HPA axis activity follows a daily or circadian rhythm (Pruessner et al. 1997) rising quickly in early morning (referred to as the

cortisol awakening response [CAR]) and decreasing steadily throughout the remainder of the day (see Fig. 2). In a stressed or fatigued state, abnormalities in this normal pattern may be observed (Schlotz et al. 2004; DeLuca 2005; Whitehead et al. 2007; Fries et al. 2009; Kumari et al. 2009).

CHL who are stressed and/or fatigued may also show alterations (e.g., lower or higher cortisol levels) in the normal activity of the HPA system. Lower than normal cortisol levels (hypocortisolism) have been observed in individuals with chronic fatigue syndrome (CFS; Roberts et al. 2004; Fries et al. 2005; Jerjes et al. 2005)—a disabling stress-related disease with a primary fatigue symptomatology of 6 months or more in duration (Demitrack et al. 1991; Parker et al. 2001). Reduced cortisol production seen in CFS is thought to occur after a prolonged period of hyperactivity of the HPA axis due to ongoing stress (Fries et al. 2005).

In a similar vein, CHL who are stressed and/or fatigued may also exhibit blunted cortisol values similar to that seen in CFS. To test this thesis, Hicks and Tharpe (2002) collected cortisol samples twice a day in 10 CHL and 10 CNH. The first sample was collected at the beginning of the school day (9:00 A.M.) and the second sample was taken at the end of the school day (around 2:00 P.M.). Hicks and Tharpe (2002) reported no significant differences in cortisol values between the two groups at either time point. Possible reasons for not finding significant differences include, the sampling protocol (cortisol was sampled at only two times points in the day, thus the CAR could not be reliably assessed), small sample size, and the potential influence of hearing aids worn by most of the children during the school day. Also, there is the possibility that no true differences actually exist.

Alternatively, CHL who are stressed and/or fatigued might exhibit elevated, rather than blunted, cortisol values. Preliminary work by Gustafson et al. (2013) found that some CHL exhibited higher CAR's than CNH especially at the time point of awakening. Examples of cortisol profiles obtained in a group of CNH and two CHL are shown in Figure 2. It is seen that the CNH exhibit a normal circadian pattern. The CAR of one child (hearing loss 1), however, shows marked deviations from the early morning profile of CNH—elevated CARs are associated with chronic social stress, perceived stress, and worrying about the burdens of the upcoming day (Wust et al. 2000a, 2000b). It thus appears that this child needs to mobilize much more energy than the average child with normal hearing in early morning—before school—just to prepare for the new day. Such early energy requirements might well put CHL at increased risk for fatigue. In contrast, the second child with hearing loss (hearing loss 2) exhibits a flattened cortisol pattern—cortisol values that start low and finish low. Individuals with such cortisol deficiency experience difficulty mobilizing sufficient energy just to cope with the challenges of daily life activities.

### **Behavioral Measures for Assessing Fatigue**

The consequences of fatigue are not only subjective and physiologic. In addition to the physiologic changes associated with fatigue, deficits in cognitive processing abilities may also be observed via behavioral measures. In fact, another method for quantifying fatigue is to measure cognitive performance over an extended time period. A decrease over time from optimal performance is taken as an objective marker of fatigue. Tasks assessing cognitive abilities such as attention, vigilance, concentration, processing speed, and decision-making

have all been used as objective markers of fatigue (DeLuca 2005). Monitoring fatigue-related changes in cognitive processing is most easily done in a laboratory setting. A common approach is to obtain a baseline assessment of processing ability and then have the individual complete a fatiguing task or scenario (e.g., completing simple or complex tasks for an extended time period). To identify fatigue effects, processing ability may be monitored before (baseline) and after the task, as well as, multiple times over the course of the task if there is interest in the time course of fatigue effects. Tasks could include simple speech recognition in noise measures and more complex tasks such as a dual-task that combines speech recognition in noise with a visual RT task or a “speech vigilance” task that requires sustained attention.

Hornsby (2013) used such an approach to assess the effects of hearing aid use on fatigue-related decrements in cognitive processing in adults with hearing loss. Word recognition, word recall, and cognitive processing speed (time to respond to a visual stimulus) were measured in adults with hearing loss while they completed a sustained (~50 min) cognitively demanding speech dual-task. Evidence of increased listening effort and fatigue was observed. Word recognition ability, as expected, was poorer when listening unaided. In this more challenging listening condition word recall was also poorer and visual RTs were slower—consistent with an increase in listening effort compared with the aided condition. In addition, although word recognition and recall remained stable over the course of the 50-min test procedure in both aided and unaided conditions, fatigue-related deficits in cognitive processing speed (visual RTs) were observed in some conditions. Specifically, when testing was conducted without hearing aids, processing speed decreased systematically over time—an objective indication of fatigue. However, processing speed remained stable during the same task when participants wore their hearing aids, highlighting the potential benefits of amplification for reducing fatigue effect.

## IDENTIFICATION AND MANAGEMENT OF FATIGUE

There is mounting evidence to suggest that CHL are at increased risk for cognitive fatigue (Bess et al. 1998; Hicks & Tharpe 2002; Gustafson et al. 2013; Hornsby et al. 2013; Rentmeester et al. 2013). Given such a prospect, an increasingly important role for those interested in pediatric hearing loss will be the identification and management of CHL who exhibit stress and subsequent fatigue in school.

Fatigue can be identified through casual observation of behavior. Symptoms commonly associated with fatigue in children include tiredness, sleepiness in the morning, inattentiveness, mood changes, and changes in play activity (e.g., decrease in stamina). Children suspected of fatigue should receive a subjective fatigue evaluation (scales similar to those described earlier) to confirm its presence and to determine the intensity and characteristics of the fatigue (Hockenberry et al. 2003; Hinds et al. 2007; Varni et al. 2002). Although a number of fatigue scales have been developed for different chronic health conditions in children (and adults) it is noteworthy that none have been designed specifically for CHL; and, many available scales excluded the voice of children and parents in their development. Most assuredly, a need exists for the development of a child-centered scale that measures fatigue specific to hearing loss.

Even though evidence-based intervention strategies are not yet available, one intuitive approach to the management of fatigue is the use of amplification devices. Hornsby (2013) provides evidence to suggest that hearing aid use may reduce susceptibility to fatigue resulting from sustained listening demands, at least in adults. It is possible that problems in listening/fatigue may be further minimized through the use of special hearing technology such as directional microphones and/or the use of hearing assistance technology systems. If so, then identifying those at most risk for fatigue may improve the hearing aid fitting process. Hearing aid selection in children typically involves the identification of a hearing aid(s) that afford the best speech understanding. While a reasonable starting point, some hearing aid technologies (e.g., digital noise reduction, frequency lowering) which might impact effort and fatigue may have only a minimal effect on speech understanding (Pittman 2011b; McCreery et al. 2012; Ching et al. 2013). Thus, in addition to optimizing speech understanding and comfort, a more comprehensive 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. 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. 2013), not all CHL wear their hearing aids and/or FM systems in school; especially older aged children (Gustafson et al. 2013).

## AFTERWORD

“Fatigue is the Central Africa of medicine, an unexplored territory which few men enter”

(Beard 1869).

This observation, made about chronic fatigue many years ago, could well apply to fatigue in today’s CHL. Although fatigue has long been a concern of teachers of the hearing impaired and parents of CHL, scientific exploration of this topic is in its infancy. Only recently have we begun to see an uptick in professional presentations and publications in this area; the importance and need for systematic research on fatigue in CHL including its identification, its mechanisms and its management, seems obvious. This brief overview was developed to enhance the awareness of fatigue in CHL by presenting a review of the importance of fatigue, its definition and its consequences; by offering a brief synopsis of subjective and objective fatigue measures; and by providing a thumbnail sketch of common-sense management strategies and considerations for audiologists who serve CHL.

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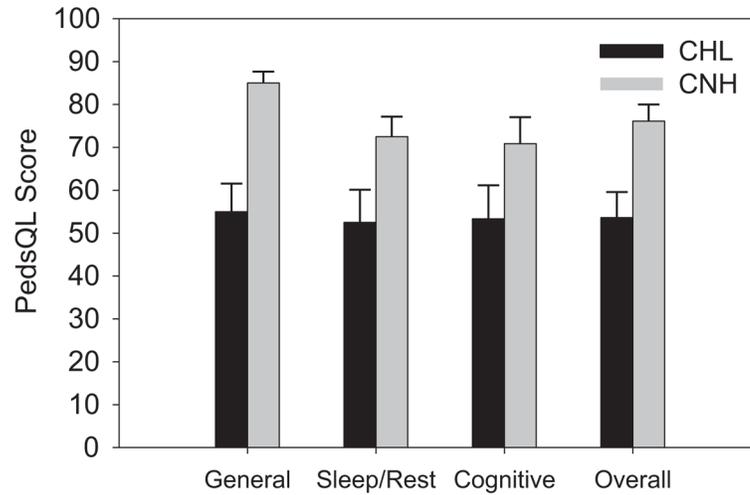
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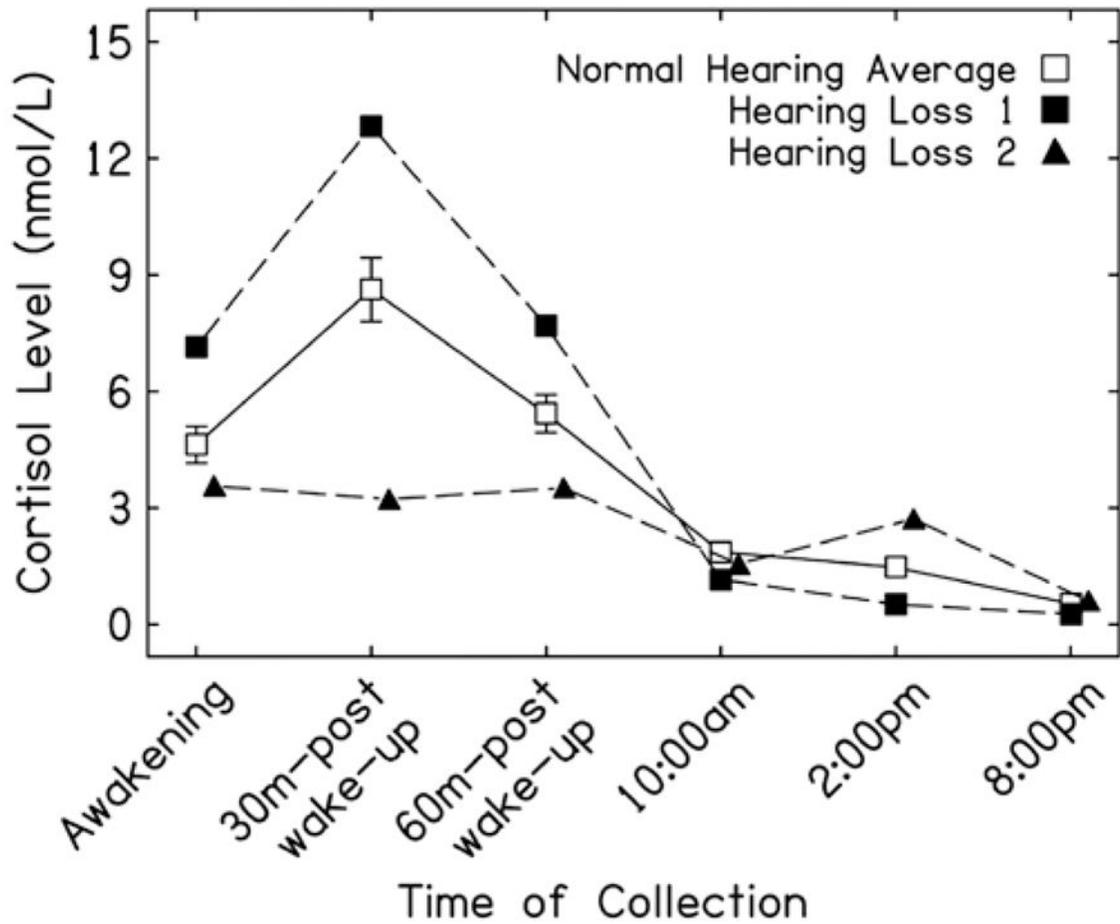
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**Fig. 1.** Mean PedQL Multidimensional Fatigue Scale subscale and total fatigue scores from children with hearing loss (CHL) and children with normal hearing (CNH). *Lower values depict more fatigue.* Error bar = 1 standard error (From Hornsby et al. 2013).



**Fig. 2.** Mean cortisol levels (standard error bars) at all times of collection for children with normal hearing (open squares) and two children with hearing loss (solid square and triangle). Elevated cortisol awakening response values (solid square) are associated with chronic social stress, perceived stress, and worrying about the burdens of the upcoming day. Blunted values (solid triangle) are associated with an inability to mobilize sufficient energy to cope with the challenges of daily life activities.