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Perceived listening difficulty in the classroom, not measured noise levels, is associated with fatigue in children with and without hearing loss

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Conflict of Interest Statement

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Abstract

Purpose: The purpose of this study was to examine if classroom noise levels and perceived listening difficulty were related to fatigue reported by children with and without hearing loss.

Method: Measures of classroom noise and reports of classroom listening difficulty were obtained for 79 children (ages 6-12 years) at two time points on two different school days. Forty-four children had mild- to moderately-severe hearing loss in at least one ear. Multiple regression analyses were conducted to evaluate if measured noise levels, perceived listening difficulty, hearing status, language abilities, or grade level would predict self-reported fatigue ratings measured using the Pediatric Quality of Life Inventory Multidimensional Fatigue Scale.

Results: Higher perceived listening difficulty was the only predictor variable that was associated with greater self-reported fatigue.

Conclusions: Measured classroom noise levels showed no systematic relationship with fatigue ratings, suggesting that actual classroom noise levels do not contribute to increased reports of subjective fatigue. Instead, perceived challenges with listening appears to be an important factor for consideration in future work examining listening-related fatigue in children with and without hearing loss.

Fatigue is a subjective feeling of tiredness that can occur in the physical (e.g., muscular weakness) or mental/cognitive domain (Hockey, 2013; Hornsby et al., 2016). Although everyone experiences transient feelings of fatigue, others experience fatigue that endures for extended periods of time. This type of enduring fatigue is of particular concern in children, as it can adversely affect the child's mood, sleep, academic performance, social interactions, and quality of life (Eddy & Cruz, 2007; Krilov et al., 1998; McCabe, 2009). The sustained mental effort and accumulated stress that adults and children with hearing loss experience during repeated communication breakdowns appears to lead to *listening-related* fatigue (Bess et al., 2014; Bess & Hornsby, 2014; Davis et al., 2020, in review). Consistent with this hypothesis, research has shown greater listening effort and physiologic signs of stress in children with hearing loss compared to those without hearing loss (Bess et al., 2016; McGarrigle et al., 2019; Oosthuizen et al., 2021) and that children with hearing loss report more fatigue than their peers without hearing loss (Bess et al., 2020; Davis et al., in review; Hornsby et al., 2014, 2017).

Using information from focus groups and interviews conducted with children with hearing loss, their parents, and school professionals who work with children with hearing loss, Davis and colleagues (in review) proposed a theoretical framework for listening-related fatigue in children with hearing loss. In this framework, several situational determinants of listening-related fatigue were identified. Specifically, environmental/talker factors (e.g., background noise), school-specific factors (e.g., multitasking), and child-specific factors (e.g., age, motivation) were reported to give rise to physical, cognitive, and social-emotional experiences of listening-related fatigue.

Focus group participants and interviewees also identified strategies employed by children, parents, and school professionals to reduce listening-related fatigue in children as well as barriers to successfully executing these strategies. In the framework proposed by Davis and colleagues, these coping strategies and barriers are shown to interact with situational determinants to influence the experience of listening-related fatigue in children with hearing loss.

Background noise was one of the most commonly reported factors associated with fatigue-related problems in children with hearing loss (Davis et al., in review). This was no surprise, as classroom environments often exceed national recommendations for noise levels (American National Standards Institute, 2010; Brill et al., 2018; Gremp & Easterbrooks, 2018; Picard & Bradley, 2001; Spratford et al., 2019). It is widely understood that competing noise levels found in classrooms disproportionally affect children with hearing loss in the areas of speech understanding, language comprehension, listening effort, and word learning (Brännström et al., 2020; Lewis et al., 2015; McCreery et al., 2019; McGarrigle et al., 2019; Pittman, 2011). However, research is limited with regard to the effects of high classroom noise levels on physiological and psychosocial factors such as fatigue and stress in children with and without hearing loss.

Wålinder and colleagues (2007) measured the effect of overall classroom noise levels on reported symptoms of fatigue and physiologic signs of stress in three classrooms of 10-year-old, typically-developing children. Daily recordings of classroom noise levels were made in each classroom over a period of four weeks. Once per week, children completed a custom five-item questionnaire assessing their perceived disturbance and symptoms due to noise in the classroom. The children responded to questions asking them to rate their difficulties, due to classroom noise, hearing the teacher, reading, or doing their classwork. They also were asked to rate how frequently they became tired or had headaches because of noisy classrooms. Weekly measures of physiologic activity related to stress (pulse rate, blood pressure, and change in salivary cortisol from morning to afternoon) were also recorded. Results from this study showed that, as classroom noise levels increased, physiologic signs of stress, subjective ratings of problems, and complaints due to noise in the classroom also increased.

Findings from Wålinder and colleagues (2007) are consistent with a large body of work showing school-age children – as young as six years of age – are reliable reporters of classroom listening difficulty. That is, children report greater difficulty listening to the teacher when other classmates are talking or when measured noise levels are high compared to when the classroom is quiet (Astolfi et al., 2019; Connolly et al., 2013, 2015; Dockrell & Shield, 2004; Silva et al., 2016). Although children with and without hearing loss both report difficulty listening in noisy classrooms (Krijger et al., 2018; Nelson et al., 2020), it is not surprising that children with hearing loss report increased difficulty compared to their peers without hearing loss (Connolly et al., 2013, 2015). Although perception of hearing difficulties is strongly associated with fatigue in adults (Alhanbali et al., 2018; Davis et al., 2020; Hornsby & Kipp, 2016), it is unknown if this relationship exists in children with respect to classroom listening during childhood.

This study examined the role of the classroom environment on subjective reports of fatigue in children with and without hearing loss. Classroom measures included an *objective* (acoustic) measure of overall noise level and a *subjective* rating of classroom listening difficulty due to noise. We hypothesized that children in noisier classrooms (and thus, those reporting more difficulty listening) would report more fatigue than those in quieter classrooms.

Method

These data were collected as part of a larger project examining listening effort and fatigue in school-age children with hearing loss (see Bess et al., 2014 for an overview of the larger project). The study was reviewed and approved by the institutional review board of Vanderbilt University. All children provided their assent, and parents/caregivers provided written informed consent prior to the initiation of any research procedures. Families were compensated for their time.

Participants

Seventy nine children (ages 6.0-12.9 years, *M* = 9.66 y*,* *SD* = 2.2 y) participated. Children were recruited through the Vanderbilt Kennedy Center's StudyFinder website, Vanderbilt's pediatric audiology clinics, school systems throughout middle Tennessee, word-of-mouth, and advertisement in a local parenting magazine. Children were excluded from this study based on any a priori factors thought to affect fatigue such as: (a) children who were bilingual or whose primarily language in the home was not listening and spoken language, (b) children with autism, (c) children with linear metabolic or endocrine disorder, and (d) children who use stimulant medications. All children were reported by their parent to spend at least two hours per day in a general education classroom.

Children in the control group (n=35) passed a standard hearing screening at 15 dB HL in both ears from 250-8000 Hz. Children with hearing loss (n = 44) had sensorineural hearing loss ranging from mild to moderately-severe in one or both ears. This audiologic examination included air and bone conduction threshold testing at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz (Carhart & Jerger, 1959). Mild hearing loss was defined as pure-tone average (PTA; thresholds at 500, 1000, and 2000 Hz) between 20 and 40 dB HL or thresholds greater than 25 dB HL at two or more frequencies above 2000 Hz. Moderately-severe hearing loss was defined as PTA of 45-70 dB HL. Figure 1 shows a composite audiogram for the children with hearing loss.

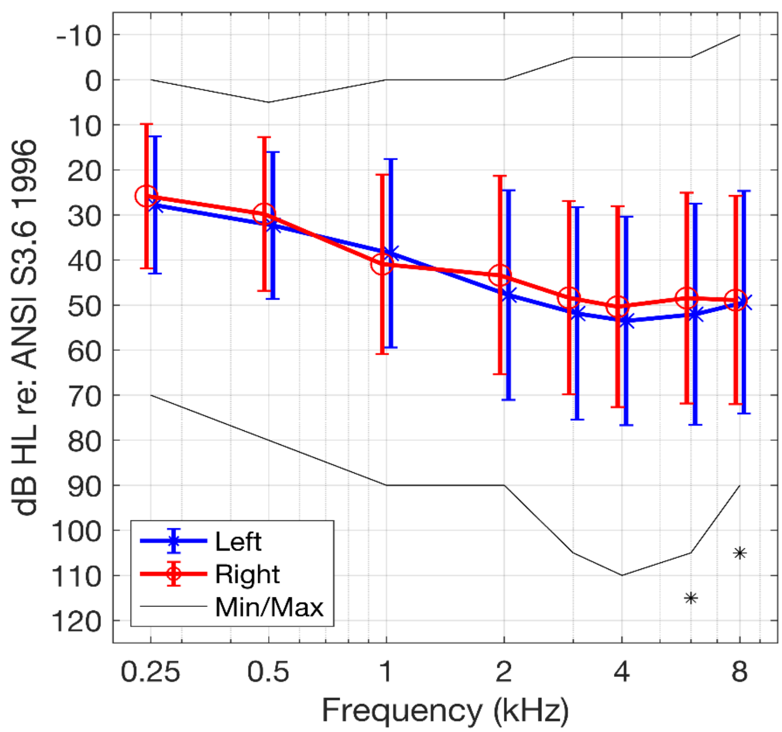

Figure 1. Mean (± 1 standard deviation) hearing thresholds for children with hearing loss. Minimum and maximum thresholds across children are noted. Asterisks indicate no response obtained at limits of the audiometer for at least one child.

Upon entry to the study, demographic information was provided by each child's parent/guardian. This included information about any diagnoses – other than hearing loss – that the child had received (e.g., cerebral palsy, Pendred syndrome). Based on parental report, ten (22.7%) children with hearing loss and six (17.1%) children without hearing loss had at least one additional disability. This is consistent with the known increase in additional disabilities found in children with hearing loss (Cupples et al., 2014; Gaullaudet Research Institute, 2008). At time of study entry, children completed a standardized measure of language ability, the Clinical Evaluation of Language Fundamentals-Fourth Edition (CELF-4; Semel et al., 2003), including all regular subtests. This evaluation provided a reliable, norm-referenced measure of language performance by age. Non-verbal intelligence was also assessed at study entry using the Test of Nonverbal Intelligence-Fourth Edition (TONI-4; Brown et al., 2010). Language and intelligence ability for each group, and other demographic information, is included in Table 1. The age-adjusted overall language level for this sample of children with hearing loss was significantly lower than the sample of children without hearing loss $t(75) = 4.45$, $p < .001$, $d = 1.04$. Both groups were within normal limits for nonverbal intelligence (above a normal mean value of 100); however participants without hearing loss scored significantly higher on the TONI-4 than children with hearing loss, $t(77) = 2.32$, $p = .023$, $d = 0.54$.

Table 1.

Participant characteristics.

Group	No Hearing Loss	Hearing Loss
Number of participants	35	44
Males/Females	21/14	21/23
Number of participants with an additional disability	6	10
Age (years)	9.21 (2.38)	10.01 (2.00)
Grade level	3.71 (2.29)	4.07 (1.98)
Language[a] **	108.7 (10.52)	90.6 (22.14)
Nonverbal IQ[b] *	108.6 (9.69)	102.5 (12.86)

Note. Means (±SD) for children with hearing loss and children with normal hearing.

[a]Standard score on the core language index of the Comprehensive Evaluation of Language Fundamentals-Fourth Edition (CELF-4).

[b]Standard score on the Test of Nonverbal Intelligence-Fourth Edition (TONI-4).

**p* = .023. ***p* < .001.

Procedures

Upon entry into the larger study, hearing thresholds were confirmed and language and intelligence measures were obtained. At this time, the the Pediatric Quality of Life Inventory Multidimensional Fatigue Scale (PedsQL MFS; Varni et al., 2002) was also completed (see detailed description in next section). For this measure of self-reported fatigue, a trained research assistant read the instructions aloud and administered each item of the scales to the child. The child was asked how much s/he agreed with each statement (see Hornsby et al., 2017 for additional details). Classroom noise levels and ratings of perceived listening difficulty due to classroom noise (Listening Difficulty Questionnaire, see detailed description in next section) were obtained by research assistants who visited each participant’s classroom on two typical school days (e.g., no fire alarm, no standardized testing on visit days). On each day, participants were pulled out of class at approximately 10:00 am and 2:00 pm to complete the Listening Difficulty Questionnaire in a quiet location. The research assistant read aloud the instructions and each item of the questionnaire to the child, and asked them to indicate how much they agreed with each statement. The 10-minute measure of classroom noise was obtained while the questionnaire was being completed. Noise measures and listening difficulty ratings were repeated four times to provide a better estimate of the typical classroom noise levels and perceived listening difficulties experienced by the children in our study. The timing of data collection for this study (measures obtained in the morning and afternoon on two separate days) coincided with the collection of salivary cortisol samples that were used in a separate study (Bess et al., 2016).

Self-Reported Fatigue Measure

Subjective ratings of fatigue were measured using the PedsQL MFS (Varni et al., 2002). The PedsQL is a standardized, generic, self-report measure developed for use with children who have chronic health conditions other than hearing loss (e.g., cancer, rheumatoid arthritis; Varni et al., 2002, 2004). This 18-item measure includes three subscales with six items each: general fatigue, sleep/rest fatigue, and cognitive fatigue. A composite fatigue score is also calculated by combining scores from the subscales. All items use a five-point Likert response set, which is transformed into a scale ranging from 0 to 100 (0 = 100, 1 = 75, 2 = 50, 3 = 25, 4 = 0). *Lower* reports of fatigue are reflected in *higher* PedsQL MFS scores. During survey administration, participants are asked how much of a problem each item has been over the past month, or the past few weeks for children 5–7 years old. As reported by Hornsby et al. (2017), both parent-and child-ratings of fatigue were obtained in the larger study. The current study focuses only on child-ratings of fatigue, as parents were not expected to have an accurate understanding of classroom listening environments.

Classroom Noise Levels

Measures of classroom noise levels (L_{eq}, peak, min, and max) were obtained using a Quest NoisePro™ Personal Noise Dosimeter, Type I (Quest Technologies, Oconomowoc, WI). The microphone was positioned using a binder clip to the top edge of the dosimeter so the microphone was oriented upwards. The dosimeter was mounted to a tripod adjusted so the microphone height was between 1.0 and 1.2 meters (40-48 inches) above the floor. The tripod was placed in a central listening area within the classroom where direct teacher and student communication generally takes place. Placement was always at least one meter (40 inches) away from a wall or other fixed objects and at least 0.5 meters (20 inches) away from movable objects (e.g., desk, chair, table). Following these constraints, the tripod was placed in the general vicinity of the participant’s desk.

Prior to the first measure of each day, the dosimeter calibration was checked using a piston phone which presented a 114 dB SPL, 1000 Hz pure tone, as per manufacturer’s recommended protocol. Each classroom noise measurement was recorded using a slow (1-second) time response and “A” weighting. Noise levels were measured continuously over a 10 minute period.

Listening Difficulty Questionnaire

Perceived level of difficulty listening in the classroom was measured using a five-point, Likert-type scale adapted from the scale used by Wålinder et al. (2007; Appendix 1). This scale consisted of seven questions designed to assess the perception of listening difficulty caused by classroom noise. Response options for each item were worded and scored so that *lower values* indicated *more difficulty* due to classroom noise. Specifically, responses to item 1 (How noisy is your classroom?) were scored as Very Noisy = 0, Pretty Noisy = 25, Just Right = 50, Pretty Quiet = 75, and Very Quiet = 100. Responses to item 4 (My classroom is so quiet, it is easy to hear what my teacher says) were scored as Never = 0, Almost Never = 25, Sometimes = 50, Often (A lot) = 75, and Almost Always = 100. Responses to the remaining items were scored as Almost Always = 0, Often (A lot) = 25, Sometimes = 50, Almost Never = 75, and Never = 100. Perceived listening difficulty ratings for each measurement time point were caluclated by averaging scores across the seven items. Resultant scores ranged from 0 to 100. Consistent with the format of the PedsQL, *lower* scores indicate *more* perceived problems due to classroom noise. Because some participants received instruction in multiple classrooms throughout the day, participants were asked to consider the classroom they were in when they were pulled out for this survey. This provided a subjective rating of perceived listening difficulty based on the same classroom from which objective measure of overall noise level was obtained.

Data Analysis

Intraclass correlation coefficient (ICC) was used to assess reliability of the Listening Difficulty Questionnaire. A two-way, mixed-effects model based on single ratings and absolute agreement was used to assess intra-rater reliability. Interpretation of reliability was considered poor if ICC $\leq$ 0.5, fair if 0.5 < ICC $\geq$ 0.75, good if 0.75 < ICC $\geq$ 0.9, and excellent if ICC > 0.9 (R. J. Cohen et al., 1996).

Standard multiple linear regression analyses were completed using IBM SPSS Statistics (Version 27) to examine factors that influence subjective fatigue ratings. Statistical significance was evaluated with an alpha level of 0.05. Four models were tested, one for each of the three subscales reported in the PedsQL MFS: general fatigue, sleep/rest fatigue, and cognitive fatigue. A fourth model was tested using the composite fatigue score provided by the PedsQL MFS. Independent variables entered simultaneously into each model included measured noise levels, perceived difficulty ratings, hearing status, language level, and grade level. Because children with hearing loss have been found to report more cognitive fatigue than children without hearing loss (Hornsby et al., 2017), hearing status (hearing loss vs no hearing loss) was included. Child language level was included because children with low language skills—regardless of hearing status—are more likely to report higher levels of fatigue (Hornsby et al., 2017). Previous findings are conflicting regarding the influence of grade level on perceived listening difficulty ratings (Brännström et al., 2017; Connolly et al., 2013); therefore, we included grade level as a predictor in our analyses.

Results

Recall that the primary purpose of this study was to determine if classroom noise levels and perceived listening difficulty were predictive of reported fatigue in children with and without hearing loss. Because the PedsQL MFS asks children to consider their symptoms of fatigue over the period of three weeks to one month, we pooled acoustic noise level measures and our ratings of perceived listening difficulty across the four measurement points. Descriptive statistics of noise measurements, perceived difficulty ratings, and self-reported fatigue for children with and without hearing loss are reported in Table 2. Intra-rater reliability in our sample of children was good across the four measures of perceived listening difficulty (ICC = 0.792, 95% CI = 0.720 – 0.853).

Table 2.
Measured noise levels, perceived difficulty ratings, and fatigue reports for children with and without hearing loss

Group	No Hearing Loss	Hearing Loss
Measured noise levels		
Mean	64.3 (4.55)	63.2 (4.22)
Median	63.8	63.3
Range	51.7 – 73.1	55.5 – 73.6
Perceived difficulty ratings		
Mean	64.1 (19.5)	61.8 (17.5)
Median	67.9	69.7
Range	14.28 – 91.1	21.4 – 99.1
Fatigue reports[a]		
General	72.7 (17.8)	71.7 (16.7)
Sleep/Rest	63.0 (20.6)	59.9 (18.8)
Cognitive	58.0 (21.4)	53.7 (26.2)
Composite	64.6 (16.9)	61.8 (15.8)

Note. Mean (± SD) measured noise levels (L_{eq} dBA), perceived listening difficulty ratings (out of 100), and reported fatigue (out of 100). Median values and ranges are also reported for measured noise levels and perceived difficulty ratings.

[a]Child ratings of fatigue from Pediatric Quality of Life Inventory Multidimensional Fatigue Scale (PedsQL-MFS).

Multiple regression models were completed to ascertain whether reports of fatigue could be predicted based on measured noise level, perceived listening difficulty rating, hearing status, language, and grade level. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. Models conducted using mean and median measured noise levels (L_{eq}, peak, min, and max) and perceived listening difficulty ratings resulted in a consistent pattern of results; therefore, only models based on average values of measured noise (L_{eq}) and listening difficulty ratings are presented here.

Multiple regression models which included classroom noise level, perceived listening difficulty, hearing status, language, and grade level, significantly predicted general, cognitive, and composite fatigue [general: $F(5,67) = 5.70$, $p < .001$; cognitive: $F(5,67) = 7.386$, $p < .001$; composite: $F(5,67) = 7.092$, $p < .001$]. Adjusted R^2 for these models ranged from 24.6-30.7% which are considered large effect sizes according to J. Cohen (1992). The model predicting sleep/rest fatigue was not significant [$F(5,67) = 1.614$, $p = .168$]. Regression coefficients and standard errors can be found in Tables 3-6.

Table 3.

Summary of the regression model predicting general fatigue ratings.

Variable	*B*	*SE_B*	*T*	*p*	95% CI
Intercept	70.8	32.2	2.20	.032	[6.46, 135.1]
Hearing Status	-1.58	4.20	-0.375	.709	[-9.95, 6.80]
Language	0.073	0.099	0.741	.461	[-0.124, 0.270]
Grade Level	0.387	0.920	0.420	.675	[-1.449, 2.22]
Perceived Listening Difficulty	0.476	0.497	4.727	<.001	[0.275, 0.677]
Measured Noise Level	-0.596	0.449	-1.326	.189	[-1.492, 0.301]

Note. adj R2 = .246; CI = confidence interval; B = unstandardized regression coefficient; SE_B = standard error of coefficient.

Table 4.

Summary of the regression model predicting sleep/rest fatigue ratings.

Variable	*B*	*SE_B*	*T*	*p*	95% CI
Intercept	44.6	44.5	1.076	.286	[-38.13, 127.3]
Hearing Status	-7.38	5.40	-1.366	.176	[-18.15, 3.40]
Language	-0.009	0.127	-0.073	.942	[-0.262, 0.244]
Grade Level	0.454	1.183	0.384	.702	[-1.907, 2.815]
Perceived Listening Difficulty	0.327	0.129	2.524	.014	[0.068, 0.585]
Measured Noise Level	-0.023	0.578	1.076	.286	[-38.14, 127.3]

Note. adj R2 = .041; CI = confidence interval; B = unstandardized regression coefficient; SE_B = standard error of coefficient.

Table 5.

Summary of the regression model predicting cognitive fatigue ratings.

Variable	*B*	*SE_B*	*T*	*p*	95% CI
Intercept	12.144	44.59	0.272	0.79	[-76.9, 101.1]
Hearing Status	0.010	5.807	0.002	0.99	[-11.58, 11.6]
Language	0.382	0.136	2.802	0.007	[0.110, 0.655]
Grade Level	-0.595	1.272	-0.049	0.641	[-3.135, 1.944]
Perceived Listening Difficulty	0.646	0.139	4.638	<.001	[0.368, 0.924]
Measured Noise Level	-0.547	0.621	-0.881	0.382	[-1.787, 0.693]

Note. adj R2 = .307; CI = confidence interval; B = unstandardized regression coefficient; SE_B = standard error of coefficient.

Table 6.

Summary of the regression model predicting composite (total) fatigue ratings.

Variable	*B*	SE_B	*T*	*p*	95% CI
Intercept	42.507	30.09	1.413	0.162	[-17.54, 102.6]
Hearing Status	-2.980	3.918	-0.761	0.450	[-10.80, 4.841]
Language	0.149	0.092	1.615	0.111	[-0.035, 0.332]
Grade Level	0.082	0.858	0.095	0.924	[-1.632, 1.795]
Perceived Listening Difficulty	0.483	0.094	5.138	<.001	[0.295, 0.670]
Measured Noise Level	-0.389	0.419	-0.927	0.357	[-1.226, 0.448]

Note. adj R2 = .297; CI = confidence interval; B = unstandardized regression coefficient; SE_B = standard error of coefficient.

We examined the contribution of individual predictor variables within each model. Perceived listening difficulty was the only predictor variable that significantly added to the prediction of fatigue across all models tested. That is, all regression analyses consistently yielded perceived listening difficulty as a significant predictor of subjective fatigue (general: $p < .001$; sleep/rest: $p = .014$; cognitive: $p < .001$; composite fatigue: $p < .001$). Figure 2 shows associations between perceived listening difficulty and PedsQL MFS scores for general, sleep/rest, cognitive, and composite scores. Data show that lower perceived listening difficulty scores (i.e., more listening difficulty) is related with lower PedsQL scores (i.e., more fatigue). Language was also a significant predictor for cognitive fatigue ($p = .007$), with higher language scores associated with less cognitive fatigue, but not for other domains or composite fatigue. Measured noise levels, hearing status, and grade level did not significantly contribute to the prediction of fatigue in any domain.

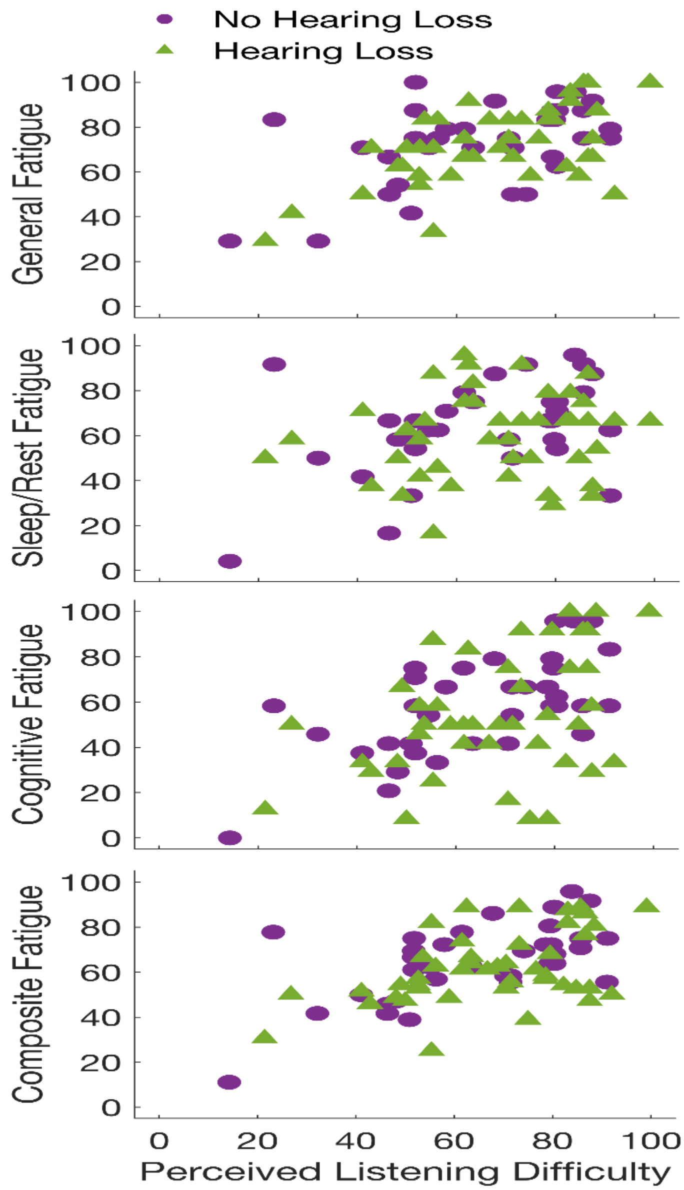

Figure 2. General, sleep/rest, cognitive, and composite fatigue scores as a function of perceived listening difficulty ratings for children with (green triangles) and children without (purple circles) hearing loss.

Discussion

Perceived listening difficulty ratings, not measured noise levels, grade level, or presence of hearing loss, were significantly associated with subjective fatigue. That is, children who reported more listening difficulty in their classroom also reported more fatigue when compared to those who reported less classroom listening difficulty. This finding is consistent with work conducted with adults who have hearing loss showing perception of hearing difficulties was strongly associated with fatigue (Alhanbali et al., 2018; Davis et al., 2020; Hornsby & Kipp, 2016). For adults and children, perceived challenges with listening appears to be an important factor for consideration in future work examining listening-related fatigue.

It is possible that children included in this study were fatigued because they were struggling to communicate in their classrooms. An alternative explanation might be that children perceived classroom listening to be difficult because they were fatigued. This latter directional relationship has been proposed to account for instances of reduced listening effort in adults who report high levels of daily-life fatigue (Wang et al., 2018). That is, fatigued listeners may be less willing to apply the high levels of effort required to maintain successful communication in a noisy setting. If so, their perceived difficulty in that setting may be due, at least in part, to a lack of applied effort in the noisy setting (Wu et al., 2016). At this time, it is unclear to what degree motivation influences listening effort and fatigue in children. Importantly, the significant association found in this study does not establish causality. It is possible that the relationship between perceived listening difficulties and fatigue is bidirectional.

Consistent with our previous work (Hornsby et al., 2017), we found lower language abilities were associated with higher reports of cognitive fatigue. This finding is also consistent with data from our lab showing that lower receptive language and reading skills are associated with cognitive fatigue in children with hearing loss (Camarata et al., 2018). That is, children with lower language and reading abilities are likely to experience increased cognitive fatigue when compared to their typically-developing peers. The non-significant association of grade level and fatigue reports is also consistent with the findings of Hornsby and colleagues (2017) who reported no effect of child-age on fatigue reports. This suggests that all school-age children are susceptibile to fatigue, regardless of their age and that additional disabilities, such as language delay can also impact fatigue.

Results from this study found no significant association between hearing status and reported fatigue. These results conflict with previous findings that children with hearing loss report more fatigue than those without hearing loss (Bess et al., 2020; Hornsby et al., 2017). This discrepancy likely arises from the methodological differences between the current study and those conducted previously. For example, the results of Hornsby et al., (2017) were based on a non-parametric analysis of variance that included fatigue rating of the children and their parents, making direct comparisons with the current study difficult. Davis et al. (in review) argue that some of the inconsistent findings regarding the impact of hearing loss on fatigue result from the use of generic measures, like the PedsQL-MFS, which may not be sensitive to listening-related fatigue experienced by children with hearing loss. This limitation of generic fatigue measures has recently been highlighted in a study showing similar levels of fatigue reported by adults with and without hearing loss when using a general fatigue measure but higher levels of fatigue in adults with hearing loss when using questions that target listening-related fatigue (Dwyer et al., 2019).

Objective Measure of Classroom Noise and Fatigue

In the current study, we expected that measured classroom noise levels would be significantly associated with fatigue, as high levels of classroom noise has been linked to reduced speech recognition, physiologic signs of stress, and subjective problems and complaints (Wålinder et al., 2007). Classroom noise levels measured in this study are consistent with previous studies reporting occupied classroom noise levels (Gremp & Easterbrooks, 2018; Picard & Bradley, 2001; Wålinder et al., 2007) but are slightly higher than those reported by Spratford and colleagues (2019). Contrary to our hypothesis, measured classroom noise levels showed no systematic relationship with fatigue ratings, suggesting that actual classroom noise levels do not contribute to increased reports of subjective fatigue. This is in contrast with self-reports from children with hearing loss, their parents, and their teachers who note that children with hearing loss experience fatigue more frequently when listening in high noise environments (Davis et al., in review).

It is possible that the four, brief measures of classroom noise obtained in this study did not provide an accurate reflection of daily classroom noise levels, which are known to fluctuate throughout the school day depending upon activity (Shield & Dockrell, 2003). To address whether continual exposure to high classroom noise levels is associated with fatigue, future work would need to examine the dosing relationship between noise exposure and fatigue. Future research could examine whether obtaining reports of fatigue at the end of the day might be sensitive to daily variations in noise levels. Additionally, the PedsQL MFS asks respondents to consider their daily life over the past month – a time period which includes a number of non-school days, particularly if the scale is completed during a school break. Importantly, we did not control for time of the school year in this study. It is plausible that this type of intermittent exposure to classroom noise might lead to fatigue and recovery cycles that could be missed by long-term fatigue measures.

It is important to note that the measure of perceived listening difficulty used in this study was adapted from a questionnaire used in a research study (Wålinder et al., 2007). Information regarding the development of the original questionnaire was not provided; however, Wålinder and colleagues found that ratings of perceived listening difficulty were significantly correlated with measured classroom noise levels. Our results replicate this finding, showing a weak but significant correlation between mean measured noise levels and average perceived listening difficulty ratings (r = -.198, p = .046). Together, these results suggest that higher classroom noise levels are related with greater perceived listening difficulty in children. However, future research is needed to understand the psychometric properties of this questionnaire.

When considering our non-significant findings for hearing status and noise level together, our results suggest that hearing status and overall classroom noise levels alone, do not influence the child's fatigue experience. Rather, it is the perceptual impact of these factors that must be considered. This is consistent with the framework proposed by Davis et al. (in review). Namely, that there is an interplay between situational determinants, experiences, and coping strategies with respect to the child's experience of listening-related fatigue. Importantly, this study suggests that this interaction between acoustic degradations and individual factors on listening-related fatigue is not adequately captured in the PedsQL-MFS. The use of generic measures to understand the linkage between hearing loss and fatigue has been mixed (Davis et al., 2020; Dwyer et al., 2019) and our results add to the emerging body of research suggesting current generic fatigue measures may not be optimal for detecting listening-related fatigue in individuals with hearing loss.

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Appendix 1: Listening Difficulty Questionnaire

How much are these statements like your classroom?

<table>
<tr><td></td><td>1. How noisy is your classroom?</td><td></td></tr>
</table>

Please circle one for each statement.				
Very Noisy	Pretty Noisy	Just Right	Pretty Quiet	Very Quiet
0	1	2	3	4

<table>
<tr><td></td><td>2. My classroom is so noisy, it's hard to focus on my work.</td><td></td></tr>
</table>

Please circle one for each statement.				
Never	Almost Never	Sometimes	Often (A lot)	Almost Always
0	1	2	3	4

<table>
<tr><td></td><td>3. My classroom is so noisy, I feel tired.</td><td></td></tr>
</table>

Please circle one for each statement.				
Never	Almost Never	Sometimes	Often (A lot)	Almost Always
0	1	2	3	4

How much are these statements like your classroom?

4. My classroom is so quiet, it is easy to hear what my teacher says.

Please circle one for each statement.

Never	Almost Never	Sometimes	Often (A lot)	Almost Always
0	1	2	3	4

5. My classroom is so noisy, my head hurts.

Please circle one for each statement.

Never	Almost Never	Sometimes	Often (A lot)	Almost Always
0	1	2	3	4

6. My classroom is so noisy, it's hard for me to read.

Please circle one for each statement.

Never	Almost Never	Sometimes	Often (A lot)	Almost Always
0	1	2	3	4

How much are these statements like your classroom?

<table>
<tr><td colspan="2"></td><td>7. My classroom is so noisy, it's hard to hear what my teachers says.</td><td colspan="2"></td></tr>
<tr><td colspan="5">Please circle one for each statement.</td></tr>
<tr><td>Never</td><td>Almost Never</td><td>Sometimes</td><td>Often (A lot)</td><td>Almost Always</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
</table>