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ARTICLES

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An Assessment of Open Plan and Enclosed Classroom Listening Environments for Young Children: Part 1 – Children's Questionnaires

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Purpose: **Open plan classrooms, where several classes share the same area, have recently re-emerged in primary schools. This study investigated Kindergarteners' perceptions of noise and how it affects speech perception in four classrooms: an enclosed classroom (25 children), double classroom (44 children), fully open plan triple classroom (91 children), and a semi-open plan K-6 classroom (205 children).**

Method: **Ninety-five Kindergarteners (M_{age} = 5;6) split over the four schools completed a questionnaire with the researcher assessing whether they could hear/were annoyed by sound sources (using yes/no) and how well they could hear their teacher/classmates in different listening scenarios (using simple ordinal ratings). Children's responses were also compared to the classroom's acoustic conditions.**

Results: **Most children were annoyed by noise from other children/teachers, and it significantly affected how well they could hear their teacher, especially in the open plan classrooms with only a small distance between class bases. Children in all classrooms had difficulty hearing their teacher when their own class was noisy. The children's responses of how well they could hear their teacher correlated with the noise levels, signal-to-noise ratios, and speech transmission index scores measured in the classrooms.**

Conclusions: **Noise was problematic, particularly in the open plan classrooms, and it negatively impacted the children. These results show the importance of meeting the recommended acoustic limits for classrooms with 5- to 6-year-old children to ensure they can hear their teacher "well".**

Introduction

Open plan classrooms, often renamed as '21st century learning spaces', have recently been re-emerging in primary schools (Shield, Greenland, & Dockrell, 2010). This is despite evidence from the 1970s that suggests noise can be a major problem in these spaces (see Shield et al., 2010, for a review). Therefore, it is timely to assess whether or not these new open plan classrooms are appropriate learning environments for young children. This paper is the first part of two qualitative studies that investigated (1) 5- to 6-year-old Kindergarten children's perceptions of how noise affects their ability to hear their teacher/classmates and (2) the teachers' perceptions of noise and its effect on learning and teaching in different types of classrooms.

Classroom Configurations

The most common classroom type over the past 30-40 years has been a traditional enclosed classroom with four walls and 20-30 children and their teacher occupying the space. However, a current trend in Australia and other countries, such as New Zealand; the United States; the United Kingdom; Japan; Norway; Sweden; Portugal; and Denmark, is to replace these classrooms with new open plan '21st century learning spaces' that have up to 200 children sharing the same area (Stevenson, 2011). Open plan style classrooms were first popular during the educational reform in the 1960's and 1970's due to traditional didactic teaching methods being replaced by a more 'child-centered' approach where the emphasis was placed on child-directed learning rather than the teacher being the instructor (Brogden, 1983; see also Shield et al., 2010). However, many of these classrooms were converted back to enclosed classrooms towards the end of the 20th century due to noise problems and visual distraction, and a return to more traditional teaching methods (Shield et al., 2010). Despite this, the

21st century has seen a re-emergence of open plan classrooms due to the child-centered educational philosophy again being favored (Shield et al., 2010).

In addition to being architecturally fashionable, these spaces are perceived as being less authoritarian, hence creating a more secure feeling for the child (Maclure, 1984). This type of space also allows for a range of activities to be carried out and is thought to better facilitate group activities, the children's social development, and to make the children take more responsibility for their work (Brogden, 1983; Hickey & Forbes, 2011). Despite these claims of benefits, several studies have shown high noise levels are a problem in open plan classrooms (see Shield et al., 2010, for a review). The American National Standards Institute (2002) strongly discourages the use of open plan classrooms because the high levels of background noise have a "negative impact on the learning process and tend to defeat any teaching methodology advantages that may accrue from their use" (p. 24). Nonetheless, recent years have seen open plan '21st century learning spaces' growing in popularity, especially in Australia. Therefore, it is important to assess whether these new-style open plan classrooms can provide adequate listening environments for young children.

Noise in Classrooms and its Effect on Learning

Speaking and hearing are the primary modes of communication in the educational setting, so it is essential that children find their teacher's and classmates' speech intelligible (Rosenberg et al., 1999). The major noise source found in classrooms is the noise generated by other children (Picard & Bradley, 2001; Shield & Dockrell, 2004), and this is also the most distracting noise type, compared to tapping and traffic noise, due to its speech masking effects (Prodi, Visentin, & Feletti, 2013; see also Leibold & Buss, 2013). Classrooms with the youngest children tend to be the loudest and younger children are also more affected by noise (Picard & Bradley, 2001; Prodi et al., 2013). Many experimental studies have shown that younger children have greater perceptual difficulties than older children and adults in discriminating and understanding speech (Crandell & Smaldino, 2000; Finitzo-Hieber & Tillman, 1978; Johnson, 2000; Leibold & Buss, 2013; Nelson & Soli, 2000; Nishi, Lewis, Hoover, Choi, & Stelmachowicz, 2010). Young children are also more affected than adults by the "café effect" (i.e. the increasing noise level from people raising their voices so they are heard by themselves and others), which happens in the classroom, especially when children are engaged in group work activities (Whitlock & Dodd, 2008). Furthermore, large untreated rooms and sound-reflecting surfaces and can result in long reverberation times. When noise and reverberation combine, it results in the speech signal being masked, which reduces speech intelligibility (Crandell & Smaldino, 2000; Finitzo-Hieber & Tillman, 1978). Children's poorer speech perception abilities compared to adults is largely because they cannot use accrued linguistic knowledge, context, or top-down processes to fill in missing information, as their auditory systems are neurologically immature (Boothroyd, 1997; Nelson & Soli, 2000; Wilson, 2002). For this reason, it is important to consider children's perceptions of noise in the classroom rather than relying solely on adults' perceptions, as they may not accurately reflect those of the children.

High noise levels not only adversely affect children's speech perception, but also affect children's psychoeducational and psychosocial achievement, including their reading and language comprehension, cognition, concentration, behavior, and anxiety levels (Klatte, Lachmann, & Meis, 2010; Maxwell & Evans, 2000; Ronsse & Wang, 2013; see also reviews by American Speech-Language-Hearing Association, 2005; Crandell & Smaldino, 2000; Klatte et al., 2010; Maxwell & Evans, 2000; Ronsse & Wang, 2013; Shield et al., 2010). Poor acoustical conditions and noise can result in children 'tuning out' and giving up on tasks as a result of being overloaded by auditory sounds (Anderson, 2001; Cohen, Evans, Krantz, & Stokols, 1980; Maxwell & Evans, 2000). Furthermore, children with special educational needs are even more affected by poor classroom acoustics and noise (see Nelson & Soli, 2000, for a review). This includes i) children with hearing impairments and/or otitis media, who need more favourable classroom acoustics to perceive speech compared to their normal hearing peers (Crandell & Smaldino, 2000; Nelson & Soli, 2000), ii) children with auditory processing disorders, who find listening challenging when there is background noise and/or reverberation (Keith, 1999), iii) children who have English as a second language (ESL), who are poorer at perceiving and comprehending speech in noise (Nelson, Kohnert, Sabur, & Shaw, 2005; Wang, 2014), and iv) introverts, who find it difficult to concentrate in noisy environments (Cassidy & MacDonald, 2007).

Recommended Acoustic Conditions for Classrooms

The effects of poor classroom acoustics on children emphasize the importance of controlling classroom noise. Many countries, including Australia, have acoustic standards for classrooms (e.g. Australia/New Zealand Standard, 2000, which recommends that the unoccupied noise level should be < 35-45 dBA, and the unoccupied reverberation time should be < 0.4-0.5 seconds), but these are not enforced and are only for unoccupied rather than occupied classrooms.

There are, however, recommendations in the academic literature about what acoustic conditions should be achieved in occupied classrooms. It is generally recommended that the signal-to-noise ratio (SNR; a direct comparison of the teacher's speech level with the noise level), should be > +15 dB throughout the classroom to ensure that children can clearly hear speech (American Speech-Language-Hearing Association, 2005). This value has been derived from studies that show speech perception for people with sensorineural hearing loss remains fairly constant above a +15 dB SNR, but deteriorates at lower SNRs (Crandell & Smaldino, 2000). As a result, it is recommended that occupied noise levels should be < 50 dBA (Berg, Blair, & Benson, 1996) to ensure an SNR of +15 dB given that an average speaking voice is 65 dBA. Furthermore, Greenland and Shield (2011) have demonstrated that speech transmission index scores (STI scores; a 0-1 scale of how intelligible speech is in a room by measuring the reduction in fidelity introduced into the speech transmission channel from the source to the receiver, caused by both reverberation and noise (MacKenzie & Airey, 1999)) should be > 0.75 for 6-year-old children for satisfactory speech intelligibility. However, many studies assessing the acoustic conditions of classrooms reveal that these noise level, SNR, and STI recommendations are rarely achieved (see American Speech-Language-Hearing Association, 2005, for a review). This raises the question of whether these recommendations are too conservative and/or unrealistic, or if they are not achieved because schools have not been required to make the necessary modifications. Therefore, it would be valuable to correlate children's reports of how well they can hear their teacher in different listening scenarios with the classroom acoustic conditions measured during these scenarios. This would allow us to determine what acoustic conditions are needed for children to rate they can hear their teacher "well".

The main problem created by open plan classrooms is that there are no walls to reduce the intrusive noise from the classes entering into other class spaces. This is particularly problematic when one class is engaged in critical listening activities (hence the children need quiet conditions), but the teacher of that class cannot control or shut out the noise coming from the other classes. Enclosed classrooms, in contrast, minimize this noise as there are walls that reduce sound transmission between classes. A recent study by Mealings, Buchholz, Demuth, and Dillon (2015) found much higher intrusive noise levels from adjacent classes in a triple classroom with 91 children and a K-6 classroom with 205 children compared to an enclosed classroom with 25 children and a double classroom with 44 children. These high noise levels directly affected children's ability to discriminate words on the Mealings, Demuth, Dillon, and Buchholz (MDDB) Classroom Speech Perception Test (Mealings, Demuth, Buchholz, & Dillon, 2015a), which was conducted live in these classrooms while the other class/es in the area engaged in quiet versus noisy activities (Mealings, Demuth, Buchholz, & Dillon, 2015b). Interestingly, however, the noise levels when the tested classes were engaged in group work activities were excessive irrespective of classroom size. Little research, however, has been conducted directly comparing the children's perceptions of noise in different types of classrooms.

Children's Reports of Noise in Classrooms

Although little research has been conducted comparing the experiences of children in open plan versus enclosed classrooms, one study in the United Kingdom (Shield, Greenland, Dockrell, & Rigby, 2008) investigated children's perceptions of noise in semi-open plan primary classrooms and compared these with a different study investigating the perceptions of noise from children in enclosed classrooms. The results from the open plan classrooms study suggested that intrusive speech (primarily from the children, but also from the teachers) from adjacent classes was the most annoying sound source for children with an unacceptable proportion (defined as over 32%) of children reporting annoyance. Additionally, the ability of the children to hear their teacher decreased as the activity level of the adjacent classes (hence intrusive noise level) rose and was unsatisfactory when adjacent classes were working in groups and moving around the classroom. Children in open plan classrooms with more than three class bases were significantly more likely to hear children's and teachers' voices from other classes and be annoyed by the teachers' voices than children in the enclosed and double classrooms. The ability to hear their classmates was not a problem for children in either open plan or enclosed classrooms. Children in enclosed classrooms, however, reported hearing their teacher better than children in any of the open plan classrooms when all classes were quiet. Unfortunately, because different questionnaires were used by Shield et al. (2008) for the open plan and enclosed classroom studies, few other comparisons between the classroom types were able to be made.

Present Study

The purpose of this study, therefore, was to investigate how the children in the four different sized open plan and enclosed classrooms used in the classroom acoustics study by Mealings, Buchholz, et al. (2015) perceive their listening environment using the same questionnaire and methodology across participants. The aim of this study was to answer the following research questions:

1) Are the children in open plan classrooms more annoyed by noise generated by the children and teachers in the adjacent classes, and do they have more difficulty hearing their teacher and classmates than children in enclosed classrooms?
2) If so, is this annoyance and difficulty hearing their teacher related to the number of children and/or class bases in the area, or do other factors such as the classroom layout and acoustic treatment affect this?
3) Do the children's perceptions of noise match the objective acoustic measurements by Mealings, Buchholz, et al. (2015), and what acoustic conditions are required for a child to rate they can hear their teacher well?

Method

Schools Involved

The study took place in Sydney, Australia during the second half of the school year as part of an in depth project investigating the acoustics and listening conditions in open plan and enclosed Kindergarten classrooms. The same schools that were involved in the acoustic measures study by Mealings, Buchholz, et al. (2015) and the speech perception test by Mealings, Demuth, et al. (2015b) were involved in this study. As described in Mealings, Buchholz, et al. (2015), three open plan classrooms representing the range of classroom sizes found in Sydney were chosen for this study, along with one enclosed classroom with 25 children. During the selection process, effort was made to choose schools with similar scores on The Index of Community Socio-Educational Advantage (ICSEA) scale. The ICSEA scale represents a school's level of educational advantage based on family backgrounds. The scores range from 500-1300, with a mean of 1000 and standard deviation of 100. Higher ICSEA scores represent more advantaged schools. (More information about ICSEAs can be found on the My School website http://www.myschool.edu.au.) We used the ICSEA scores calculated for 2013 when the study was conducted. Below are the descriptions of the classrooms as found in Mealings, Buchholz, et al. (2015). The building details and acoustic conditions of the participating classrooms as measured in Mealings, Buchholz, et al. (2015) are shown in Table 1 and Table 2. Table 2 also shows the average scores the children achieved on the MDDB Classroom Speech Perception Test for each classroom when the adjacent class/es were engaged in quiet versus noisy activities (Mealings, Demuth, et al., 2015b).

Enclosed Classroom: 25 Kindergarten Children. This classroom consisted of 25 Kindergarten children in a classroom with 3 solid brick walls, a closed floor-to-ceiling 4 cm thick operable wall with pin boards, and a shared storeroom with the adjacent Kindergarten class. The class area was carpeted with loop pile carpet and windows were located on both side walls (Figure 1). The ceiling was rough concrete textured. No acoustic treatment was evident. A survey of 50 primary schools in the region found that 60% of Kindergarten classrooms have an operable wall between them and an additional 10% have a shared storeroom or door with another class. Only 30% of schools had fully enclosed classrooms with four solid walls. Therefore this classroom with its operable wall and shared storeroom was more typical of those enclosed classrooms found in the Sydney region, and hence was chosen for the study. The average unoccupied reverberation time (T30) of this classroom was 0.50 s, which is within the recommended time of 0.4-0.5 s (Australia/New Zealand Standard, 2000).

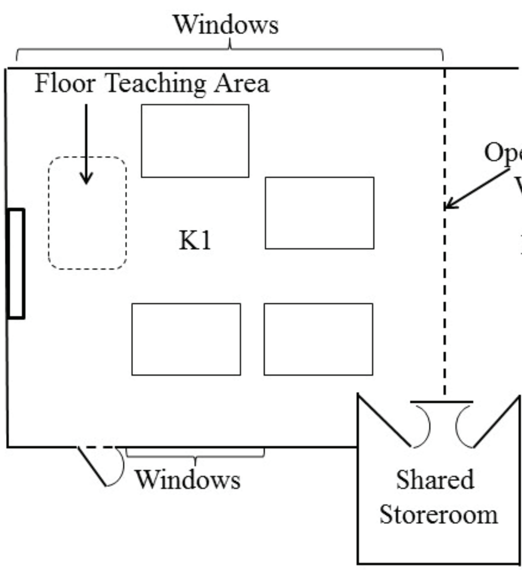

Figure 1. Floor plan of the enclosed classroom with 25 children.

Double Classroom: 44 Kindergarten Children. This space originally consisted of two separate classrooms with plasterboard walls, but the wall between had been removed at the start of the year to make it an open double classroom for the 44 Kindergarten children. The ceiling was made of plasterboard and was triangular in shape, and the top half of the wall still remained in this area between the two classrooms where the original wall had been. The class area was carpeted with loop pile carpet, but the utility area was a hard surface. Windows were located on two walls and pin boards covered the other two walls (Figure 2). No other acoustic treatment was evident. The average unoccupied reverberation time (T30) of this classroom was 0.60 s, which is above the recommended time of 0.4-0.5 s (Australia/New Zealand Standard, 2000).

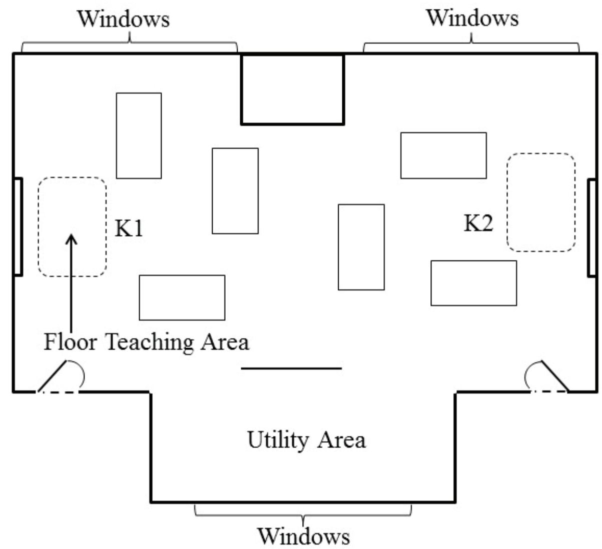

Figure 2. Floor plan of the double classroom with 44 children.

Triple Classroom: 91 Kindergarten Children. This open plan classroom consisted of 91 Kindergarten children grouped linearly into three classes (K1, K2, K3), with no barriers between them. This classroom represented a mid-range child and class base number for an open plan space. The Year 1 and 2 classes were located off an adjacent corridor but had no doors/walls separating the spaces, hence noise from these classes could also be heard. Originally the space had consisted of separate enclosed classrooms with 30 children in each, but these walls had recently been removed to make the area fully open plan. The walls were plasterboard and the class area was carpeted with loop pile carpet, but the corridor floor was a hard surface. The ceiling was acoustically tiled. Windows were located on both the front and back walls and pin boards were on the other two walls (Figure 3). No other acoustic treatment was evident. The average unoccupied reverberation time (T30) of this classroom was 0.70 s, which is above the recommended time of 0.4-0.5 s (Australia/New Zealand Standard, 2000).

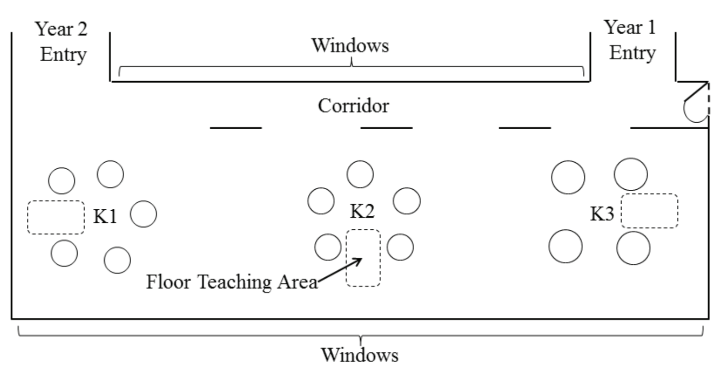

Figure 3. Floor plan of the triple classroom with 91 children.

K-6 Classroom: 205 Kindergarten to Year 6 Children. This classroom contained the entire primary school (205 children) in the one area representing one of the biggest types of open plan classrooms found in Sydney. It had been purpose-built to be a '21st century learning' open plan school. The children were separated into class stages with Kindergarten, Year 1, and Year 2 in a semi-open plan layout with dividers between them and only one open wall. Years 3/4 and 5/6 were in the fully open plan area. The Kindergarten class was located in the corner in the acoustically most sheltered location, particularly for their whole class teaching area where the children are grouped together on the floor to listen to their teacher (see Figure 4). The ceiling height in this area was the lowest of the room measuring 3.2 m. The entire area was carpeted with loop pile carpet, and 3 cm thick pin boards along the walls and soft furnishings provided some acoustic absorption. The ceiling was acoustically tiled. Windows were located on the external wall. The average unoccupied reverberation time (T30) of this classroom was 0.58 s, which is above the recommended time of 0.4-0.5 s (Australia/New Zealand Standard, 2000), but lower than the reverberation times of the double and triple classrooms.

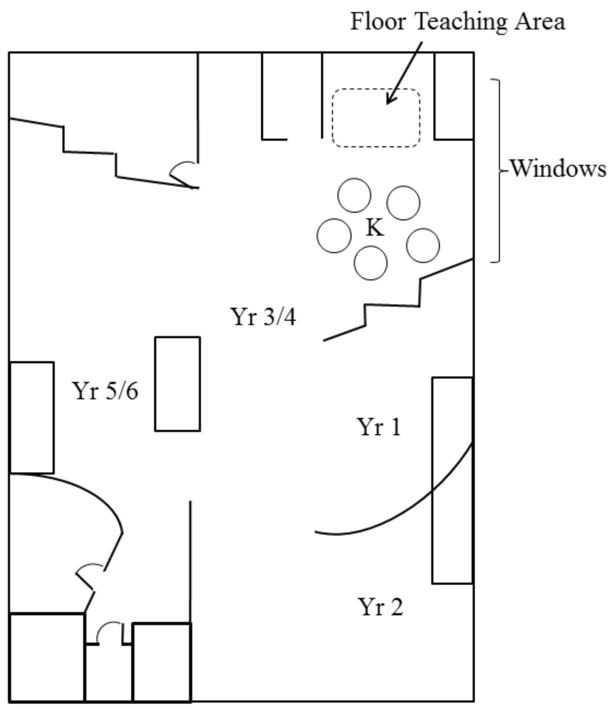

Figure 4. Floor plan of the K-6 classroom with 205 children.

Table 1. *Building details of the participating classrooms (from Mealings, Buchholz, et al., 2015).*

	Enclosed Classroom	Double Classroom	Triple Classroom	K-6 Classroom
Total number of students in area	25	44	91	205
School's ICSEA	1141	1133	1035	1090
Classroom type	Enclosed classroom with shared concertina wall	Fully open double classroom	Linear, fully open plan classroom	Semi-open plan classroom
Class grades in area	Kindergarten (5- to 6-year-olds)	Kindergarten (5- to 6-year-olds)	Kindergarten (5- to 6-year-olds)	Kindergarten to Year 6 (5- to 12-year-olds)
Number of class bases in area	1	2	3	5-7 (depending on activity)
Number of students in each class base	25	21-23	30-31	30-50
Room dimensions (m)	8 x 9	15 x 9	37 x 11	27 x 32
Total floor area (m^2)	72	135	407	864
Space per child (m^2)	2.9	3.1	4.5	4.2
Distance between edge of class bases (m)	N/A	2	6	7
Ceiling height (m)	3.0	2.8-4.2	3.3	3.2-6.0
Total room volume (m^3)	216	470	1340	3900

Table 2. *Average noise levels, signal-noise ratios (SNRs), speech transmission index (STI) scores and MDDB Classroom Speech Perception Test scores in each classroom during different scenarios (see also Mealings, Buchholz, et al., 2015; Mealings, Demuth, et al., 2015b).*

Noise Type	Classroom	Average Noise Level (dBA)	Average SNR (dB)	Average STI Score	Average MDDB Score (%)
Unoccupied ambient noise	Enclosed	42	+18	0.86	
	Double	37	+26	0.83	
	Triple	36	+24	0.92	
	K-6	46*	+12*	0.84	
Intrusive noise (adjacent class/es doing quiet activities)	Enclosed	43	+18	0.73*	80
	Double	46	+14*	0.75	76
	Triple	57*	+2*	0.54*	67
	K-6	60*	-1*	0.45*	66
Intrusive noise (adjacent class/es doing noisy activities)	Enclosed	49	+14*	0.73*	64
	Double	50	+10*	0.68*	60
	Triple	62*	-3*	0.41*	45
	K-6	60*	-1*	0.45*	68

Note. * indicates acoustic conditions are outside of the recommended 45 dBA unoccupied and 50 dBA occupied maximum noise level,+15 dB minimum SNR, and 0.75 minimum STI score (Australia/New Zealand Standard, 2000; Berg et al., 1996; Crandell & Smaldino, 2000; Greenland & Shield, 2011).

Participants

Twenty-three to twenty-five Kindergarten children from each school (N_{total} = 95) whose parents gave consent for their child to participate in the study completed the questionnaires approved by Macquarie University ethics. No children from the triple or K-6 classroom were reported by their parents to have otitis media, a hearing loss, or intellectual or behavioural disabilities. One child in the double classroom was reported to have a sensory processing disorder, and one child in the enclosed classroom had a history of otitis media, but was not currently suffering from it. Table 3 shows the demographics of the participating children as reported by their parents.

Table 3. *Demographic information for participating children.*

Classroom	Number of participants	Number of males/females	Age range and mean	Number who have ESL	Number who have attended preschool	Average time spent in preschool (years, hours per week)
Enclosed	24	14M; 10F	5;1-6;3 *M* = 5;6	13	23	2.4, 23
Double	23	12M; 11F	5;1-6;3 *M* = 5;5	0	20	2.7, 18
Triple	25	11M; 14F	5;1-6;3 *M* = 5;6	12 (+ 4 multilingual)	23	2.3, 21
K-6	23	13M; 10F	4;11-6;1 *M* = 5;7	4 (+ 7 multilingual)	22	2.6, 22

Questionnaire Design

The children's questionnaires were based on previous questionnaires used in similar studies with a similar age group by Canning (1999), Greenland (2009), Shield and Dockrell (2004), and Shield et al. (2008). The questionnaire consisted of three main sections. The first section asked children whether they could hear a particular sound source when they were in the classroom, and then if they could, whether or not it annoyed them. Each question was in a dichotomous yes/no format to make it easy for young children. The sound sources assessed were traffic, children outside, fans/air conditioning units, computers/iPads, TVs/Smart Boards, children in other classes, and teachers of other classes.

The second section examined how well children could hear their teacher in different listening scenarios. These scenarios included when all classes were quiet, when adjacent classes were working at their tables, when adjacent classes were doing group work and moving around, when there was outside noise, when the child could not see their teacher's face, and when their own class was being noisy. The third section assessed how well the children could hear their classmate when they were answering their teacher, and when their class was engaged in group work. These two sections used a five point Likert scale (1 = not at all, 2 = not very well, 3 = ok, 4 = well, and 5 = very well) represented as a smiley face scale as used by Canning (1999).

Questionnaire Procedure

Given the young age group, the questionnaires were administered individually to the participating children to ensure each child understood the task. Each participating child was introduced to the researcher and taken individually out of the classroom during the school day to complete the questionnaire. The child was told that he/she was going to fill in a worksheet together with the researcher. The researcher explained that they would ask the child to answer some questions about what they hear in the classroom, and were assured that there were no right or wrong answers. The child was then asked if he/she was happy to participate (which all children were) before commencing the questionnaire. Each question was read out loud by the researcher to the child. For the first section, the child gave his/her answer by replying with a yes or no for each sound source. For the second and third sections, the child responded either verbally or by pointing to the relevant smiley faces indicating how well he/she could hear his/her teacher/classmate in each scenario. The whole procedure took 3-5 mins for each child.

Results

Noise Sources

The percentage of children who reported hearing each noise source is shown in Table 4. High percentages of children could hear the children of other classes, and this increased as class size increased.

Table 4. *Percentage of children in each classroom reporting they could hear a particular sound source.*

Sound Source	Percentage of Children Hearing Sound Source			
	Enclosed (*N* = 24)	Double (*N* = 23)	Triple (*N* = 25)	K-6 (*N* = 23)
Traffic	33	17	68	30
Children outside	67	65	76	61
Fans/air conditioners	63	43	44	43
Computers/iPads	33	39	56	30
TVs/Smart Boards	54	30	76	43
Children in other classes	79	87	88	100
Teachers of other classes	63	65	72	57

Figure 5 shows the percentage of children who found particular sound sources annoying. As described in Shield et al. (2008), previous research into noise annoyance in open plan offices and classrooms have proposed that a minimum of 68% of people need to be satisfied with the environment for it to be acceptable (see p. 12). This means that if over 32% of people are dissatisfied, the environment is unacceptable. In our analyses we call this maximum acceptable dissatisfaction rate the dissatisfaction criterion. As shown in Figure 5, the noise generated from children outside, as well as the noise generated by children and teachers of other classes, was unacceptable in every classroom. Additionally, traffic noise and noise from TVs/Smart Boards was unacceptable in the triple classroom. The triple classroom also had the highest percentage of children reporting annoyance for five out of the seven sound sources.

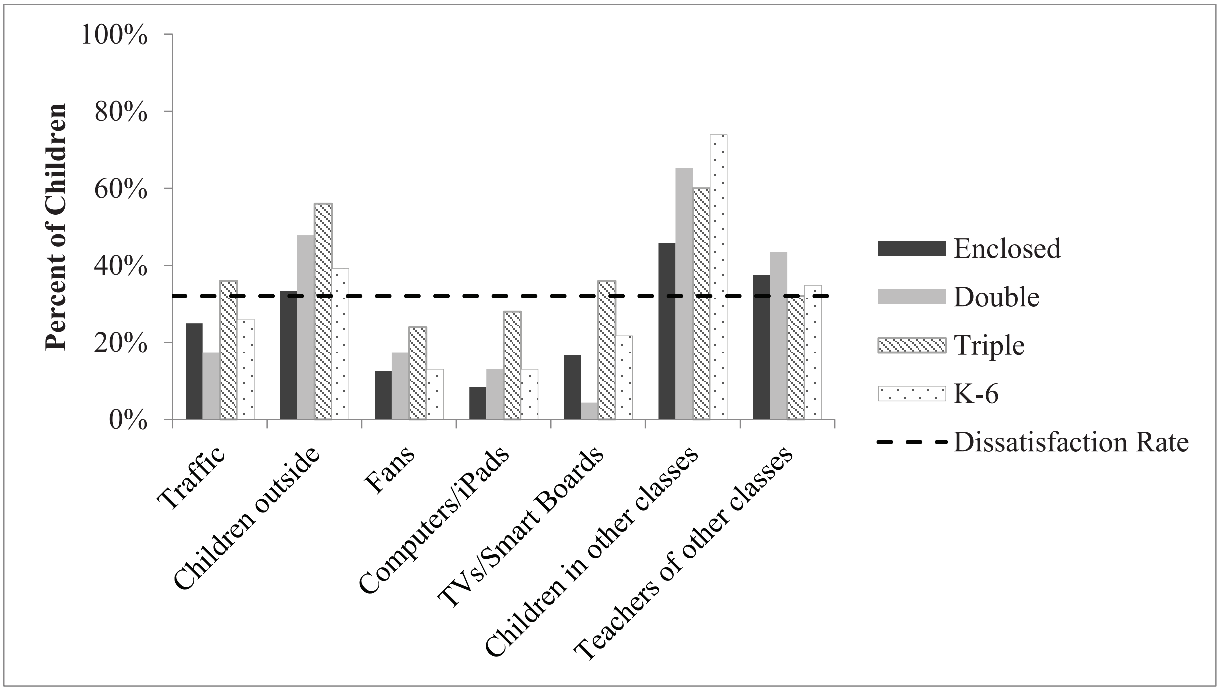

Figure 5. Percentage of children reporting annoyance of different sound sources for each classroom type. The dissatisfaction criterion is set at 32%.

A series of chi-squared tests were run to investigate possible differences in the proportion of children reporting each sound source as annoying between classrooms. There were no significant differences, however, for any of the sound sources $\chi2(3, N = 95)_{traffic} = 2.18$, $p = .54$; $\chi2(3, N = 95)_{children\ outside} = 2.92$, $p = .40$; $\chi2(3, N = 95)_{fans} = 1.48$, $p = .69$; $\chi2(3, N = 95)_{computers/iPads} = 4.07$, $p = .25$; $\chi2(3, N = 95)_{TVs/Smart\ Boards} = 7.73$, $p = .05$; $\chi2(3, N = 95)_{children\ in\ other\ classes} = 4.12$, $p = .25$; $\chi2(3, N = 95)_{other\ teachers} = 0.73$, $p = .87$.

How Well Children Can Hear Their Teacher

Figure 6 shows the mean rating scores of how well children could hear their teacher in different listening scenarios, such as when all classes were quiet, when adjacent classes were working at their tables, when adjacent classes were doing group work and moving around, when there was outside noise, and when their own class was being noisy. A Friedman test combining all classrooms showed a significant difference in mean scores between scenarios $\chi2(4) = 121.44$, $p < .001$. A post hoc Wilcoxen signed-rank test with Bonferroni correction applied $p = .05/10 = .005$ revealed significantly poorer hearing ratings when other classes were doing group work that involved movement or when their own class was noisy compared to the other three listening scenarios $Z_{outside\ noise\ vs.\ moving} = -4.03$, $p < .001$, $r = 0.41$; $Z_{tables\ vs.\ moving} = -3.91$, $p < .001$, $r = 0.40$; $Z_{all\ classes\ quiet\ vs.\ moving} = -7.53$, $p < .001$, $r = 0.77$; $Z_{outside\ noise\ vs.\ own\ class\ noisy} = -3.74$, $p < .001$, $r = 0.38$; $Z_{tables\ vs.\ own\ class\ noisy} = -3.87$, $p < .001$, $r = 0.40$; $Z_{all\ classes\ quiet\ vs.\ own\ class\ noisy} = -7.52$, $p < .001$, $r = 0.77$. Hearing ratings were also significantly poorer when other classes were working at their tables or there was outside noise compared to when all classes were quiet $Z_{tables\ vs.\ quiet} = -6.80$, $p < .001$, $r = 0.70$; $Z_{outside\ noise\ vs.\ quiet} = -5.62$, $p < .001$, $r = 0.58$. This means that the child's ability to hear their teacher in different scenarios ordered from best to worst was:

1) When all classes are quiet
2) When other classes are working at their tables or there is outside noise
3) When other classes are doing group work with movement or their own class is noisy.

A series of Kruskal Wallis tests were conducted to assess possible differences in the children's mean hearing ratings between classrooms. There were no significant differences between classrooms when all classes were quiet $H(3) = 1.86$, $p = .60$, when other classes were working at their tables $H(3) = 6.716$, $p = .10$, when there was noise from outside $H(3) = 5.65$, $p = .13$, or when their own class was being noisy $H(3) = 2.06$, $p = .56$. However, there was a statistically significant difference between the classrooms when other classes were doing group work and moving around the classroom $H(3) = 9.72$, $p = .02$. A post-hoc test using Mann-Whitney U tests with Bonferroni correction $p = .05/6 = .0083$ showed that the hearing rating for the double classroom (where the classes were closest together) was significantly poorer than the enclosed classroom $U = 150$, $Z = -2.75$, $p = .006$, $r = 0.40$; see Figure 6.

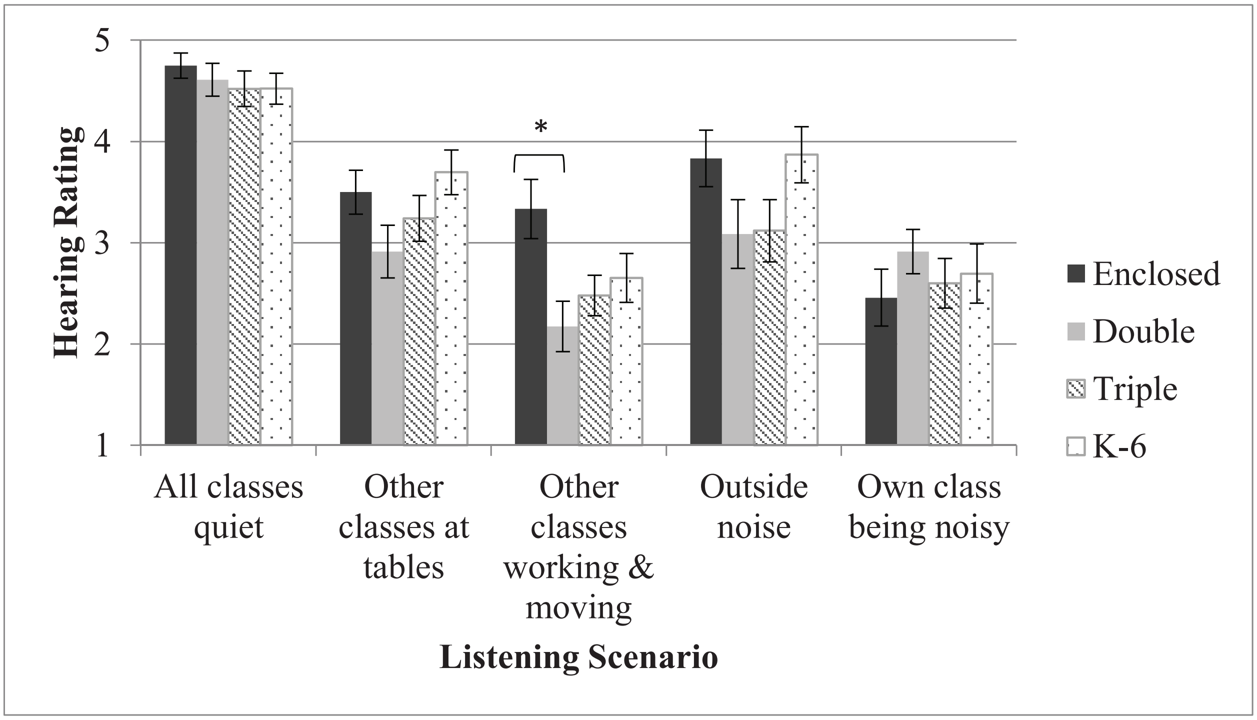

Figure 6. Mean hearing ratings for different listening scenarios by classroom type (1 = not at all, 2 = not very well, 3 = ok, 4 = well, and 5 = very well). Error bars show the standard error of the mean. *p = .05/6 = .0083.

Figure 7 shows the percentage of children who reported not being able to hear their teacher very well or at all in different scenarios. These ratings represent those not satisfied with the listening environment. Again, the dissatisfaction criterion was set at 32% (see Shield et al., 2008), so if over 32% of children reported not being able to hear their teacher very well or at all, then the listening environment was considered unsatisfactory. Notice that the listening environment when a child was trying to hear their teacher while their own class was being noisy was unsatisfactory for all schools. This was also the case when adjacent classes were doing group work that involved movement, even for the enclosed classroom (which was just over the 32% dissatisfaction criterion at 33%). Although there were no significant differences in proportions between classrooms for any of the scenarios $\chi2(3, N = 95)_{\text{all classes quiet}} = 0.99$, $p = .80$; $\chi2(3, N = 95)_{\text{tables}} = 6.31$, $p = .10$; $\chi2(3, N = 95)_{\text{moving}} = 6.75$, $p = .08$; $\chi2(3, N = 95)_{\text{outside noise}} = 5.81$, $p = .12$; $\chi2(3, N = 95)_{\text{teacher's face hidden}} = 2.40$, $p = .49$; $\chi2(3, N = 95)_{\text{own class noisy}} = 1.80$, $p = .62$, there was a trend in the percentage of children who struggled to hear their teacher while adjacent classes were doing group work that involved movement that was related to the distances between classes. That is, the smaller the distance between classes (hence the more distracting the noise is expected to be), the higher the percentage of children was who could not hear their teacher very well or at all when the other classes were being noisy. Furthermore, it was only the double classroom (which had the least distance between classes) that reported an unsatisfactory listening environment when the adjacent class was working at their tables. Additionally, outside noise interfered with how well the children could hear their teacher for the double and triple classrooms, and not being able to see their teacher's face when they were talking was problematic in the enclosed classroom.

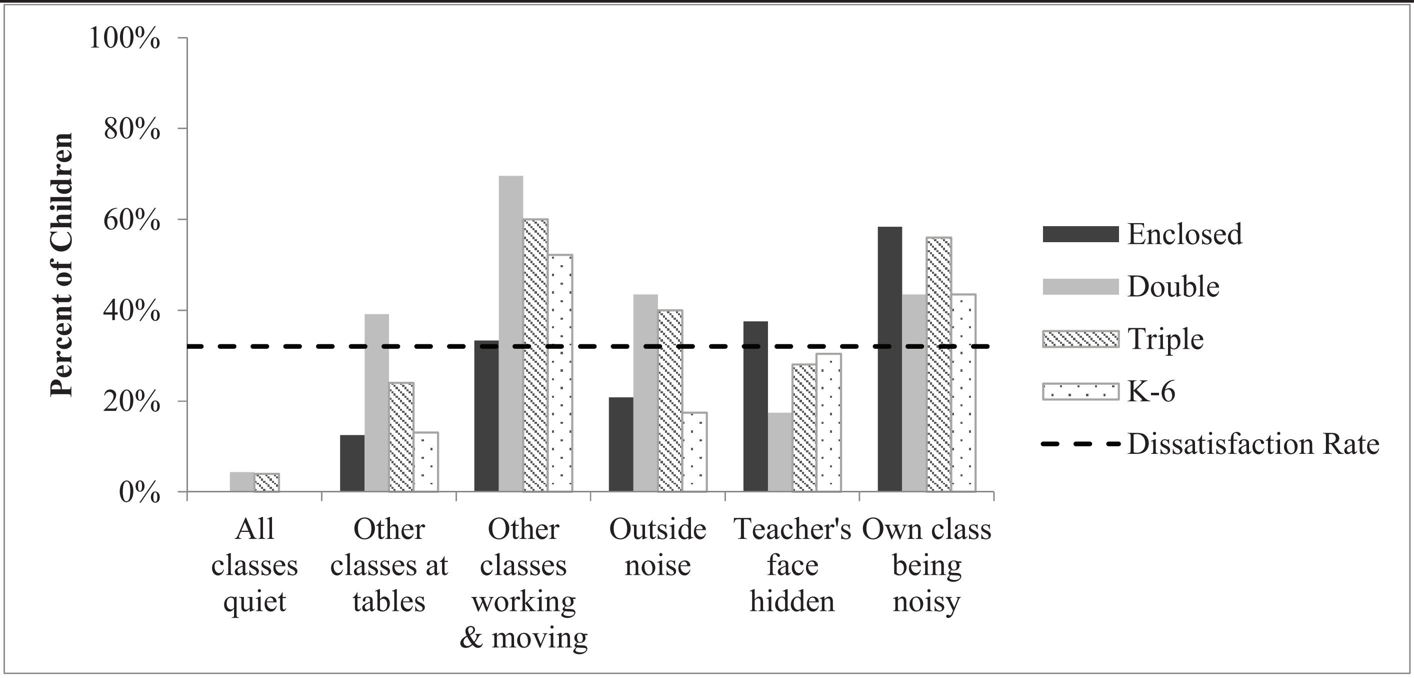

Figure 7. Percentage of children who reported not being able to hear their teacher very well or at all for different listening scenarios. The dissatisfaction criterion is set at 32%.

How Well Children Can Hear Their Classmates

Table 5 shows the children's mean hearing ratings of how well they could hear their classmate when their classmate was i) answering their teacher and ii) when they were working in groups. No significant difference was found between classrooms for either scenario as determined by a Kruskal-Wallis test (see Table 5). Table 5 also shows the percentage of children who reported that they could not hear their teacher very well or at all (i.e. those dissatisfied with the listening scenario). This exceeded the acceptable rate of 32% for the double classroom. This classroom had the least distance between classes and one of the smallest areas for the number of children, so the close proximity of the 44 children may explain why there was a high proportion of children who had difficulty hearing their classmates when the classes were carrying out group work activities.

Table 5. *Children's mean hearing ratings of how well they can hear their classmates and the dissatisfaction criterion (D; percentage of children who reported they cannot hear their teacher very well or at all) in different scenarios.*

Scenario	Enclosed Classroom			Double Classroom			Triple Classroom			K-6 Classroom			Kruskal-Wallis Test	
	M	*SD*	D (%)	*M*	*SD*	D (%)	*M*	*SD*	D (%)	*M*	*SD*	D (%)	*H*(3)	*p*
Answering teacher	4.38	0.88	4.17	3.83	1.15	13.04	3.92	1.15	8.00	3.87	1.22	13.04	4.02	0.26
Working in groups	3.79	1.10	17.67	3.13	1.46	43.48*	4.10	1.15	12.00	3.74	1.01	13.04	6.49	0.09

Note. * indicates percentage of children dissatisfied is unacceptable.

Comparison of Children's Ratings with Quantitative Acoustic Data

A series of correlations were run to assess the relationship between the mean hearing ratings by the children in each classroom and the average noise levels, SNRs, and STI scores reported for these classrooms in Mealings, Buchholz, et al. (2015) and shown in Table 2. The average unoccupied ambient noise levels were used with the children's ratings of how well they could hear their teacher when all classes were quiet, the average intrusive noise levels during quiet activities were used with the children's ratings of how well they could hear their teacher when other classes were working at their tables, and the average intrusive noise levels during noisy activities were used with the children's ratings of how well they could hear their teacher when other classes were doing group work with movement. A moderate-to-strong negative correlation was found between noise level and hearing rating $r = -0.68$, $N = 12$, $R^2 = 0.46$, $p < .05$, indicating that the children's report of how well they could hear their teacher decreased as noise level increased. A moderate-to-strong positive correlation was found between SNR and hearing rating $r = 0.66$, $N = 12$, $R^2 = 0.43$, $p < .05$, indicating that the children's report of how well they could hear their teacher increased as SNR increased. A moderate-to-strong positive correlation was also found between STI score and hearing rating $r = 0.69$, $N = 12$, $R^2 = 0.48$, $p < .05$, indicating that the children's report of how well they could hear their teacher increased as STI scores increased.

An additional reason for examining these relationships was to compare them to the current acoustic recommendations for classrooms with 5- to 6-year-old children (see Table 6). Figure 8 shows the regression lines for the average hearing rating of the children with the noise levels, SNRs, and STI scores. As there was error in both the noise levels/SNRs/STI scores and the hearing ratings and an assumption about how the noise conditions matched the questionnaire scenarios, we have plotted two regression lines: the regression of hearing rating on acoustic measurement (shown by the dotted line), which can be used to estimate the hearing rating given an acoustic measurement, and the regression of acoustic measurement on hearing rating (shown by the solid line), which can be used to estimate the acoustic measurement needed to achieve a given hearing rating. To estimate what noise level/SNR/STI score is needed to get a rating of 4 (which means the child can hear their teacher "well"), we used the regression line of acoustic measurement on hearing rating (i.e. the solid line) and compared these values to the recommendations. As shown in Table 6, there was a close match between our values and those recommended in the literature, reinforcing the importance of meeting these recommendations to ensure adequate speech perception in the classroom.

Finally, a fourth correlation analysis was run to assess whether there was a relationship between the children's mean hearing ratings and their mean speech perception scores on the MDDB Classroom Speech Perception Test (Mealings, Demuth, et al., 2015a) for the relevant scenarios as reported in Mealings, Demuth, et al. (2015b) and Table 2. A strong positive correlation was revealed between the children's mean hearing rating and speech perception score $r = 0.87$, $N = 8$, $R^2 = 0.75$, $p < .05$, indicating that the children's report of how well they could hear their teacher in quiet and noisy conditions strongly represented their actual ability to hear their teacher in different listening situations. A speech perception score of 71% corresponds to a hearing rating of 4 (i.e. "well") as shown by the solid line in Figure 8.

Table 6. *Measured value versus recommended value for classroom noise level, signal-to-noise ratio, and speech transmission index score.*

Acoustic Variable	Measured Value	Recommended Value
Noise Level	< 45.9 dBA	Occupied: < 50 dBA (Berg et al., 1996) Unoccupied: < 35-45 dBA (Australia/New Zealand Standard AS/NZS2107:2000, 2000)
SNR	> +14.5 dB	> +15 dB (Crandell & Smaldino, 2000)
STI	> 0.75	> 0.75 (Greenland & Shield, 2011)

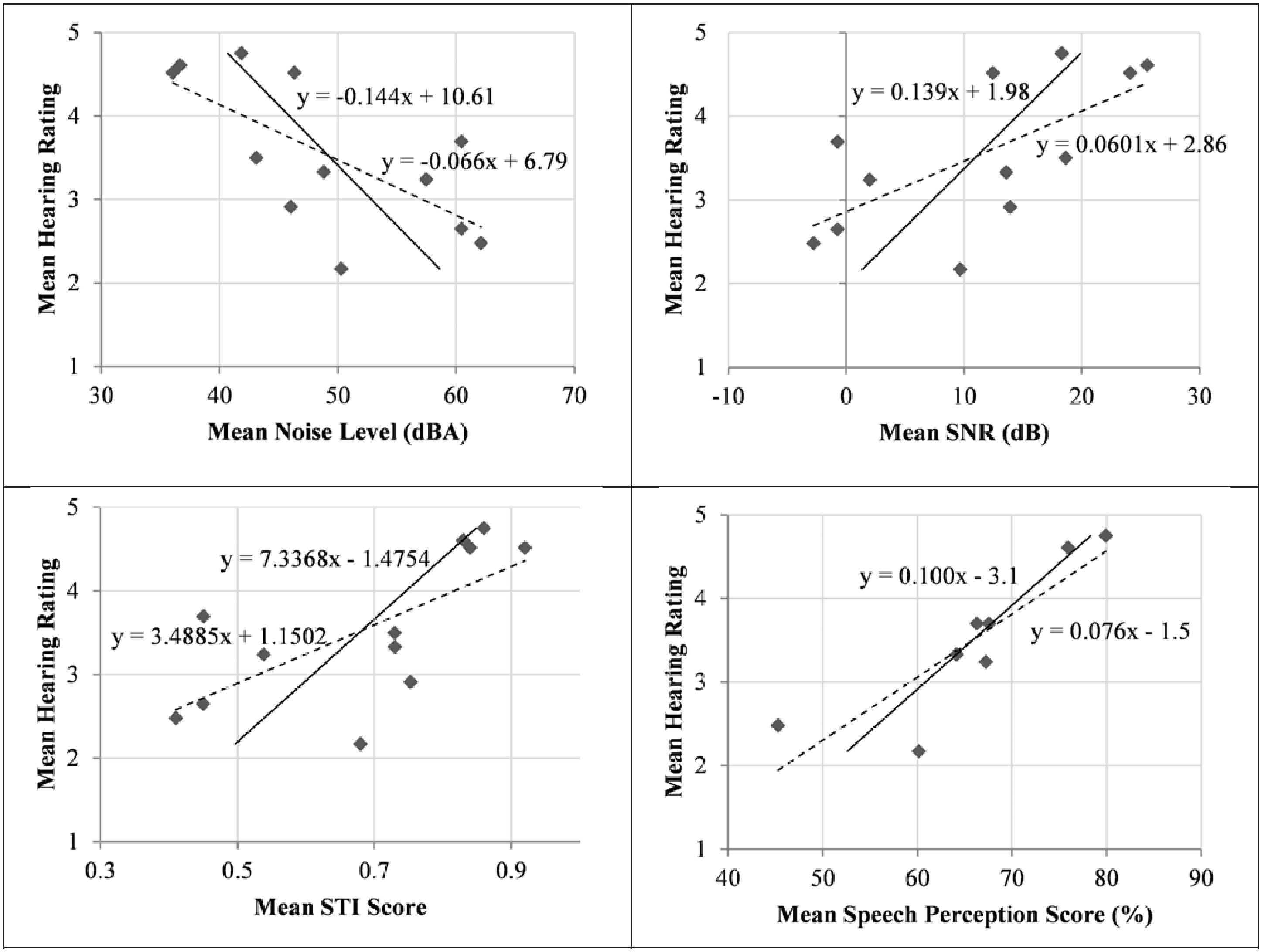

Figure 8. Children's mean hearing ratings of how well they can hear their teacher compared to previously measured classroom noise levels, signal-to-noise ratios, speech transmission index scores, and MDDB Classroom Speech Perception Test scores for similar scenarios. The dotted line shows the regression of hearing rating on acoustic parameter, and the solid line shows the regression of acoustic parameter on hearing rating, where a mean hearing rating of 1 = cannot hear teacher at all, 2 = cannot hear teacher very well, 3 = can hear teacher ok, 4 = can hear teacher well, and 5 = can hear teacher very well.

Discussion

The aim of this study was to compare how Kindergarten children in four different sized open plan and enclosed classrooms perceive their listening environment, how well they can hear their teacher and classmates in different listening scenarios, how their perceptions relate to the acoustics of these classrooms measured by Mealings, Buchholz, et al. (2015), and what acoustic conditions are required for children to rate they can hear their teacher well.

As predicted, a high proportion (60-76%) of children in the open plan classrooms were annoyed by the children of other classes, which is well above the maximum acceptable rate of 32% (see Figure 5). Surprisingly, 46% of children in the enclosed classroom also reported being annoyed by the children in the classroom next door despite there being an operable wall between them and intrusive noise levels being within those recommended (Mealings, Buchholz, et al., 2015). Although the 46% dissatisfaction rate for the enclosed classroom is markedly less than that for the other three classrooms, it is still substantially higher than the 32% dissatisfaction criterion used by Shield et al. (2008). Additionally, unacceptable proportions of children were annoyed by the teachers of other classes in the open plan classrooms (which was also found by Shield et al., 2008) but also in the enclosed classroom. It is likely that this noise annoyance in the enclosed classroom was largely due to the shared storeroom door always being open, which allowed sound to be transmitted between classes. This annoyance is an important finding to take note of as it shows that some children are still sensitive to noise, even if it is thought to be at an acceptable level (Mealings, Buchholz, et al., 2015). Most concerning, however, was the triple classroom, which had the highest proportions of children who found the noises annoying for five out of the seven sound sources examined. This classroom also had some of the highest noise levels, which resulted in SNRs and STI scores to be well below those recommended (see Table 2). This is likely related to the classroom having no acoustic treatment, so these noises probably had a greater effect on the children. These results suggest that it is likely that a fully enclosed, acoustically treated classroom is needed to achieve acceptable listening conditions for all children. The results also show the importance of closing doors/windows during critical listening activities, and making sure the teacher is facing the children when they are talking to aid in speech perception. Furthermore, it may be beneficial for classrooms to install sound field amplification systems to increase the SNR throughout the room. These systems are not suitable, however, for open plan classrooms as they will disturb the other classes, which is a further shortcoming of these spaces.

The results also revealed, as predicted, that the children in the enclosed classroom were able to hear their teacher better than those in the open plan classrooms when the other classes were engaged in group work and moving around the class. Following from Shield et al. (2008), we also predicted that the children in the larger open plan classes, which had higher noise levels, would have more trouble hearing their teacher than those in the smaller open plan classes. Interestingly, however, the reverse was true with the trend being related to the distance between class bases rather than the number of children in the area. That is, the smaller the distance between classes, the higher the proportion of children was who could not hear their teacher very well or at all when the other classes were being noisy. Although the noise levels were lower in the double classroom compared to the larger open plan classrooms (Mealings, Buchholz, et al., 2015), the closer proximity of the two classes meant that the speech from the adjacent class was likely to be more intelligible, hence more distracting. This is because it is harder for children to segregate the target and masker speech sounds when the masker is multi-talker babble compared to speech shaped noise or non-lingual noise, due to informational masking (Leibold & Buss, 2013; Prodi et al., 2013). In the larger classrooms, the noise should be more diffuse hence less intelligible. This is likely to explain why 70% of children in the double classroom, which only had 2 m separating the classes compared to 6-7 m in the other open plan classrooms, could not hear their teacher very well or at all when the other class was engaged in group work activities involving movement. This also helps to explain why it was only this classroom that reported an unacceptable proportion of children who could not hear their classmates very well or at all during group work activities. This shows the importance of having adequate separation (i.e. at least 6.5 m; Shield et al., 2010) between classes in open plan spaces, or more effectively, having acoustic barriers between classes to minimize noise transmission and enhance the children's ability to hear their teacher and classmates.

Another interesting finding from the study was that the mean score of how well the children could hear their teacher when their own class was being noisy was "not very well" to "ok" in all classrooms, irrespective of their size or design. These results show that noise during group work can be excessive in any classroom, so it is important that teachers try to control it. It also shows the importance of having sufficient acoustic absorption in classrooms as this will help minimize the effect of this noise (Siebein, Gold, Siebein, & Ermann, 2000).

An additional aim of this study was to relate the children's perceptions of the listening environment to the acoustic measures of the classrooms and the children's speech perception test results (Mealings, Buchholz, et al., 2015; Mealings, Demuth, et al., 2015b). This allowed us to examine whether the children's experiences in the classroom are reflective of the quantitative measures. Using this relationship we were also able to assess the appropriateness of current acoustic recommendations for classrooms with 5- to 6-year-old children. The moderate-to-strong negative correlation found between how well children reported hearing their teacher in different scenarios and the noise levels recorded during similar scenarios shows the direct effect of how high noise levels interfere with the children's ability to hear their teacher. The regression line for this relationship revealed that young children may need slightly lower noise levels than the recommended 50 dBA occupied noise limit suggested by Berg et al. (1996) to hear their teacher well. This may also explain why the higher than expected proportion of children in the enclosed classroom reported being annoyed by the children in the adjacent class, as in the noisier periods this level was above the 45.9 dBA limit our study suggests (see Mealings, Buchholz, et al., 2015 and Table 2). The moderate-to-strong positive correlations between how well children reported hearing their teacher in different scenarios with the SNRs and STI scores for similar scenarios demonstrates that these measures provide a good estimate of how well speech is heard by children in the classroom. Additionally, the SNR and STI score that corresponded to children hearing their teacher "well" was very similar to those recommended in the literature (see Table 6), reinforcing the importance of meeting these recommendations to ensure adequate speech perception in the classroom. Finally, the strong positive correlation revealed between the children's mean hearing ratings and the MDDB speech perception scores indicate that the children's report of how well they can hear their teacher strongly represents their actual ability to hear their teacher.

Limitations of the Study and Future Directions

The main limitation of this study was that it involved children from only four schools, hence it only allowed a relatively small number of participants to be involved for a questionnaire design. It would therefore be beneficial to continue this study and examine a wide range of classrooms that could be grouped together by design type, hence providing more participants and more power for the statistical analysis. This would allow for more generalized conclusions to be drawn about how children cope in different types of classrooms. It would also allow us to better understand which designs and acoustic treatments are appropriate and what the maximum number of children in a classroom area, and/or minimum spacing between class bases is needed in open plan areas to maintain adequate speech perception. It is important that this future research uses multiple approaches that take into account the physical acoustic conditions in the classrooms (i.e. the noise levels, SNRs, and STI scores) as well as how the children perceive the listening environment, as they are the ones who need to be able to function well in the classroom. It would also be worthwhile to explore children's perceptions of how well they can hear their teacher while taking into consideration the class activity, noise level, and the teacher's vocal quality. This is important as the loudness and quality of a teacher's voice is affected differently depending on the type and intensity of the background noise (Rantala, Hakala, Holmqvist, & Sala, 2015), so it is likely that this will also affect children's speech perception.

In addition, it would be beneficial to take this research further to assess how noise affects how well children function in the classroom. The results of the current study show that children's perceptions of noise and hearing is related to their ability to perceive speech, but future research is needed to examine how this affects their ability to learn new concepts during different activities and in different classrooms. Furthermore, a recent study by Valente, Plevinsky, Franco, Heinrichs-Graham, and Lewis (2012) showed that even if children recognize speech accurately, increasing background noise and reverberation can negatively affect secondary tasks such as comprehension. Therefore, examining this link between noise, speech perception, comprehension, and learning will help provide important insight into how classroom configuration may affect children's educational progression.

It would also be interesting to investigate the perceptions of classroom noise from children in different grades. A recent study by Prodi, Visentin, and Feletti (2013) demonstrated that older children can adapt better to different noise types and acoustical room conditions in relation to their speech perception accuracy and/or response time. Therefore, examining children's perceptions of noise, along with their speech perception abilities and learning outcomes, would help us to further examine the different effects of classroom noise on children depending on their age. These results would provide further understanding about what classroom designs are appropriate for different grades.

In addition, it would be helpful to investigate how children with special educational needs such as hearing impairments, auditory processing disorders, language delays, and attention deficits find different classroom listening environments. These children are increasingly being integrated into mainstream schools and need noise levels to be 10 dBA lower than their peers, so it is vitally important to ensure the listening environment for these children is favourable (Crandell & Smaldino, 2000; Konza, 2008; MacKenzie & Airey, 1999; Nelson & Soli, 2000). A recent study by Connolly, Dockrell, Shield, Conetta, and Cox (2014) found that adolescents aged 11- to 16-years-old with special educational needs were more annoyed by noise and more sensitive to the negative effects of noise and its consequences than their peers. It would therefore be worthwhile to explore these effects in younger children. Furthermore, it would be beneficial to explore the perceptions of noise by children who have ESL, as noise has been shown to have a greater impact on speech perception for this population (Nelson & Soli, 2000; Nelson et al., 2005). In the present study, 31% of the participants identified as having ESL. While we did run analyses comparing the perceptions of children with ESL to those who had English as their first language, we did not find any significant differences between the two groups. Furthermore, we did not have enough information on these children's language backgrounds to draw any firm conclusions about this effect, hence these results were not reported in this study. Therefore, further investigation involving a larger number of participants and more information on their language backgrounds is needed to fully examine this factor.

Overall, the results of this study suggest that it would be beneficial for Australia (and other countries) to implement the Australia/New Zealand Acoustics Standards (2000) for unoccupied classrooms and the recommended acoustic limits for occupied classrooms referred to and calculated in this paper. Modifications that can be made in classrooms to help achieve these acoustic limits include i) having 90% absorption on the ceiling and walls and limiting ceiling height to 3.5 m to control reverberation (Shield et al., 2010; Siebein et al., 2000; Wilson, 2002), ii) making sure air conditioning systems and equipment have low noise level ratings to reduce ambient noise levels (Wilson, 2002), iii) using sound field systems to increase the SNR and minimize teacher's vocal strain (Massie & Dillon, 2006a, 2006b), and iv) using FM systems with hearing impaired children (Wilson, 2002). The teachers should also gather children as close as possible to them and make sure the children can see their face to further aid speech perception in the classroom (Kim, Sironic, & Davis, 2011; Sumby & Pollack, 1954). Once more research has been conducted in a variety of schools and with different populations, it may also be worthwhile to have enforced criteria for classroom designs and acoustic treatment to ensure classrooms meet these standards so all children are comfortable and able to learn effectively in every educational setting.

Conclusion

The results of this study show that many of the children in open plan classrooms are annoyed by the noise generated by the children and teachers of other classes in the same open plan space. This noise significantly affects how well children can hear their teacher and classmates, especially when there is only a small distance separating the classes. The results also show the benefit of having an operable wall to separate classes and reduce noise transmission. Even then, however, some children may still be affected by noise in an adjacent class when it is engaged in loud activities, especially when, as in this case, the doors to a storeroom opening into both classrooms are left open. Additionally, children in all the classrooms examined found it difficult hearing their teacher when their own class was engaged in group work because of the high noise levels. The results of this study show the importance of meeting the recommended acoustic limits for classrooms with 5- to 6-year-old children to ensure children can hear their teacher well in the classroom. Therefore, controlling noise in all classrooms and ensuring that they are built in a suitable layout with appropriate acoustic absorption and adequate separation between classes is essential for children's educational progression.

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An Assessment of Open Plan and Enclosed Classroom Listening Environments for Young Children: Part 2 – Teacher's Questionnaires

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Purpose: **Recently open plan classrooms have been growing in popularity in primary schools. This paper is part of a two-part study that investigated how classroom noise affects teaching and learning in different types of open plan and enclosed classrooms. Part 1 of this research investigated Kindergarten children's perceptions. This study explored the teachers' perspectives.**

Method: **Sixteen Kindergarten and Year 1 teachers (four from enclosed classrooms, three from double classrooms, six from triple classrooms, and three from a Kindergarten-to-Year 6 classroom) completed a questionnaire about their teaching background and style, the demographics of the children in their class, how they perceive the classroom listening environment, what internal and external noise sources are present, how they cope with noise, and their perceptions of open plan versus enclosed classrooms.**

Results: **Teachers of larger, noisier classrooms (especially those that were not acoustically treated) were more distracted by noise and found speech communication significantly more difficult than the teachers of smaller, quieter classrooms. They also needed to elevate their voice and experienced vocal strain and voice problems more often.**

Conclusions: **These results suggest that noise is a problem particularly in large, untreated open plan classrooms, and it negatively impacts teachers. This suggests that smaller enclosed classrooms are more appropriate learning spaces for teachers of young children. Differences between the teacher's and children's perceptions of the classroom environments from Part 1 of this study are also discussed.**

Introduction

Recent changes in teaching methods has seen open plan classrooms growing in popularity, particularly in primary schools (Shield, Greenland, & Dockrell, 2010). This paper is the second part of two qualitative questionnaire studies that aimed to provide insight into the acoustic suitability of open plan learning spaces for listening activities with young children. The first study investigated the Kindergarten (i.e. 5- to 6-year-old) children's perceptions of noise and its effect on learning in different types of classrooms. The current paper investigated how the teachers of these different types of classrooms perceive their teaching environment and compares this to the children's perceptions.

Changing Teaching Methods

Up until the 1960's, the main teaching style was didactic with children seated in rows of desks while they listened to their teacher who taught from the front (Shield et al., 2010). During the progressive educational reform in the 1960's, however, there was a major shift in teaching style to a more 'child-centred' approach which focused on experiential learning and group work (Brogden, 1983; Shield et al., 2010). This change in teaching style also saw the emergence of open plan classrooms to better facilitate these teaching methods (Shield et al., 2010). In the 1980's, however, there was shift back to more traditional values and teaching methods, hence many open plan classrooms were converted back to enclosed classrooms (Shield et al., 2010).

Nonetheless, the 21st century has seen a return to progressive educational styles such as constructivism, which is predominant in Western countries including Australia (Rowe, 2006). Constructivism is currently a major feature of teacher training courses with didactic teaching methods seen as being boring and old-fashioned (Rowe, 2006; Westwood, 1999). Constructivist methods focus on the teacher being the facilitator who provides opportunities for the children to acquire their own knowledge and meaning, rather than the teacher being the instructor (Rowe, 2006). This change in teaching method has been demonstrated in a recent study by Greenland (2009) which assessed 84 teachers' perceptions of semi-open plan classroom environments from 12 schools in the United Kingdom. In this study, 58% of teachers surveyed used a child-centred style compared to only 15% of teachers who used a didactic whole class teaching style (Greenland, 2009). The remaining 27% of teachers used a mix of both teaching methods (Greenland, 2009). This change has also been found in New Zealand in a study by Wilson (2002) which involved 122 teachers from seven schools in Auckland. This study reported that traditional didactic style only made up 12% of teaching time, compared to group work which made up 38% of teaching time. Furthermore, the majority of teachers (i.e. 71%) tended to walk around the class when teaching rather than teaching from the front.

This change in teaching methods has again seen the reemergence of open plan classrooms, often renamed as '21st century learning spaces' (Shield et al., 2010). These spaces are thought to better suit the range of activities and group work focus of this more child-centred teaching philosophy (Hickey & Forbes, 2011). They are also thought to aid children's social development and make them take more responsibility for their work (Brogden, 1983; Hickey & Forbes, 2011). Additionally, open plan classrooms are seen to benefit teachers as they promote the sharing of skills, ideas, and experiences (Brogden, 1983). They also allow for team-teaching, joint planning and organisation, provide access to a wide range of resources and equipment, allow teachers to share children, thereby reducing child-teacher personality clashes, and facilitate a more cooperative and supportive teaching and learning atmosphere (Brogden, 1983; Hickey & Forbes, 2011). The teachers of the semi-open plan classrooms in the study by Greenland (2009) generally agreed that open plan classrooms enabled a wider range of activities for the children than enclosed classrooms, and that children were more independent and responsible, and benefited socially from the more open plan space. However, the teachers also agreed that children in open plan classrooms were more easily distracted visually and by noise compared to children in enclosed classrooms.

Classroom Acoustics

The current recommendations for classrooms in Australia are that the unoccupied noise level should be < 35-45 dBA, and the unoccupied reverberation time should be < 0.4-0.5 seconds (Australia/New Zealand Standard, 2000). Like many countries, however, these standards are only for unoccupied classrooms. For occupied classrooms, the literature suggests that noise levels should be < 50 dBA (Berg, Blair, & Benson, 1996). Additionally, the signal-to-noise ratio (SNR; which compares the teacher's speech level with the noise level), should be > +15 dB (i.e. the teacher's voice should be 15 dB above the noise level) throughout the classroom (American Speech-Language-Hearing Association, 2005; Crandell & Smaldino, 2000). These acoustic conditions, however, are rarely achieved in the classroom (see American Speech-Language-Hearing Association, 2005, for a review).

One of the problems with open plan classrooms is that they can have high noise levels due to different class bases engaging in different activities. A recent study by Mealings, Buchholz, Demuth, & Dillon (2015) investigated the acoustics of four different types of classrooms: an enclosed classroom (with 25 children), a double classroom (with 44 children), an untreated, fully open plan triple classroom (with 91 children), and a Kindergarten-to-Year 6 (K-6) purpose-built semi-open plan '21st century learning space' (with 205 children). Mealings, Buchholz, et al. (2015) found much higher intrusive noise levels coming from the other classes sharing the space in the triple classroom and the K-6 classroom compared to the double and enclosed classroom. This resulted in SNRs to be well below those recommended. When all classes including the participating class were engaged in group work activities, however, the noise levels were excessive in all classroom types.

Effects of Noise on Teachers' Vocal Health

Many research studies have shown the adverse impact of classroom and environmental noise on teachers' (and students') health; noise raises blood pressure, increases stress levels, causes headaches, and results in fatigue (see Anderson, 2001, and Shield et al., 2010, for a review of these studies). The high noise levels that are especially present in open plan classrooms can make the environment seem chaotic (Hickey & Forbes, 2011). This can result in teachers feeling distracted, anxious, and stressed (Hickey & Forbes, 2011). Additionally, teachers in any classroom are already prone to experiencing vocal strain from their constant vocal use; research shows that while only 5% of the general population experiences vocal fatigue, it is experienced by 80% of teachers (Gotaas & Starr, 1993). This puts them at high risk of vocal abuse and developing pathological vocal problems from the need to continually raise their voice above what is comfortable so they are heard (Gotaas & Starr, 1993; Smith, Gray, Dove, Kirchner, & Heras, 1997). In noisy conditions, teachers report decreased vocal comfort and vocal control, and increased vocal fatigue compared to quiet conditions (Hunter et al., 2015). Teachers in classrooms with poor acoustics are more likely to believe their job contributes to voice and throat problems and take sick days from work (MacKenzie & Airey, 1999; Smith et al., 1997). Interestingly, however, teachers' vocal use depends on the type of noise present in the classroom. A recent study by Rantala, Hakala, Holmqvist, and Sala (2015) found that in the presence of ambient noise (i.e. noise from equipment, air-conditioning system, and outside noise such as traffic), teachers tend to raise the level of their voice. Furthermore, teachers who work in noisy classrooms tend to speak louder outside of work compared to teachers in quieter classrooms. During child-generated activity noise, however, teachers tend to change their voice quality, rather than their vocal level. This was demonstrated by more uneven vocal fold vibration for teachers working in higher activity noise levels than those working in lower noise levels. These vocal changes may lead to weakened muscle tone and long term vocal effects (Rantala et al., 2015). We would therefore expect vocal health problems to be a major issue for teachers in poorly designed open plan classrooms. There are, however, strategies that teachers can use to help minimize the need to raise their voice. These include clapping their hands or using a whistle to get the children's attention, using visual cues to get the children's attention, gathering the class close to them, changing the seating arrangement, changing the teaching activity, and arranging a compatible activity schedule with other teachers if in an open plan classroom (Greenland, 2009; Rantala et al., 2015).

Perceptions of Noise by Teachers

Recently there has been growing evidence that the physical work environment influences both the workers' performance and their job satisfaction (see Vischer, 2007, for a review). According to Vischer (2007), ergonomic factors such as lighting, noise, and space affect people's ability to work. When these factors are not suitably considered in the workspace design, they can elevate stress amongst workers (McCoy & Evans, 2005). This stress can result in decreased performance, motivation, comfort, and social interaction (see McCoy & Evans, 2005, and Vischer, 2007, for reviews).

While noise from their own class was the most common reported noise source (reported by 83% of teachers in semi-open plan classrooms) in the study by Greenland (2009), noise from other classes was reported by 62% of teachers as a dominant noise source and noise from other teachers was reported by 37% of teachers. Twenty-five percent of teachers reported that the noise from other classes was highly distracting. Teachers in classrooms with more than four class bases were significantly more distracted by noise and reported higher perceived noise levels than teachers in classrooms with less than four class bases. Ten percent of teachers reported that they frequently or more often experienced voice/throat problems. Grouping the class closely around them was the most frequently reported coping strategy which was used by nearly half the teachers.

In the New Zealand study by Wilson (2002), most of the teachers were from enclosed classrooms, but the acoustic quality of these classrooms varied widely. As a result, noise was still a major problem in these classrooms with 71% of teachers reporting inside noise problematic and 59% of teachers attributed this to the children. Forty-seven percent of teachers said that noise from other classes was problematic. Significantly more teachers from classes with poor acoustic ratings reported they needed to raise their voice often or always (55%) and experienced vocal strain (41%). Group work required the highest vocal level with 49% of teachers needing to raise their voice during this teaching style which is concerning as this was the most frequent teaching style.

The results of these studies indicate that noise can be problematic for teachers in both semi-open plan classrooms and enclosed classrooms. However, because different surveys were used for these studies and a broad range of classrooms were clustered together for each study, it is difficult to make direct comparisons across the classroom types to determine which classrooms provide better teaching environments. Additionally, these studies only report qualitative data from the teachers' perspectives. It has long been known that young children are more affected by poor room acoustics than adults (Nelson & Soli, 2000; Picard & Bradley, 2001; Prodi, Visentin, & Feletti, 2013). Many studies have shown that children find it more difficult discriminating and understanding speech than adults especially in noisy and/or reverberant environments (Crandell & Smaldino, 2000; Finitzo-Hieber & Tillman, 1978; Johnson, 2000; Leibold & Buss, 2013; Nelson & Soli, 2000; Nishi, Lewis, Hoover, Choi, & Stelmachowicz, 2010; Whitlock & Dodd, 2008). This is because children's auditory systems are still developing neurologically, so they may not be as efficient as adults at using top-down processes, or may still be developing the skills adults use to aid speech perception (Boothroyd, 1997; Nelson & Soli, 2000; Wilson, 2002). This raises the importance of considering the children's perceptions of noise in the classroom as well as the teachers' perceptions. However, there have been no studies to our knowledge that directly compare teachers' and children's perceptions of classroom environments. Therefore, comparing the teachers' and children's perceptions in the present study would provide valuable insight as to whether particular classrooms are suitable for both the teachers and children to successfully work in.

Present Study

The purpose of the present study, therefore, was to directly compare how the teachers in the four different types of open plan and enclosed classrooms used in the classroom acoustics study by Mealings, Buchholz, et al. (2015) perceive their teaching environment using the same questionnaire and methodology across participants. Investigating the perceptions of the teachers is of vital importance as they are often not consulted in the decision-making process when classrooms are converted to open plan designs (Hickey & Forbes, 2011). Additionally, this paper compares the teachers' perceptions to the children's perceptions reported in Part 1 of this two-part study (Mealings, Dillon, Buchholz, & Demuth, 2015). This is an important comparison as children struggle listening in noisy environments more than adults (see Nelson & Soli, 2000), so this needs to be taken into consideration when adults are designing classrooms. Therefore, the aim of the current paper was to answer the following research questions:

1) Do teachers of open plan classrooms spend more time in group work activities and less time out the front in didactic teaching than teachers in enclosed classrooms, as open plan classrooms are thought to better facilitate group work (Brogden, 1983; Shield et al., 2010)?
2) Do the teachers of noisier open plan classrooms rate their classroom listening environment poorer than teachers in quieter enclosed classrooms?
3) What noise sources can the teachers hear inside and outside their classrooms and are these similar to those identified by the children in Part 1 of this study (Mealings, Dillon, et al., 2015)? Furthermore, are the teachers of the noisier open plan classrooms more distracted by these noises?
4) Do the teachers of the noisier open plan classrooms find speech communication significantly more difficult and think their children have more difficulty hearing them than the teachers of quieter enclosed classrooms think their children do? Do these perceptions match those of the children measured in Part 1 of this study (Mealings, Dillon, et al., 2015)?

5) What strategies do teachers use to cope with noise? Do the teachers of the noisier open plan classrooms need to elevate their voice and experience vocal strain and voice problems more often than the teachers in quieter classrooms?
6) Do the teachers of open plan classrooms agree more with the positive aspects and less with the negative aspects of open plan classrooms than teachers in enclosed classrooms? Do these perceptions depend on the acoustic conditions of the different types of classrooms?

Method

Schools Involved

Four schools were chosen to be involved in the study. These were the same schools that were involved in an acoustic measures study (Mealings, Buchholz, et al., 2015), a speech perception test study (Mealings, Demuth, Buchholz, & Dillon, 2015b) and the children's questionnaires in Part 1 of this two-part paper (Mealings, Dillon, et al., 2015). The first school had two 8 x 9 m enclosed Kindergarten classroom and two enclosed Year 1 classrooms with approximately 25 children in each class. Three of the classroom walls were solid brick and one wall was a closed operable wall which had an open door storeroom that was shared with the adjacent class. The second school had a 15 x 9 m double Kindergarten classroom which consisted of 44 children divided into two classes with two teachers. The third school had a 37 x 11 m untreated fully open plan triple Kindergarten classroom and an untreated fully open plan triple Year 1 classroom. The Kindergarten classroom had 91 children divided into three classes with three teachers and the Year 1 classroom had 83 children divided into three classes with three teachers. The fourth school consisted of one 32 x 27 m purpose-built '21st century learning space' that contained Kindergarten-to-Year 6 (i.e. 205 children in total split into 7 classes). This included one Kindergarten class with 29 children and one Year 1 class with 21 children. Both of these classes were located in a semi-open plan area (i.e. only one open wall). More details on the classrooms can be found in Part 1 of this study (Mealings et al., 2015) and the classroom acoustics study by Mealings, Buchholz, et al. (2015).

Participants

The Kindergarten teachers of the children who had completed the children's questionnaires in Part 1 of this study (Mealings et al., 2015) were invited to participate in the present study. In order to increase participant numbers, we also invited the Year 1 teachers to participate that had classrooms very similar to the Kindergarten classrooms tested. Sixteen out of 18 teachers invited became involved in the study: four from the school with enclosed classrooms (two Kindergarten teachers and two Year 1 teachers), three from the school with a double classroom (two permanent Kindergarten teachers and one relief Kindergarten teacher), six from the school with triple classrooms (three Kindergarten teachers and three Year 1 teachers), and three from the K-6 school (one Kindergarten teacher and two part-time Year 1 teachers). All teachers were female. Details on the teachers and children are found in Table 1 along with the average noise levels and average unoccupied reverberation times recorded in the Kindergarten classrooms by Mealings, Buchholz, et al. (2015).

Table 1. *Demographic and acoustic information for the participating classrooms.*

Classroom	Teachers			Children			Acoustics			
							Noise level			
	Number of participants	Years taught in enclosed classrooms	Years taught in open plan classrooms	Total number in area	Average number in each Kindergarten/ Year 1 class	Average number with special educational needs in each Kindergarten/ Year 1 class	All classes unoccupied (dBA)	Adjacent classes occupied (dBA)	All classes occupied during group work (dBA)	Average unoccupied reverberation time (s)
Enclosed	4	3-7 *M* = 4.50	0-1 *M* = 0.25	25	25	6 ESL	41.8	43.1-48.8	71.0*	0.50
Double	3	5-10 *M* = 7.67	1-3 *M* = 2.00	44	22	1 learning disability	36.7	46.0-50.3*	69.7*	0.60*
Triple	6	0-5 *M* = 1.75	0.5-5 *M* = 2.25	91	30	21 ESL + 3 learning disability	36.0	57.5*-62.1*	67.7*	0.70*
K-6	3	0-15 *M* = 5.33	1.5-15 *M* = 7.50	205	25	2 ESL	46.3*	60.5*	72.4*	0.58*

Note. * indicates unoccupied noise levels are outside 35-45 dBA limit (Australia/New Zealand Standard, 2000), occupied noise levels are outside of the maximum 50 dBA recommended level (Berg et al., 1996) and/or reverberation time is outside 0.4-0.5 s limit (Australia/New Zealand Standard, 2000). These acoustic measurements are from the Kindergarten classrooms as found in Mealings, Buchholz, et al. (2015).

Questionnaire Design

The teachers' questionnaire was based on those used in similar studies (Greenland, 2009; Wilson, 2002) and investigated the following areas:

1) Teacher and student demographics
   - Consisted of the questions shown Table1.
2) Teaching style
   - Asked teachers what their main teaching position is (front, centre, or walking around the classroom).
   - Asked teachers what amount of time is spent in different teaching styles (didactic, table work, group work, other style).
3) Room characteristics
   - Asked teachers to rank lighting, ventilation, acoustics, equipment, and space from most important (1) to least important (5).
   - Asked teachers to tick which descriptors (comfortable, clear, relaxing, confusing, echoes, harsh, irritating, or specify their own) represent the classroom listening environment.
   - Asked teachers to rate the overall classroom listening environment as 1 = very poor, 2 = poor, 3 = acceptable, 4 = good, or 5 = very good.
4) Noise sources inside
   - Asked teachers if internal noise is a problem (yes/no), and if so, what noise sources are heard in the classroom and what is the most intrusive noise.
5) Noise sources outside
   - Asked teachers if external noise is a problem (yes/no), and if so, what noise sources are heard outside the classroom and what is the most intrusive noise.
   - Asked teachers if internal or external noise is more problematic.
   - Asked teachers if eliminating or reducing internal and external noises is unimportant, not very important, important, or critical for the children.
6) Speech communication in the classroom
   - Asked teachers if they think the students have difficulty hearing them, and do they think the acoustics of the classroom have a direct effect on the children's learning.
   - Asked teachers how easy they find speech communication (from 1 = very difficult, to 7 = very easy) in the classroom during different teaching scenarios.
7) Coping with noise
   - Asked teachers what actions they take to cope with noise (raise their voice, gather the class close around them, arrange a compatible activity schedule with other teachers, change the seating arrangement, stop or change the teaching activity, use visual cues for attention, or any other actions).
   - Asked teachers if they need to elevate their voice for different teaching styles, how often they elevate their voice, and how often they experience vocal problems (1 = never, 2 = sometimes, 3 = often, 4 = always).
8) Perceptions of open plan versus enclosed classrooms
   - Asked teachers to rate how much they agree with general statements about open plan classes on a five point Likert scale from "strongly disagree" to "strongly agree". The statements were those used by Greenland (2009) which were based on a questionnaire developed by Bennett, Andreae, and Hegarty (1980).

Questionnaire Procedure

The questionnaires were distributed to each of the teachers with a consent form and information sheet outlining the project approved by Macquarie University ethics. The researcher also gave a brief summary verbally to each of the teachers and asked them if they had any questions. The teachers were asked to complete the questionnaire (which took less than 10 minutes) in their own time. The questionnaires were collected after a fortnight. On return of the survey, each teacher received a small gift as a thank you for their time.

Results

Teaching Style

The main teaching position for the surveyed teachers was walking around the classroom. This was the case for all surveyed Kindergarten/Year 1 teachers from enclosed and double classrooms. Two of the three surveyed teachers from the K-6 classroom reported that they usually walked around when teaching while the other teacher reported teaching mainly from the centre of the class. In the triple classrooms, three of the six teachers said their usual teaching position was walking around the classroom, two teachers said they mainly taught from the front of the room, and one teacher reported usually teaching from the centre of the classroom.

Figure 1 shows the average percentage of time Kindergarten/Year 1 teachers spend in different teaching styles for each classroom. Interestingly, the teachers of the larger open plan classrooms (i.e. the triple and K-6 classrooms) spent less time in group work than the teachers of the enclosed and double classrooms, despite the belief that open plan classrooms better facilitate group work (Brogden, 1983; Shield et al., 2010). The teachers in the large open plan classrooms, however, spent roughly an equal amount of time in each of the different teaching styles rather than favouring group work. While Figure 1 averages the teaching time over the Kindergarten and Year 1 teachers, it was interesting to note that the Kindergarten teachers in the triple classroom spent 40% of their time in didactic-style teaching but then this dropped to 10% for the Year 1 teachers.

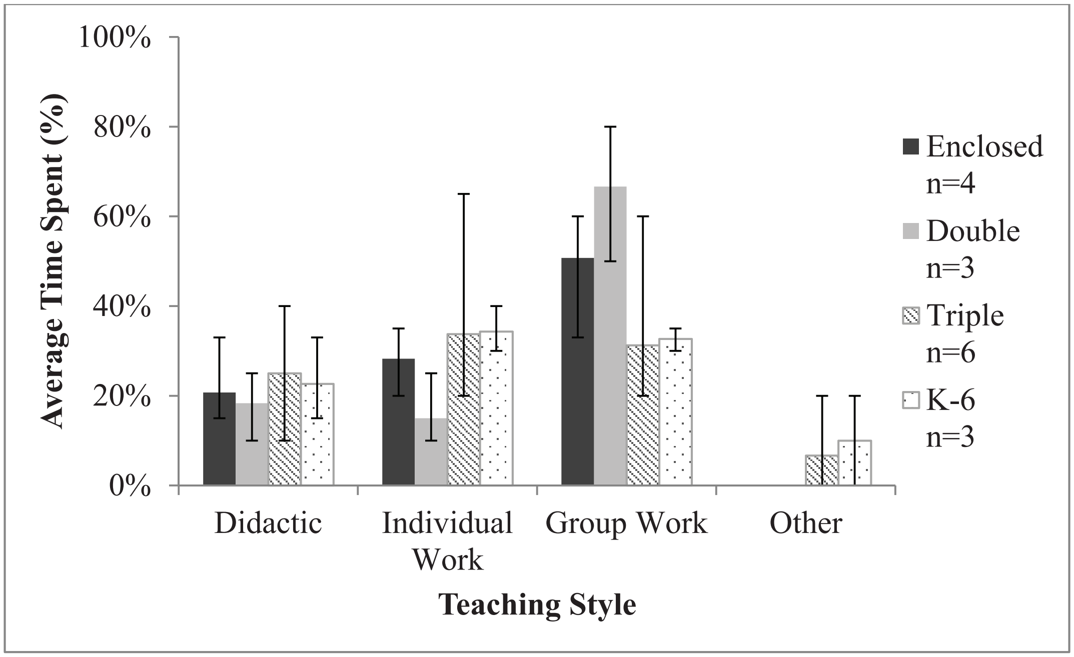

Figure 1. Average percentage of time teachers spend in different teaching styles by school. "Other" includes team teaching and teaching a small group separately. Error bars show range.

Room Characteristics

The participating teachers were asked to rank different aspects (lighting, ventilation, acoustics, equipment, and space) of their classroom from 1 (most important) to 5 (least important). The acoustics of the classroom was given the highest average rank in the K-6 classroom, the second highest rank after space in the double and triple classrooms, and the lowest rank in the enclosed classrooms.

The teachers were also asked to choose which descriptors (comfortable, clear, relaxing, confusing, echoes, harsh, irritating, or specify their own) represented their perceptions and experiences in their classroom. All teachers from enclosed classrooms said that the environment was comfortable (although it could be noisy at times). Two out of three teachers from double classrooms said that the environment was comfortable but the other teacher said it was distracting. In contrast, five of the six teachers from the triple classrooms found the environment confusing and four of the six teachers said the classroom echoed. Two out of three teachers from the K-6 classroom said that the environment was comfortable, but one teacher said it echoed and was harsh.

Additionally, the teachers were asked to rate the classroom listening environment overall where 1 = very poor, 2 = poor, 3 = acceptable, 4 = good, 5 = very good (see Table 2). Interestingly, the best average rating was by the teachers of the double classroom (average rating of 4.3 = good to very good) despite it having some of the highest percentages of children who said they could not hear their teacher very well or at all, especially when the adjacent class was being noisy (Mealings, Dillon, et al., 2015). The average ratings of the enclosed classrooms (4 = good) and triple classrooms (2.5 = poor to acceptable) were generally in consensus with the acoustics of the classrooms (Mealings, Buchholz, et al., 2015; see also Table 1) and the children's perceptions (Mealings, Dillon, et al., 2015). Again, the triple classrooms had the worst report of the schools with four of the six teachers surveyed (i.e. 67%) rating the listening environment as poor. All of these teachers said that this was because the classrooms were open plan. Three of the four teachers said it was also because of the noise levels, and one of the teachers said it was also because it echoed. Interestingly, the teachers in the K-6 classroom thought their classroom was an acceptable listening environment (i.e. average rating of 3), however, the results from the classroom's acoustic measures (see Table 1) and children's questionnaires suggested noise is a problem (Mealings, Buchholz, et al., 2015; Mealings, Dillon, et al., 2015).

Table 2. *Teachers' ratings of their classroom listening environment.*

Classroom	Percentage/proportion of teachers selecting each rating					Average rating
	1 Very Poor	2 Poor	3 Acceptable	4 Good	5 Very Good	
Enclosed	0	0	0	100% (4/4)	0	4 Good
Double	0	0	0	67% (2/3)	33% (1/3)	4.3 Good to very good
Triple	0	67% (4/6)	17% (1/6)	17% (1/6)	0	2.5 Poor to acceptable
K-6	0	0	100% (3/3)	0	0	3 Acceptable

Noise Sources Inside

In this section of the questionnaire, the teachers were asked whether they thought noise from inside the classroom was a problem. If so, they were asked to identify what noise sources they heard in the classroom and what proportion of noise was student generated. Three out of four teachers from enclosed classrooms, two out of three teachers from the double classroom, five out of six teachers from triple classrooms, and all three teachers surveyed from the K-6 classroom believed internal noise was problematic. Three teachers from enclosed classrooms and two teachers from the double classroom thought that most of this noise was student generated. In the triple classrooms, three out of five teachers thought most internal noise was student generated while the other two thought only some of it was. For the K-6 classroom, one teacher thought most of this noise was student generated while another teacher thought only some of it was. The other noise sources the teachers found problematic are shown in Table 3. The noise sources the teachers identified were a close match to those identified by the children in each of the classrooms (Mealings et al., 2015). Noise from air-conditioning units and equipment were also recognized by Mealings, Buchholz, et al. (2015) as contributors to the high unoccupied ambient noise levels in the enclosed and K-6 classrooms (see Table 1).

Figure 2 shows what noise source the teachers reported as the most intrusive. All teachers chose either the children of other classes or the children of their own class. Surprisingly, all of the teachers in the K-6 classroom reported that the children in their own class was the most intrusive noise rather than the children in the other classes despite this classroom reporting some of the highest intrusive noise levels from the other classes sharing the area (Mealings, Buchholz, et al., 2015; see also Table 1). Interestingly, however, the teacher percentages for the other classrooms followed a trend. As the number of children in the entire area increased, so did the percentage of teachers who reported other children as the most intrusive noise. Furthermore, as the number of children in the entire area decreased, the percentage of teachers who reported the children in their own class as the most intrusive noise increased. Noise from children in other classes was also the most frequently reported noise source heard by the children in these classes and the proportion of children reporting this also increased as class size increased (Mealings, Dillon, et al., 2015).

Table 3. *Teachers' report of problematic internal and external noise sources.*

Classroom	Percentage/proportion of teachers reporting noise source problematic						
	Air-conditioning units	Equipment	Lights	Other teachers	Other classes	Children outside	Traffic
Enclosed	75% (3/4)	0	0	50% (2/4)	25% (1/4)	25% (1/4)	25% (1/4)
Double	0	0	0	66% (2/3)	0	33% (1/3)	0
Triple	50% (3/6)	33% (2/6)	0	83% (5/6)	83% (5/6)	67% (4/6)	17% (1/6)
K-6	33% (1/3)	33% (1/3)	0	0	33% (2/3)	33% (1/3)	0

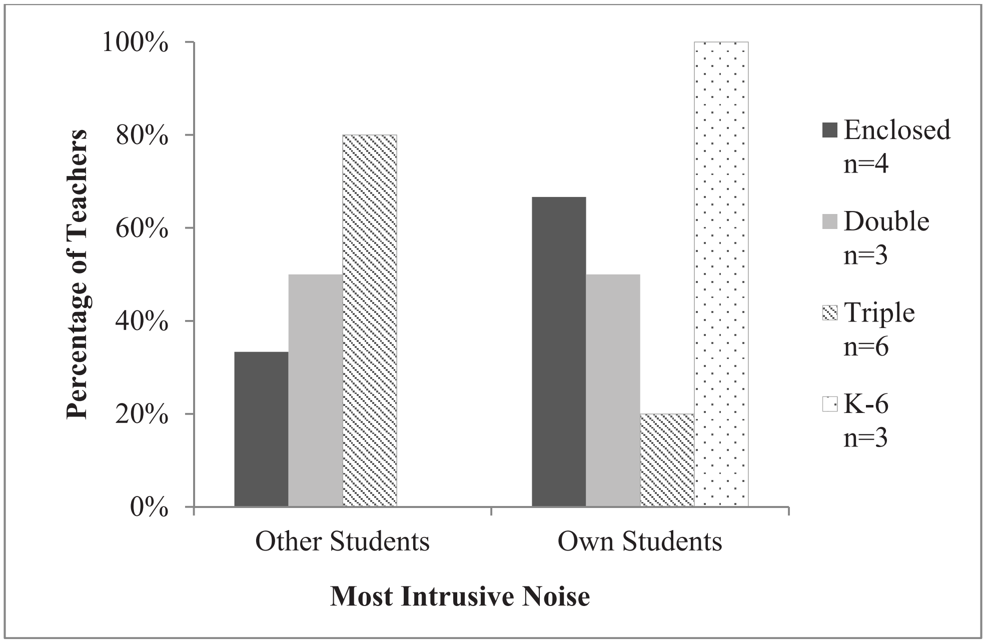

Figure 2. Teachers' report of what they find the most intrusive noise in the classroom.

Noise Sources Outside

The teachers were asked whether they thought noise from outside the classroom was a problem and if so, what noises they could hear. One out of four teachers from the enclosed classrooms, one out of three teachers from the double classroom, five out of six teachers from the triple classrooms, and two out of three teachers from the K-6 classroom believed external noise was problematic. The specific noise sources the teachers found problematic are also shown in Table 3. The most intrusive outside noise reported by the teachers was children outside for the enclosed, double, and K-6 classrooms, which supports the findings from the children's questionnaires (Mealings, Dillon, et al., 2015). Other noise sources identified by teachers of the enclosed and triple classrooms included noise from children in other classes and noise from traffic which largely agree with the noise sources identified by the children in these classrooms (Mealings, Dillon, et al., 2015).

The teachers were also asked whether internal or external noises were the most problematic, or if noise was not a problem when teaching in the classroom. In the enclosed classrooms, two teachers believed inside noise was the most problematic while the other two did not believe noise was a problem. One teacher from the double classroom reported outside noise the most problematic whereas the other two did not believe noise was a problem. Three out of six teachers from the triple classrooms reported inside noise the most problematic whereas the other three reported outside noise was. In the K-6 classroom, two out of three teachers thought inside noise was the most problematic noise while the other teacher thought outside noise was. Additionally, the teachers were asked to rate how distracting they find inside and outside noise. As shown in Table 4, there was lots of variability in the teachers' ratings, but the general trend was that the teachers of the triple and K-6 open plan classrooms found both inside and outside noise more distracting than the teachers of the enclosed and double classrooms.

Table 4. *Teachers' ratings of how distracting they find inside and outside noise from 1 = not at all distracting to 7 = extremely distracting.*

Classroom	Teacher ratings					
	Inside noise			Outside noise		
	Mean	Range	*SD*	Mean	Range	*SD*
Enclosed $n = 4$	3.50	1-5	1.91	2.50	1-5	1.91
Double $n = 3$	2.67	2-3	0.58	1.67	1-3	1.15
Triple $n = 6$	5.33	4-6	0.55	4.33	2-6	1.63
K-6 $n = 3$	4.33	3-6	1.52	4.00	1-6	2.65

The teachers also rated whether they thought eliminating or reducing internal and external noises was unimportant, not very important, important, or critical for the children. All four teachers from enclosed classrooms believed it was important to eliminate noise. Only one teacher in the double classroom thought it was important to eliminate or reduce noise in the classroom. The other two teachers said it was not very important which is concerning as this classroom had some of the poorest ratings of how well the children reported they could hear their teacher, particularly when the adjacent class was being noisy (Mealings, Dillon, et al., 2015). Three of the six teachers surveyed from the triple classrooms thought it was critical to eliminate noise and the other three teachers thought it was important. All three teachers in the K-6 classroom believed it was important to eliminate noise.

Speech Communication in the Classroom

The teachers were asked if they thought the children in their class had difficulty hearing them, and if the acoustics of their classroom had a direct effect on the children's learning. None of the teachers in the enclosed classrooms believed the children in their class had difficulty hearing them. Furthermore, none of the teachers in the double classroom believed the children in their class had difficulty hearing them despite high proportions of children reporting that they could not hear their teacher very well or at all during many classroom activities (Mealings, Dillon, et al., 2015). In contrast, all of the teachers from the triple classrooms believed that the acoustics had a direct effect on the children's learning. Additionally, all teachers from the triple classrooms believed that the children in their class had difficultly hearing them, with three of six teachers saying this was irrespective of where they stood. This is consistent with the children's perceptions (Mealings, Dillon, et al., 2015). In the K-6 classroom, all teachers believed that the children had difficulty hearing them, which was also revealed in the children's questionnaires, indicating that noise is perceived as a problem in this classroom (which is also shown objectively by the noise levels in Table 1).

Figure 3 shows the teachers' average ratings of how easy they find speech communication in the classroom for different scenarios. The trend shows that the teachers of the two larger classrooms (i.e. the triple and K-6 classrooms) found speech communication more difficult in each scenario compared to the teachers of the smaller enclosed and double classrooms. Figure 4 also combines the three teaching scenarios to give an overall average rating of ease of speech communication in the classroom. A Kruskal Wallis test revealed a statistically significant difference between the classroom types $H(3) = 14.01$, $p = .003$. A post-hoc test using Mann-Whitney U tests with Bonferroni correction $p < .05/6 = .0083$ showed speech communication in the enclosed classrooms was significantly easier than in the triple classrooms $U = 40.00$, $Z = -2.97$, $p = .003$, $r = 0.43$ and K-6 classroom $U = 15.50$, $Z = -2.97$, $p = .004$, $r = 0.43$.

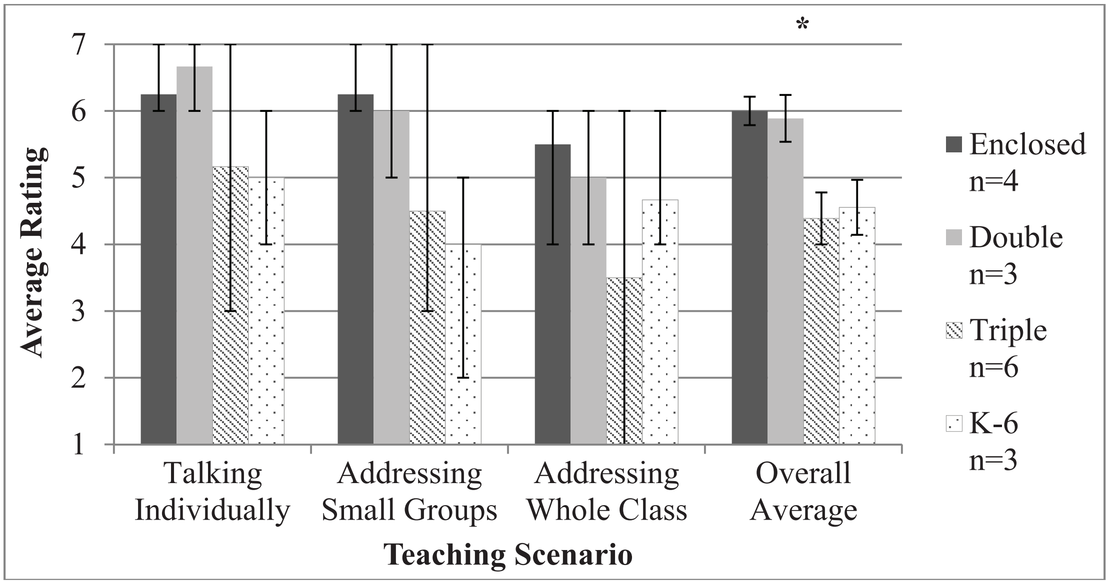

Figure 3. Teachers' average ratings of ease of speech communication for different scenarios and the overall average rating (1 = very difficult, 7 = very easy). Error bars show range for the separate scenarios and standard error of the mean for the overall average. Brackets show significance at *$p < .05/6 = .0083$.

Coping With Noise

Figure 4 shows the actions teachers take to cope with noise in the classroom. All teachers reported using at least one strategy rather than taking no action. The actions taken included raising their voice, gathering the class close around them, arranging a compatible activity schedule with other teachers, changing the seating arrangement, stopping or changing the teaching activity, and using visual cues for attention. It was positive that the teachers in the K-6 classroom used many different strategies to cope with the high noise levels in their classroom rather than always raising their voice. It is concerning, however, that all teachers in the triple classrooms raised their voice to cope with noise. These teachers were also using other coping strategies, but unfortunately they were not effective enough for the teachers to not have to raise their voice as well.

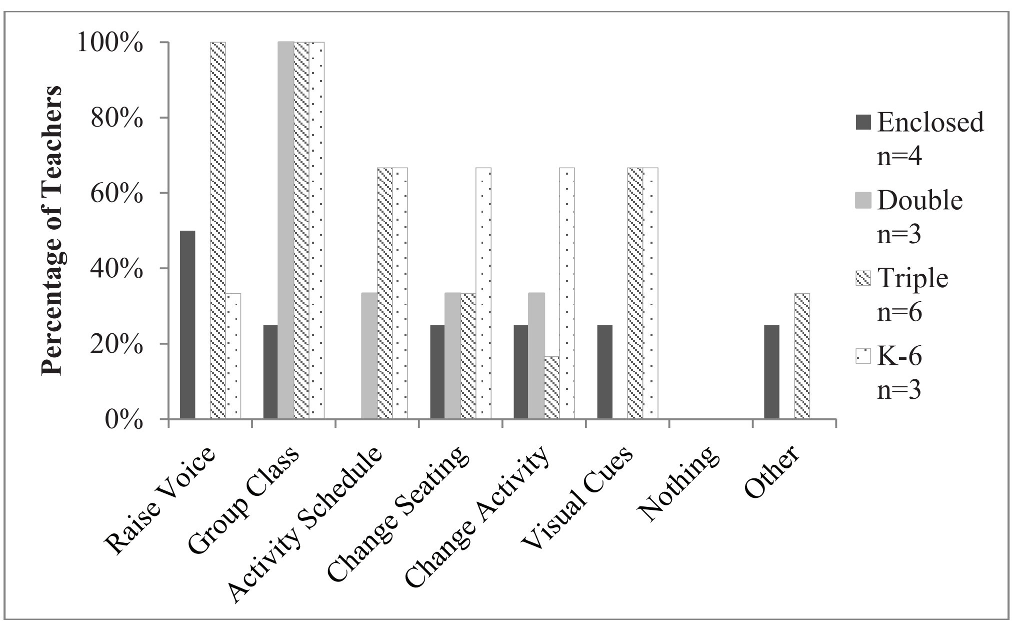

Figure 4. Actions teachers take to cope with noise in the classroom. "Other" includes ringing a bell to get the class's attention, using a traffic light noise scale, rewarding children for quiet voices, and gaining the class's attention to remind them to work more quietly.

Figure 5A shows the average percentage of teachers who reported that they needed to elevate their voice to be heard clearly for different teaching styles. All of the teachers in the triple and K-6 open plan classrooms reported that they needed to elevate their voice during group work, compared to only 50% or less of the teachers in smaller enclosed and double classrooms.

Figure 5B shows the average ratings of how often teachers needed to raise their voice overall when teaching, and how often they experienced vocal problems. The surveyed teachers from the triple classrooms had to elevate their voice often, and also experienced vocal problems more than teachers in the other classrooms. All six teachers surveyed from this school reported that the level they needed to speak at strained their voice. This contrasts with the responses of the teachers in the enclosed and double classrooms; none of these teachers reported that the level they usually spoke at strained their voice and none of the teachers surveyed in the enclosed classrooms had ever experienced voice problems. Finally, the responses from the teachers in the K-6 classroom were in between those from the enclosed, double, and triple classrooms. Only one of the three teachers in this classroom experienced vocal problems, so it is likely that the acoustic treatment and semi-open plan style is beneficial for the teachers compared to the fully open plan non-treated triple classrooms.

Perceptions of Open Plan versus Enclosed Classrooms

Teachers were asked to rate how strongly they agree or disagree (on a five point Likert scale) with the following statements about open plan classrooms compared with enclosed classrooms. The statements were those used by Greenland (2009) which were based on a questionnaire developed by Bennett et al. (1980). For clarity, the statements below are organized so statements 1-9 are the positive statements about open plan classrooms and statements 10-12 are the negative statements. Note, however, that these were randomized for the questionnaire.

1) The environment provides for a wide range of activities
2) The children are more independent and responsible
3) Standards of work tend to be higher
4) Children benefit socially
5) There is greater continuity for students
6) There is better pastoral care for students
7) Teachers feel more confident
8) The environment facilitates better student supervision
9) The environment makes students feel more secure
10) Children are more easily distracted by noise
11) Children are more easily visually distracted
12) There are discipline problems

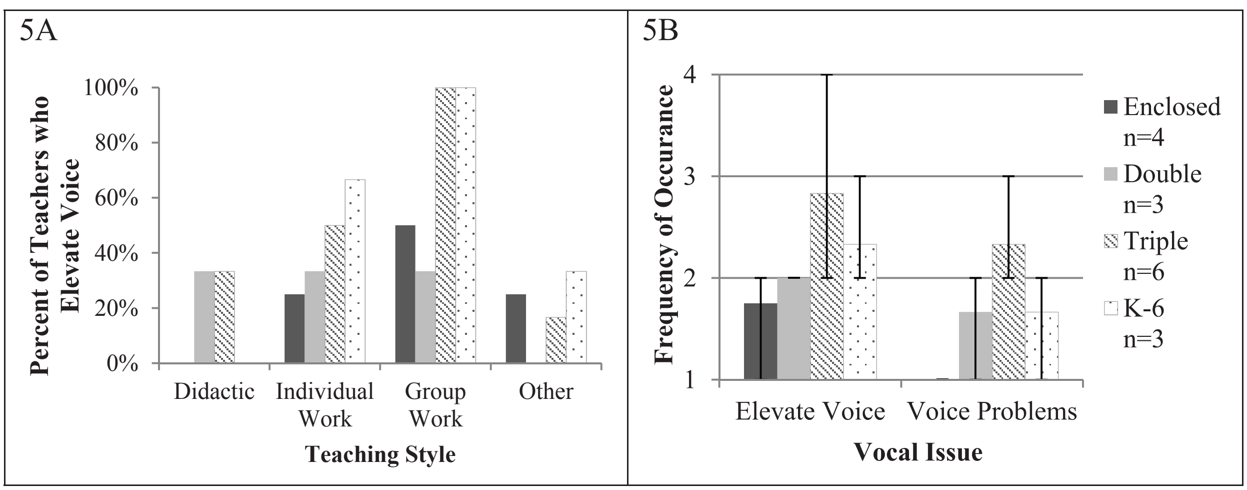

Figure 5A. Percentage of teachers reporting they needed to elevate their voice to be heard clearly for different teaching styles. "Other" includes when trying to get children to stop a group activity or trying to control children while moving between learning spaces.

Figure 5B: Average ratings of how often teachers needed to raise their voice overall and how often they experienced vocal problems (1 = never, 2 = sometimes, 3 = often, 4 = always). Error bars show range.

Figure 6 collapses these results into the positive compared to negative statements about open plan classrooms. A Kruskal Wallis test revealed a statistically significant difference between classrooms for their agreement on positive statements about open plan classrooms $H(3) = 33.97$, $p < .0005$. Post-hoc Mann-Whitney U tests with Bonferroni correction $p = .05/6 = .0083$ showed the teachers of enclosed classrooms had significantly lower agreement with the positive statements about open plan classrooms compared to those teaching in them from the double $U = 122.00$, $Z = -5.27$, $p < .0005$, $r = 0.66$, triple $U = 639.50$, $Z = -3.02$, $p < .003$, $r = 0.32$, and K-6 classrooms $U = 301.50$, $Z = -2.69$, $p = .007$, $r = 0.34$. The teachers from the double classroom also had significantly better agreement on the positive open plan statements compared to the teachers of the triple classrooms $U = 330.50$, $Z = -4.28$, $p < .0005$, $r = 0.48$. No significant difference between schools was revealed for the negative statements about open plan classrooms $H(3) = 7.74$, $p < .052$.

A Wilcoxon signed-ranks test was run to determine significant differences between agreements on positive versus negative statements about open plan schools for each classroom type. The teachers of the double classroom agreed significantly more with the positive statements than with the negative statements which they generally disagreed with $Z = -2.71$, $p = .007$, $r = 0.90$. No significant difference was found for any of the other classrooms $Z_{enclosed} = -0.83$, $p = .405$; $Z_{triple} = -0.28$, $p = .783$; $Z_{K\text{-}6} = -0.53$, $p = .595$.

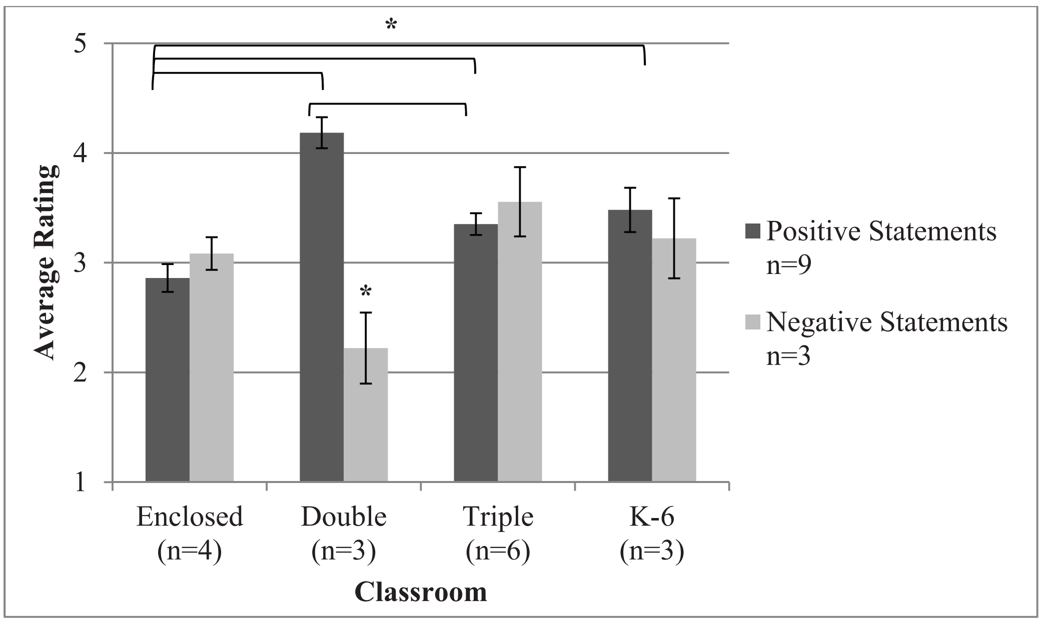

Figure 6. Mean ratings of teachers' opinions about positive and negative statements comparing open plan classrooms with enclosed classrooms where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. Error bars show standard error of the mean. Brackets and asterisks show significant difference at $p < .05/6 = .0083$.

Discussion

Recent changes in teaching methods has resulted in the re-emergence of open plan classrooms. This study investigated the teachers' perceptions of their classroom listening environment in four different types of open plan/enclosed classrooms and compared these to the children's perceptions in Part 1 of this study (Mealings, Dillon, et al., 2015).

One of the main reasons for having open plan classrooms is that they better facilitate group work (Brogden, 1983; Shield et al., 2010). However, it was interesting that the teachers in the triple and K-6 open plan classrooms only spent a third of their teaching time in group work activities compared to the teachers of the enclosed and double classroom types who spent 50-67% of time in group work activities. It is possible that the teachers of the larger open plan classes spend less time in these activities as they generate the most noise (Mealings, Buchholz, et al., 2015, see also Table 1) which makes listening difficult for both the children of that class and the other classes in the same area (Mealings, Dillon, et al., 2015). Therefore, the benefit of having these classes which are designed to better facilitate group work also has the downfall that these activities produce high levels of noise. It was also interesting that the Kindergarten teachers of the triple classroom spent 40% of their teaching time in didactic-style teaching. This shows that didactic-style teaching can still be an essential way of teaching new concepts to young children especially when they are starting primary school. This supports Rowe (2006) who raises the need for young children to learn basic literacy and numeracy skills first before they can engage in more child-centred constructivist learning. This further emphasizes the importance of having favourable acoustic conditions for these critical listening activities, which are hard to achieve in open plan classrooms (as shown in Table 1).

The results of the teachers' questionnaires, like the children's questionnaires, showed that the main noise source heard in the classroom was child generated noise. In the enclosed classrooms, this was largely from children in the teacher's own class, while for the open plan classes (with the exception of the K-6 classroom) it was from children in the other classes sharing the same open plan area. These were also the main noise sources reported by teachers in semi-open plan classrooms in the study by Greenland (2009). Children outside, air-conditioning units, and equipment were other identified noise sources which were also identified by the children (Mealings, Dillon, et al., 2015), and by Mealings, Buchholz, et al. (2015) as contributors to the high unoccupied ambient noise levels in the K-6 classroom (see Table 1). The teachers in the triple and K-6 classrooms tended to find both inside and outside noise more distracting than the teachers in the enclosed and double classrooms. The teachers of the triple and K-6 classrooms also found speech communication significantly more difficult than the teachers in the enclosed and double classrooms, and all of the teachers surveyed from the triple and K-6 classrooms believed that the children had difficultly hearing them, whereas none of the teachers in the enclosed and double classrooms did. This is expected given the high intrusive noise levels from the adjacent classes in the triple and K-6 open plan spaces (see Table 1).

Overall, the teachers of the K-6 classroom and even more so the untreated triple classrooms needed to elevate their voice more often than the teachers in the enclosed and double classrooms. The teachers of the triple and K-6 classrooms also experienced vocal strain and voice problems more often than those in the enclosed and double classroom. In response to this, the teachers tried to use other strategies to cope with noise including coordinating activities between classes (which minimizes intrusive noise if all classes are doing quiet critical listening activities at the same time) and using visual cues. All of the teachers in the double, triple, and K-6 classrooms also tried to group the children close to them when they were teaching. This was also the most common action taken by teachers in semi-open plan classrooms in the study by Greenland (2009). Using this strategy is important as being far away from the teacher can be detrimental to the child's ability to hear and understand their teacher, especially in noisy conditions (Mealings, Demuth, Buchholz, & Dillon, 2015a; Mealings, Demuth, et al., 2015b). It was positive that the teachers in the K-6 classroom used many different strategies to cope with the high noise levels in their classroom rather than always raising their voice. It was interesting that the teachers in the double classroom did not report raising their voice as a coping strategy (Figure 4), however Figure 5B shows that they did have to elevate their voice sometimes. This discrepancy may be related to the teachers having a lack of awareness of the strategies they use to cope with noise.

Of most concern, however, were the responses from the teachers of the untreated fully open plan triple classrooms. Most teachers in these classrooms rated the listening environment as poor, and believed the children had difficultly hearing them. Despite using a range of other methods to cope with noise, the teachers still needed to raise their voice above a comfortable level to be heard and experienced vocal strain. This puts them at high risk of vocal abuse and pathological voice conditions (Gotaas & Starr, 1993; Smith et al., 1997).

The overall poor ratings of the listening environment from the teachers in the triple classrooms largely agreed with the children's perceptions of noise and their difficulty hearing their teacher from Mealings, Dillon, et al. (2015). These poor ratings are even more concerning as this school has the largest proportion of children with special educational needs (see Table 1). These children are reported to be even more adversely affected by poor classroom acoustics so it is highly likely that they will struggle learning in this environment (MacKenzie & Airey, 1999; Nelson & Soli, 2000; Shield et al., 2010). Unfortunately, when the classrooms in this school were converted to open plan no additional acoustic treatments were made. As a result, these classrooms have high noise levels and long reverberation times (Mealings, Buchholz, et al., 2015; see also Table 1). This is likely to explain why the teachers of this school struggled teaching in this environment and shows the impact of having poor classroom acoustics on the teachers and children. This suggests that this classroom should be acoustically modified to make speech communication easier. Furthermore, it is likely that improving the acoustic conditions in this classroom will help children to adequately progress in their education, and create a more positive environment for the teachers so they can teach more effectively. The K-6 classroom provides an example of a classroom that is still open plan, but has been purpose-built with some acoustic treatment and dividers between classes. This may explain why the teachers in this '21st century learning space' found the environment more acceptable than those in the triple classrooms. However, because it was still semi-open plan and had over 200 children sharing the area, it still had consistently high noise levels (Mealings, Buchholz, et al., 2015; see also Table 1) which the teachers found problematic. As a result, some of the teachers still experienced vocal strain and believed the children had difficulty hearing them. This is consistent with the results of the children's questionnaires where 56-60% of children reported that they could not hear their teacher very well or at all when other classes or their own class was being noisy (Mealings, Dillon, et al., 2015). Therefore, more acoustic modifications and better divisions between the classes would be beneficial to further reduce noise.

A positive finding of the study was that the teachers of the double, triple, and K-6 classrooms ranked the classroom's acoustics as being an important aspect of the learning space and thought that reducing or eliminating noise in the classroom was important for the children. It is likely that the low ranking from the teachers of enclosed classrooms is because the acoustics in the tested classroom were mostly acceptable (Mealings, Buchholz, et al., 2015, see also Table 1). Therefore, the teachers may take the good acoustics for granted and not realize how detrimental poor acoustics can be on children's learning. Interestingly, however, two out of three teachers from the double classroom did not think noise was a problem, hence did not think it was important to reduce or eliminate it. The children in this classroom, however, thought very differently. Sixty-five percent of children found the noise from the children of the other class annoying, 43% found the noise from the teachers of the other class annoying, and 48% of found the noise from children outside annoying. Additionally, 39% of children surveyed could not hear their teacher very well or at all when the other Kindergarten class was working at their tables and 70% of children could not hear their teacher very well or at all when the other Kindergarten class was engaged in group work that involved movement. These were the largest proportions of children of all the classrooms tested (Mealings et al., 2015). Furthermore, 43% of children could not hear their teacher very well or at all when their own class was being noisy. These are all unacceptable proportions of children (i.e. over 32%) according to the dissatisfaction criterion used by Shield et al. (2008) which is based on previous research into noise annoyance in open plan offices and classrooms which propose a minimum of 68% of people need to be satisfied with the environment for it to be acceptable (see p. 12). This was also the only classroom type to have an unacceptable proportion (43%) of children who could not hear their classmates very well or at all when they were doing group work. Since this classroom had a smaller amount of space per child and a much smaller distance of only two meters between the classes compared to six to seven meters in the triple and K-6 open plan classrooms, it is likely that this close proximity combined with noise affects the children even more as the interfering speech would be intelligible. However, as shown by their greater agreement with the positive statements about open plan schools, the teachers of this school have very positive views about open plan learning spaces. The difference in the children's and teachers' perceptions about the listening environment show that we cannot rely completely on the teachers' perceptions as they may not accurately reflect how the children feel and how they cope with noise in the classroom. This is because children are more affected by poor acoustics than adults as their brain is neurologically immature (Boothroyd, 1997; Nelson & Soli, 2000; Wilson, 2002). Therefore, these findings emphasize the importance of considering children's perceptions and capabilities in the classrooms as well as the teachers' perceptions.

In contrast to the teachers of the open plan classrooms, all of the teachers surveyed from enclosed classrooms found the listening environments comfortable and none of the teachers had experienced vocal problems. This shows the benefit of having even just an operable wall between classes to minimize the intrusive noise from the adjacent class/es. However, even though intrusive noise from the other classes was minimized, the noise levels when their own class was engaged in group work were still excessive (Mealings, Buchholz, et al., 2015, see also Table 1). Most of the teachers reported that this noise was problematic, as did the children, with over half saying that they could not hear their teacher very well or at all during these noisy periods (Mealings, Dillon, et al., 2015). Therefore, controlling noise during group work activities is still important in all types of classrooms.

Overall, the results of these studies show the importance of having good acoustic conditions in classrooms. This is needed so young children can hear their teachers and classmates, but also to increase teachers' job performance and job satisfaction (McCoy & Evans, 2005; Vischer, 2007). The results suggest that the best classroom design is an enclosed classroom as it minimizes the intrusive noise from adjacent classes which is of vital importance when the children are engaged in critical listening activities. While a classroom with four solid fully enclosed walls is likely to provide the best listening environment, single classrooms with operable walls should provide adequate listening conditions the majority of the time. This type of classroom also gives the flexibility of opening the operable wall for the activities the teachers prefer to have a more open plan space for, but then closing it for critical listening activities to minimize intrusive noise and enhance speech perception. Having quiet rooms as suggested by Shield et al. (2010) is also beneficial so children who are more vulnerable to noise can work in those areas away from the other children when needed.

Limitations of the Study and Future Directions

As this study compared the perceptions of teachers from four case study schools, it only allowed a relatively small number of participants to be involved for a questionnaire design. As a result, these findings need to be interpreted cautiously and not be overgeneralized. Therefore, it would be beneficial to examine a wider range of classrooms and group them together by type of design to provide more participants and hence more power for statistical analysis. This would allow us to draw more generalized conclusions about how teachers cope in different sized classrooms. It would also provide information to help us understand how classrooms should be designed in order to maintain adequate speech perception and minimize vocal health problems for teachers.

It would also be interesting to examine whether the demographics of the children in the classroom affect teachers' perceptions of the listening environment. For example, children with ESL are typically more affected by poor classroom acoustics (Nelson, Kohnert, Sabur, & Shaw, 2005; Nelson & Soli, 2000). Furthermore, teachers have been found to have less close student-teacher relationships with children who have ESL and/or learning difficulties than their peers (see McGrath & Van Bergen, 2015, for a review). These factors may affect both teachers' and children's perceptions of their listening/learning ability in noise and/or ease of speech communication in the classroom, and may have contributed to the poorer perceptions from the teachers and children in the triple classroom which had a high number of ESL learners and several children with learning disabilities.

In addition, it would be worthwhile to conduct further research on what teaching styles are used in different classrooms. It was interesting in this study that the teachers in the triple and K-6 open plan classrooms spent less time in group work activities than the teachers in the enclosed and double classroom, despite open plan classrooms being designed for more collaborative work (Brogden, 1983; Hickey & Forbes, 2011; Shield et al., 2010). This study only included a small number of participants, however, so it would be beneficial to investigate this with a large number of different types of classrooms and assess the effectiveness of different teaching approaches. It would also be interesting to examine if teaching methods change as children progress through school. Rowe (2006) raises the problem of using constructivist methods for young children as children need to have learned the basic literacy and numeracy skills first before they can engage in more child-centred self-directed learning activities. This may have been one reason why the Kindergarten teachers in the triple classroom spent 40% of their teaching time in didactic-style teaching, but the Year 1 teachers only spent 10% of their time in didactic-style teaching. Furthermore, it is recommended that children with learning difficulties have highly structured teacher-directed lessons rather than child-directed activities (see Rowe, 2006). This is another factor that needs to be taken into consideration when designing classrooms and assessing teaching practices. In addition, it would also be interesting to examine if teachers' past experience in open plan versus enclosed classrooms affects their teaching style, perceptions of different listening environments, and how easy they find speech communication in the classroom.

Finally, it would be worthwhile to examine the relationship between teachers' reports of raising their voice with actual recordings of their vocal use and level throughout the day. This would allow us to assess if teachers' perceptions of their vocal use match their actual vocal use, and better understand how this may relate to the type of classroom and its acoustic conditions. This research would also help provide insight into how teachers' vocal quality may change as a function of how long they have been teaching. These findings will help us understand more about how different types of classroom acoustic conditions may lead to vocal abuse and how this can be potentially be prevented by designing classrooms appropriately.

Conclusion

The results of this study showed that teachers of larger, noisier classrooms (especially those that were fully open plan and not acoustically treated) were more distracted by noise and found speech communication significantly more difficult than the teachers of smaller, quieter classrooms. The teachers of larger, noisier classrooms also thought their students had more difficulty hearing them than the teachers of smaller, quieter classrooms thought their students did. These teachers also needed to elevate their voice and experienced vocal strain and voice problems more often. While the teachers in the K-6 classroom (which had been purpose-built with some acoustic treatment and dividers between classes) found the environment more acceptable than those in the triple classrooms, noise levels could still be problematic as reported by the teachers and children. These results suggest that noise is a problem particularly in large open plan classrooms, and it negatively impacts teachers. This suggests that smaller enclosed classrooms, or at least classrooms that have the flexibility to be enclosed for critical listening activities, are more appropriate learning spaces both for the teacher's vocal health and for enhancing young children's learning.

Additionally, the results of this study show the importance of using multiple approaches when assessing the acoustics of classrooms to provide a more comprehensive view of the environment. In particular, the results of this two-part study show the importance of considering how the children perceive and learn in the classroom environment, as teacher perceptions may not always accurately reflect those of the child. It is especially important to be aware of this difference in perceptions in regard to new, innovative teaching methods and classrooms spaces which may excite the teacher but may not be beneficial for the child. Therefore, future research that examines the suitability of different types of classrooms needs to take into account the perspectives of all of the different people using the classroom in addition to the physical acoustic conditions and how they affect speech perception. Hopefully, with careful consideration of these results and the results of future studies, classrooms in the future will be designed with appropriate acoustics to enhance children's learning and improve teachers' vocal health and wellbeing.

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Considerations in Speech Recognition Testing of Bilingual and Spanish-Speaking Patients Part I: Older Children and Adults

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The rapid growth of the Spanish-speaking population of the United States presents challenges for all healthcare providers to develop linguistically- and culturally- appropriate best practices. A significant need for all audiologists is language-appropriate stimuli for speech recognition testing. Unfortunately, few well-validated tests exist for this purpose. We review the timeline of development of Spanish-language speech recognition test materials and address issues facing the audiologist in evaluating accurately the hearing abilities of both older children and adults who use Spanish as their primary or only language of communication.

Introduction

Hearing loss is the third most prevalent physical condition following arthritis and heart disease (Collins, 1997). The World Health Organization (2014) reports that over 328 million adults globally have a hearing loss of 40 dB HL or greater in their better ear. Lin and colleagues (2011) estimate the prevalence of unilateral or bilateral hearing loss greater than 25 dB HL in the United States as about 20% of Americans over the age of 12, or about 48 million people. These statistics have a significant impact on the U.S. Hispanic population given the high number of health disparities observed in this population (Centers for Disease Control, 2014). This population comprises 50.5 million or 16.3% of the national population, making it the largest American ethnic minority group (U.S. Census Bureau, 2011). Though there are non-Hispanics who speak Spanish, most of the people who speak Spanish are Hispanic (Ortman & Shin, 2011). However, Ortman and Shin noted that the number of English-speaking Hispanics would soon surpass Spanish-speaking Hispanics. The Hispanic-American population is projected to rise to 132.8 million by the year 2050. Despite this growing number, Spanish-speaking children and adults in the United States have limited access to healthcare, leading to health disparities in part from lack of access to language-appropriate care.

Audiology is one of many disciplines that must consider changes in diagnostic and intervention practices to account for population changes; indeed, given the primacy of hearing and listening ability in verbal communication, changes in language and culture in the patient population are of particular interest to the audiologist among healthcare providers. In this and the accompanying paper, we discuss important factors in speech-recognition testing for Spanish-English bilingual and primarily-Spanish-speaking patients. In this Part I manuscript, considerations for older children and adults are discussed; the Part II manuscript focuses on factors of concern for younger children.

Audiology and the Spanish-Speaking Population

Hispanic Americans encounter significant social and economic barriers that can decrease the likelihood of receiving timely and appropriate health care. Escarce and Kapur (2006) note that this population's access to health care is affected by a degree of acculturation (adopting or modifying the behaviors and belief systems of another culture), language, and immigration status as more than 40% of Hispanic individuals living in the United States were born in another country. A shortage of Hispanic physicians also contributes to barriers to health care access (Association of American Medical Colleges, 2010). Saha, Taggart, Komaromy, and Bindman (2000) have reported that 40% of Hispanic patients consider a physician's knowledge of Spanish when choosing a provider.

The field of audiology is not as culturally diverse as other health professions, such as physicians and physical therapists. According to a 2008 American Speech-Language-Hearing Association (ASHA) survey, 95.4% of the audiologists surveyed were Caucasian and less than 2% identified themselves as Hispanic or Latino. A 2008 survey of physicians revealed that 75% of physicians over the age of 40 identified themselves as Caucasian and 66% of those younger than 40 years old (Boukus, Cassil, & O'Malley, 2009). A 2013 survey from The U.S. Health Workforce Chartbook (U.S. Department of Health and Human Services, 2013) reported a similar distribution, reporting 79.9% of physical therapists who identified themselves as Caucasian. Whatever the ethnic composition of the healthcare provider population, the projected increase of the Hispanic population in the United States will require all health professionals, including audiologists, to be culturally sensitive and diverse to meet these growing demands.

Effective communication is a key part of an audiologist's role as a health care provider. When working with Spanish-speaking patients, Morrison (2008) suggested repetition of important information to avoid miscommunication between the health care professional and the Hispanic patient. Interpreters can be utilized to minimize misunderstandings. An interpreter relays information from the audiologist to the patient in a manner easily understood by the patient. However, interpreters may also present barriers of their own, including availability, cost, linguistic and regional differences, and knowledge of audiology vocabulary (Talamantes, Lindeman, & Mouton, 2001). It follows then that audiologists and other health care professionals need to be acutely aware of the cultural differences in the Hispanic population to make informed decisions regarding the need for an interpreter, as well as the linguistic and cultural background of the interpreter that is most appropriate for a given patient.

Bilingualism

The growing Hispanic population in the United States has led to an increase of the number of bilingual Americans. Bilingualism is the ability to use two languages. In 1933, Bloomfield defined bilingualism as “native-like control of two or more languages” (Baker, 2011). The National Association for Language Development in the Curriculum (NALDIC, 2009), however, revises that definition to include varying degrees of proficiency and communication. For example, a person may identify as bilingual but may only be able to communicate orally in one language. Likewise, a person may have a proficiency in reading in two languages, but may be unable to converse orally in one of the languages. The separation of these two abilities draws from the four language domains: listening, speaking, reading, and writing. These four abilities can be further categorized as receptive and expressive language skills, affecting degree of language proficiency.

Proficiency in two languages also is reflected in the dominance of the languages. A dominant bilingual is a person who is dominant in one language with the less dominant language referred to as the subordinate language. Chin and Wigglesworth (2007), however, argued that dominance may not be applicable to all four domains.

Degrees of proficiency in receptive and productive language skills have led to categorization of bilingual speakers into groups, such as incipient bilinguals and balanced bilingual speakers (Baker, 2011). The term “incipient bilingual” is used to describe a person with minimal competence of a second language, such as a tourist who learns a few survival phrases. Baker warns this inclusion may be perceived as too exclusive because almost every adult in the world has knowledge of a few words in another language. A balanced bilingual is someone who is essentially equally fluent in two languages. However, true equal fluency is rare as most bilingual speakers use each language for different situations, such as at home or at work. In addition to the groups introduced by Baker, in 1994, Valdes and Figueroa (as cited in von Hapsburg & Peña, 2002) included elective and circumstantial bilinguals as other groups. Elective bilinguals are people who have chosen to learn a second language, but may not necessarily use that language everyday (e.g., tourists, study abroad). Circumstantial bilinguals are those who are required to use the language every day, requiring them to learn a second language in order to communicate (e.g., immigrants). Valdes and Figueroa also stated that bilingualism is based on a “situational continuum,” as exposure and dominance varies with the situation. Given its fluidity, it is possible for a bilingual person to be considered for any of the above categories during his or her life. Soares and Grosjean (1984) explored this continuum in their study to determine how bilingual speakers on both ends utilize the lexicons for both languages for a word recognition task. The researchers found that, depending on where the person falls on the continuum, he or she may function like a monolingual or as a bilingual. However, a person who functions as a bilingual will use one language more than the other. Shi (2014a) also noted from Weiss and Dempsey’s 2008 study that even though a person may speak Spanish as a native language, it is possible that English has now become the dominant language due to the age of acquisition and increased use of the second language.

Disuse of one language may lead to eventual loss of competence in that language. This is called passive bilingualism. Chin and Wigglesworth (2007) explained that it is common for a bilingual person to understand a language but not be able to speak the same language, especially after undergoing a shift in languages. Passive bilingualism is usually seen in the children or grandchildren of immigrants who have gradually replaced the primary language with a second language based on their community and education.

Another factor influencing the nature of an individual’s bilingualism is the age of language acquisition. Tabors’ 1997 study (as cited in Goodman, 2007) defined two types of language acquisition: simultaneous and sequential. Simultaneous bilingualism occurs when a child is exposed to two languages from an early age, whereas sequential bilingualism occurs when a child learns the second language (L2) after the first language (L1) is partially established. Typically, children in the United States develop the first language at home before learning a second language at school. Most bilingual children in the United States, therefore, are considered sequential bilinguals (Bedore & Peña, 2008). A person is considered an early bilingual if both the L1 and L2 have been mastered similarly before the age of six; a late bilingual is someone who mastered the L2 after the age of 12 (Knapp & Seidlhofer, 2009).

Speech Audiometry

Communication is the basis for interaction, and clear speech is critical to understanding what we hear. Although pure-tone audiometry provides information of a patient’s hearing status, it does not assess a person’s ability to understand and hear the sounds used in everyday communication. Speech audiometry uses stimuli, such as words or sentences, often in the presence of noise or other simulated distortion, as a presumably more ecologically valid assessment of a patient’s hearing (Gelfand, 2009).

Speech recognition can be assessed with words or sentences presented either via recorded material or monitored live voice. Generally speaking, sentences are considered to be a more realistic simulation of everyday communication, having high face validity, but may place additional cognitive demands on the listener. These cognitive demands are the result of repeating multiple words instead of a single word, which relies on working memory. The demands can be magnified when the sentence consists of words that are not meaningful or does not follow syntax rules (McArdle, Wilson, & Burks, 2005). Words minimize the cognitive demands placed on working memory and are the most popular stimuli, but are not a good representation of every day speech.

Testing using recorded materials tends to result in better control over the intensity and quality of the speech material, whereas monitored live voice may be needed for patients who need extra time to respond. Mendel and Owen (2011) determined the test administration times for monitored live voice and recorded word recognition lists. Mendel and Owen concluded no statistically significant differences in administration time between the two methods. Examples of audibility measures of speech include the Northwestern University Auditory List 6 (NU-6) (Tillman & Carhart, 1966), Auditory Test W-22 (Hirsh, Davis, Silverman, Reynolds, Eldert,, & Benson, 1952), and Phonetically Balanced (PB-50) lists (Egan, 1948).

Speech recognition tests also can be performed in the presence of noise. Speech testing with noise was first used in the 1960s as a way to determine the amount of distortion (McArdle, n.d.). Distortion is a term used to describe some undesired change in the signal and can be the result of reverberation, echo, or changes during transmission (Vaseghi, 2000). In 1970, Carhart and Tillman encouraged the use of speech-in-noise testing as part of a test battery. However, a 2003 survey by Strom (as cited in Taylor, 2007) found that only 42% of dispensing audiologists use speech-in-noise testing as part of a standard test battery. Most patients complain of difficulty understanding speech in the presence of background noise, so speech-in-noise measures are useful to address this concern. Ease of administration and duration of the test are factors to consider when selecting a speech-in-noise test. Examples of speech-in-noise tests include the Speech Perception in Noise (SPIN; Kalikow, Stevens, & Elliott, 1977), Hearing in Noise Test (HINT; Nilsson, Soli, & Sullivan, 1994), QuickSIN (Sentences in Noise; Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004), Bamford-Kowal-Bench Speech in Noise test (BKB-SIN; Bench, Kowal, & Bamford, 1979), and Words in Noise (WIN; Wilson, 2003).

History of the Development and Validation of Spanish-Language Materials Available for Audiometric Testing

In spite of growing demands, the audiology test materials currently available in Spanish are substandard (Tye-Murray, 2014). As a result, testing for the multilingual population has posed significant practical challenges for audiologists. In addition, many audiologists report a low level of knowledge and confidence in selecting Spanish-language speech-recognition tests. In order to select from the current tests available, the progression of the development and validation must first be reviewed. At the time of the first publication of Spanish-language material, Hispanics comprised 3.5% of the U.S. population (Passel & D'Vera, 2008). As the Hispanic population has grown, the development of testing materials has not kept pace with this growth. In fact, Passel and D'Vera project the Hispanic population to comprise 29% of the U.S. population by 2050, only strengthening the need for well-studied and validated Spanish-language materials. Although tests were developed for research purposes, not all have been validated for clinical use. This poses a challenge for audiologists who seek these measures for clinical use, but are unable to find normative data or supporting research. The following sections provide a chronological historical review of test material development, as well as a discussion of what reliability and validity studies (if any) have been conducted for these test materials. Tables 1 and 2 provide a summary of test materials.

Interest in speech perception in the Spanish language began in the middle of the 20th century. In 1949, Tato published "Lecciones de Audiometria," in which he studied Spanish phonology and created three lists of words based on the composition of the Spanish language. He concluded that Spanish words were typically comprised of two syllables, as very few Spanish words are monosyllabic, and were tetraphonemic, consisting of four phonemes. The three tests developed by Tato (1949) were comprised of 1) 12 phonetically-balanced lists of 25 trochaic words, 2) five lists of 15 trochaic, bisyllabic words that were not phonetically balanced, and 3) three lists of 50 monosyllabic words that were not phonetically balanced. Based on these lists, Tato defined the Spanish articulation curve, which is a function of percent words correct to presentation intensity. He found that Spanish-speaking subjects tested using Spanish stimuli required 10 dB less intensity to obtain the same percentage correct as they obtained using stimuli in English.

Table 1. Summary of speech recognition materials developed for use with Spanish-speaking patients.

Test Name	Author	Stimulus Type	Number of Lists / Stimuli	Example Stimulus
Lecciones de Audiometria	Tato (1948)	trochaic bisyllabic words	12 lists of 25 words (5 lists of 15 phonetically balanced; 3 lists of 50 not phonetically balanced)	n/a
(no title)	Ferrer (1960)	nonsense CVC syllables	4 lists of 50 words	ses, ard, nes, lat, sel
(no title)	Cancel (1965)	1000 bisyllabic *grave* words	20 lists of 50 words	[Casa, taza, masa, raza]; [dama, llama, cama, lama]
(no title)	Tosi (1966)	bisyllabic *grave* words commonly used in Spain and Latin America	12 lists of 2 forms of 648 words	n/a
(no title)	Berruecos and Rodriguez (1967)	phonetically-balanced trochaic words	Sueña, suena, tierra, venta, gesta	n/a
(no title)	Benitez and Speaks (1968)	third-order synthetic sentences with competing message	n/a	n/a
Spanish Multiple Choice Rhyme Test (Spanish MRT)	Tosi (1969)	similar to English Modified Rhyme Test (MRT) - monosyllabic words in sets of six differing by initial or final consonant	n/a	n/a
(no title)	Connery (1977)	Non-phonetically-balanced multisyllabic words ending in a vowel	20-26 words per list; number of lists not available	n/a
(no title)	Spitzer (1980)	words chosen from lists of common Spanish words (objects, animals, body parts, etc)	51 bisyllabic words	niño, toro, perro, suéter, sofá
Boston College Auditory Test	Zubick et al (1983)	bisyllabic and trisyllabic *grave* words	8 lists of 50 trisyllabic words; 7 lists of 50 bisyllabic words	precioso, respeto, espalda, completo, afecto

In 1960, Ferrer reviewed Tato's "Lecciones de Audiometria" and underlined some shortcomings in the work. First, Tato did not establish the clinical application for the lists. Second, Ferrer explained that the slope of the articulation curve depended on the syllables in the words and speaker intelligibility. This caused the articulation curve to vary depending on the type of speech presented and lucidity of the speaker. Lastly, Ferrer (1960) noted an unpublished 1952 study by Berruecos, Faria, and Fernandez in which the researchers used Tato's lists to establish thresholds for intelligibility. There was a 1 dB difference between Berruecos and colleagues' and Tato's work, confirming the lists' use for obtaining speech thresholds. However, Ferrer felt a greater degree of difficulty was needed for a speech discrimination test.

Ferrer (1960) next sought to develop a Spanish language speech discrimination test using nonsense syllables, noting that these stimuli did not depend on the listener's vocabulary and could be limited to certain phonemes. Maintaining Tato's phonetic patterns, Ferrer constructed four lists of 50 nonsense syllables in consonant-vowel-consonant configurations. A pilot study of 11 Spanish-speaking participants with normal hearing found that performance on the test was consistent across participants and lists, supporting the clinical use of the nonsense syllable corpus for speech discrimination testing.

In 1965, Cancel compiled a list of *grave* words from Spanish language newspapers for a multiple choice intelligibility test in Spanish. *Grave* is a term used in Spanish to describe words that are stressed on the penultimate, or second to last, syllable (also known as paroxytone words). Cancel chose *grave* words because they were most similar to spondaic words in English, are a very common word structure in the Spanish language, and are more intelligible in Spanish than single-syllable words. Cancel hypothesized that common *grave* words should be adequate for obtaining reliable scores for assessing speech intelligibility.

In developing the *grave* word lists, Cancel noted the lack of homogeneity in Ferrer's nonsense syllables resulting from Ferrer's prerequisite for a phonetically balanced list. Cancel highlighted factors that should be considered when developing a Spanish speech reception and discrimination test, including intensity levels, degree of difficulty, equivalent measurements in both English and Spanish, phonetic length, position of the phonemes within the word, and presence of nearby sounds. In 1968, Cancel constructed a list of phonetically balanced bisyllabic *grave* words taken from the 1965 lists and developed them into a picture-naming task for use with Spanish-speaking children. Few published data using these lists could be identified; however, it is notable that this appears to be the first of many tests employing common *grave* words as stimuli.

One of the first formal adaptations of an English-language speech recognition test was the Spanish Multiple Choice Rhyme Test (Tosi, 1969). This test was based on the Modified Rhyme Test (MRT; Kruel, Nixon, Kryter, Bell, Land, & Schubert, 1968), which uses rhyming monosyllabic words that differ by either the initial or final consonant. For this test, Tosi constructed a 12-list multiple-choice test using 648 bisyllabic *grave* Spanish words commonly spoken in Latin America and Spain, as well as a list of 1,944 error words to be used as foils.

In 1978, Cooper and Langley evaluated Tosi's Spanish-language MRT for diagnostic use. Sixty native speakers of American English and 60 native speakers of Spanish were assessed by the translated MRT with either monaural auditory only or monaural audiovisual presentations with varying signal-to-noise-ratios (SNR). Based on the number of correct items for each test, Cooper and Langley concluded that the MRT is useful for auditory, visual, or audiovisual performance measurements.

Around the same time, Connery (1977; as cited in Weisleder [1987] and Taylor [2009]) outlined the use of a word list that was used with Spanish-speaking patients at the Chicago Hearing Society. The lists consisted of 20-26 non-phonetically balanced common Spanish words. Connery deemed these lists as not sensitive enough for diagnostic use, but viable for obtaining speech recognition thresholds. Weisleder (1987) noted that an audiologist who was "moderately fluent in Spanish" read the words.

Martin and Hart (1978) also recognized the need for speech audiometry materials in Spanish for children that could be administered and interpreted by a non-Spanish- speaking clinician. To accomplish this, Martin and Hart developed lists of simple English and Spanish words that could be represented visually on illustrated cards and evaluated them in a group of young children. Based on the findings of the study, Martin and Hart concluded that both the English and Spanish lists had high degrees of homogeneity, a quickly upward sloping performance-intensity function within a limited range of intensity, and good interlist equivalency, reliability, and stability. The authors suggested that these materials may be useful not only for children, but also for Spanish-speaking older patients who have little or no knowledge of English.

In 1980, Spitzer noted problems with existing test materials, including difficulty in administering the test by non-Spanish-speaking audiologists. In addition, Spitzer acknowledged the work of Martin and Hart (1978) as feasible and reliable, but noted that its rationale for selection of words may have yielded words unsuitable for clinical use, due to regional variations of the Spanish language, even within the United States. In response, Spitzer created a tape-recorded speech reception threshold (SRT) test to be administered by a non-Spanish-speaking audiologist using a picture-identification task. Test stimuli were selected from Spanish words for people, body parts, clothing, food, animals, and common objects, which were matched to pictures. Spitzer reported good correspondence (within + 10 dB) between the SRT obtained with the test and the pure-tone average, concluding it is a feasible method for obtaining an SRT in Spanish-speaking patients.

Table 2. Summary of speech recognition materials developed for use with Spanish-speaking patients, continued.

Test Name	Author	Stimulus Type	Number of Lists / Stimuli	Example Stimulus
Auditec Spanish Speech Discrimination Lists	Weisleder (1987)	bisyllabic words, most *grave*	4 lists of 50 words	mucho, compra (*grave*); salud, ayer (second-syllable accent)
Spanish Picture Identification Task	McCullough et al (1994)	bisyllabic words selected for easy illustration	2 lists of 50 words	roca, zorro, risa, tasa, sala
Digit SRT (D-SRT)	Ramkissoon et al. (2002)	pairs of digits (monosyllabic numbers between 1 and 9)	56 digit pairs	2-4; 9-3;6-8
Hearing in Noise Test (HINT) - Latin American Spanish	Barón de Otero et al (2008)	high and low context sentences	12 lists of 20 sentences	n/a
Hearing in Noise Test (HINT) - Castilian Spanish	Huarte (2008)	high and low context sentences	24 lists of 10 sentences	n/a
(no title)	Keller (2009)	homogeneous trisyllabic words	1 list of 28 words	apenas, apoyo, comprender, derecho
(no title)	Taylor (2009)	Bisyllabic/trochaic words spoken by male and female speakers	Four lists of 50 words or eight half-lists of 25 words	abrir, ahí, algo, allá, alma
Spanish Speech Perception in Noise Test (SPIN)	Cervera and Gonzalez-Alvarez (2011)	high and low context sentences, similar to the SPIN	6 lists of high-predictability sentences and 6 lists of low-predictability sentences	En el castillo se alza la TORRE (high context); Ha estado pronunciado TORRE (low context)
Spanish Language MRT (Modified Rhyme Test)	Ball (2011)	Bisyllabic words	Six 50-word lists	Olla, papa, abril, tomo, alma Ola, patio, aquí, topo, algo
HearCom Matrix Test - Spanish	Hochmuth et al (2012)	consistently-structured sentences (name, verb, number, object, adjective); closed- and open-set presentations	Twelve triple-lists (3 test lists combined to lists of 30 sentences (part 1); 6 lists of 20 sentences (part 2)	Claudia tiene DOS libros grandes. Carmen hace tres barcos VIEJOS. ELENA toma doce platos nuevos.

In 1983, Zubick, Irizarry, Rosen, Feudo, Kelly, and Strome (1983) developed the Boston College Auditory Test, using *grave*-stressed bisyllabic and trisyllabic words. At the time of publication, Zubick and colleagues noted that field-testing and validation were pending. No further published studies on the Boston College Auditory Lists from this group could be located; however, the psychometric response function of these lists was evaluated in a 2008 study discussed later in this section.

Two significant weaknesses of early Spanish-language speech recognition tests were (1) a lack of standardization in recording and (2) limited information on the effect of presentation level on performance. These factors were assessed in two studies by Weisleder and colleagues (Weisleder, 1987; Weisleder & Hodgson, 1989) for the "Spanish Speech Discrimination Lists 1-4" by Auditec of St. Louis (an original citation for the development of these tests prior to Weisleder's evaluations could not be located).

First, Weisleder (1987) examined the performance intensity functions for the Auditec lists with native speakers of Spanish. His findings showed the /s/ phoneme as the most common source of erroneous responses, which may have been a result of the variants of the /s/ sound in the Spanish language. This is evident for the phonemes /s/, /z/, and /c/, which can be pronounced as /s/ in various dialects. Words that had a plural /s/ phoneme in the final position were also commonly missed. However, the errors did not affect the word's meaning even if the /s/ phoneme was deleted. Weisleder also reported the substitution of /k/ for /t/ phonemes, likely due to the lack of aspiration in Spanish for unvoiced plosive phonemes. He concluded the performance on the word recognition ability tasks was not related to the list but to the presentation level.

Second, Weisleder and Hodgson (1989) evaluated list equivalency of the four Auditec lists. Results suggested that List 3 was statistically significantly less intelligible than the other lists. The authors also noted that study participants of Mexican origin seemed to be at an advantage due to regional variations of the native Mexican speaker on the recording. While Weisleder and Hodgson acknowledged separate lists for each Spanish-speaking region as impractical, they advised audiologists to use the most adequate test for a patient's place of origin. Based on their findings, the authors found the slope of the performance-intensity function to be comparable to that of English lists and, with the exception of List 3, considered the Auditec lists adequate for assessing word recognition abilities in Spanish speakers.

Noting that clinicians who do not speak the same language as their patients may have difficulty understanding and scoring their responses, McCullough and colleagues (1994) developed a Spanish picture-identification task that utilized audio-visual presentation. Test items which could be identified using images were selected from the Department of Veterans Affairs' Picture Identification Tasks (Wilson & Antablin, 1980) and translated to Spanish. The multimedia approach came from a computer connected to two monitors, one of which was in the control room with the audiologist and the other in the test room with the patient. Test items were presented in closed set (a grid of pictures) allowing the clinician to administer and score the test without knowing the language of the test stimuli. In an initial evaluation of the test, English-speaking audiologists were able to administer the Spanish Picture-Identification Task to Spanish speakers successfully.

Ramkissoon and colleagues (2002) took a different approach to the problem of a non-Spanish-speaking tester evaluating a Spanish-speaking patient. Instead of developing Spanish-language stimuli, these researchers created an SRT procedure using pairs of English-language monosyllabic digits between one and nine. This test presumed that even a patient with very limited English proficiency would have some knowledge of the first ten digits. The digit SRT (D-SRT) procedure was evaluated with both native- and non-native-English speakers with normal hearing who underwent testing with the D-SRT and the CID W-1 SRT stimuli. Ramkissoon et al., reported that both measures yielded accurate hearing thresholds for all participants, but the D-SRT was more sensitive than the CID W-1 stimuli for obtaining an SRT. Based on these results, the authors concluded that the D-SRT was effective for obtaining an SRT due to the familiarity of the stimuli (spondaic pairs of digits) rather than the words typically used in an SRT measure, and that English-speaking audiologists should use the D-SRT to obtain an SRT on non-native speakers of English. This approach should allow the audiologist to discern audiometric results for a non-native speaker of English who may be limited by vocabulary, proficiency in English, and educational level from hearing sensitivity.

In 2008, Flores and Ayoama compared the psychometric function of four existing Spanish word recognition tests (the Auditec of St Louis lists, the Boston College Auditory Test, the Comm Tech monosyllabic word test, and the trochaic word lists developed by Berruecos and Rodriguez [1967]). The authors found similar performance for the Auditec of St. Louis and Boston College Auditory test measures in Spanish-speaking patients; however, these results differed from the monosyllabic words from the Comm Tech test and the trochaic word lists from Berruecos and Rodriguez (1967). Flores and Ayoama also found that bilingual speakers who learned English as a second language performed significantly better than bilingual speakers who learned both languages simultaneously, suggesting the effects of linguistic background, such as balance between the participants' first and second languages and pattern of acquisition.

The Hearing in Noise Test (HINT) is a measure of repetition of simple sentences in a background of noise (Nilsson, Soli, & Sullivan, 1994). The HINT is commonly used in clinical settings and has been developed in several other languages, including Latin American Spanish (Barón de Otero, Brik, Flores, Ortiz, & Abdala, 2008) and Castilian (Huarte, 2008).

Given the linguistically diverse countries of Latin America, the authors of the Latin American version of the HINT were challenged to create a test that could be used in several of these countries while avoiding dialectal differences. Using a general dialect of Latin American Spanish typically used by newscasters, the HINT sentences were shared among 14 Latin American countries such as Argentina, Chile, Cuba, Perú, and Venezuela. After considering each country's idiomatic usage, the words were divided into 12 lists of 20 sentences (Barón de Otero et al., 2008). Evaluations of the performance-intensity function of the test were conducted in Mexico, Colombia, and Argentina, and yielded almost identical performance-intensity functions for each list and SNR condition (-7, -4, and -2 dB). Because normative data had not yet been collected at the time of publication, the normative values from the American English HINT were used until norms had been established in Spanish. At the time of this publication, normative data for this test were unavailable.

Castilian is a variation of Spanish and is the official language of Spain. Huarte (2008) developed a Castilian Spanish version of the HINT from translated and adapted sentences from the American English version of the HINT. The phonemes in the Castilian Spanish HINT are typical of those present in conversation. Similar to the procedure described above by Barón de Otero and colleagues, a performance-intensity function was estimated for 24 lists of 10 sentences in the same SNR conditions and an initial set of normative data was collected. Based on this initial evaluation, Huarte recommended the use of the Castilian Spanish HINT for evaluations of adults using hearing aids or cochlear implants.

In 2009, Keller developed and evaluated a speech reception threshold test that used 90 Spanish trisyllabic words selected from a list of the 2,000 most commonly used words by Davies (2006). Test words were recorded by male and female speakers of Spanish. Participants, who were native speakers of Mexican Spanish and had normal hearing sensitivity, listened to and repeated the trisyllabic words, which were then scored by a native Spanish speaker. Keller selected a list of 28 words with the steepest performance-intensity function (10.1% dB for the male talker and 8.7% dB for the female talker) and recommended the use of this list for obtaining SRT from individuals with hearing loss.

Also in 2009, Taylor developed a Spanish word recognition measure with more modern vocabulary and language than the words used in older tests. Male and female adults who were native speakers of Mexican Spanish recorded four lists of 50 words or eight lists of 25 words. The highest ranked female and male speakers were chosen for the recordings. In an initial study of 20 participants with normal hearing, the lists were determined to be homogenous in audibility and psychometric function.

While the SPIN test (Kalikow, Stevens, & Elliot, 1977), a clinical speech perception measure using sentence stimuli, is not available in Spanish, Cervera and González-Alvarez (2011) used it as the basis for developing an intelligibility measure using Spanish sentences in noise. Similar to the English SPIN, the test consisted of high predictability and low predictability sentences presented with three different SNR conditions (0 dB, +5 dB, and +10 dB). Cervera and González-Alvarez (2011) highlighted the advantages of the measure, including ease of administration, simple listener response, and short duration of test. In addition, the test was designed to control for phonetic content, final word stress and frequency, and sentence length. However, to date, there have been no further published studies using these lists.

In 2011, Ball created a Spanish-language version of the Modified Rhyme Test, based on previous work by Tato (1949) and Aguilar (1991). Six lists of 50 words were developed and recorded, and normative data were collected from 44 native Spanish speakers with normal hearing. Although two of the lists produced more errors than the other lists, Ball recommended validation of the words and further use of the lists with Spanish-speaking adults with hearing loss.

In 2012, Hochmuth and colleagues developed a matrix sentence test in Spanish to obtain an SRT. The authors constructed the test as part of the HearCom project, a research project to develop and validate tests into other languages like British English, French, Spanish, Russian, and Greek (see Zokoll, Hochmuth, Warzybok, Wagener, Buschermöhle, & Kollmeier, 2013). Hochmuth and colleagues used the Spanish matrix sentence test to compare the SRT obtained with other matrix tests in other languages, the variability between lists, differences between closed and open-set versions, and performance between subjects from different Spanish-speaking countries. Test lists were generated from the most frequently used words in Spanish (Davies, 2006) to form a sentence that included a name, verb, number, object, and an adjective. Competition noise was created from superimposing all sentences, generating the same long-term average speech spectrum as the sentences for optimal masking.

The Spanish matrix test was then evaluated for practice effects (an effect of 1.1 dB SNR was observed between the first and second measurements) and compared across lists and between open- and closed-set formats. Hochmuth and her co-investigators found that the lists could be used interchangeably, as there were no significant differences between SRTs on the 10 lists. Performance on the open- and closed-set format was also similar. In addition, there were no performance differences between Spanish and Latin American subjects, nor were there regional differences between participants from Tenerife and the Spanish mainland. These findings support the use of the Spanish matrix test for Spanish speakers from different origins.

A few general findings are notable from this review of test material development in Spanish. First, while several attempts have been made to develop speech recognition materials for Spanish-speaking patients, the majority of these have not been validated adequately for clinical use. For many of these materials, no validity studies could be identified at all. Second, it is clear that both the dialect of the patient (i.e., Weisleder & Hodgson, 1989) and the dialect of the audiologist, if materials are presented via live voice (i.e., Weiselder, 1987), are likely to affect scores obtained in speech recognition testing. This presents a challenge for the audiologist to identify regionally-appropriate materials for Spanish-speaking patients and to present those materials in such a way that the tester's knowledge of Spanish and/or dialect have a minimal influence on scoring. Finally, for bilingual patients, selection of most appropriate test materials may be complicated by the nature of each patient's language knowledge and order of

Table 3. Comparison of stimuli for word-recognition and speech-reception-threshold testing in English and Spanish.

Test	English-Language Stimulus	Example Stimulus	Spanish-Language Approximate	Example Stimulus	Rationale
Speech Reception Threshold (SRT)	Spondaic Words (Spondees)	Baseball, Toothbrush, Airplane	Bisyllabic *Grave* (Trochaic) Words	Casa, Puerta, Mono	Spondaic forms (equal stress on both syllables) are uncommon in Spanish. More than half of all Spanish words are *grave* (having stress on the penultimate syllable).
			Trisyllabic *Grave* Words	Cincuenta, Manzana, Hamaca	
Word Recognition Score (WRS)	Consonant-Nucleus-Consonant (CNC) Words	Knock, Tape, Gaze	Bisyllabic *Grave* (Trochaic) Words	Casa, Puerta, Mono	Few concrete words (nouns, simple verbs and adjectives) are monosyllabic in Spanish. The consonant-nucleus-consonant construction of English word-recognition stimuli is uncommon in Spanish.

languages learned (i.e., Flores & Ayoama, 2008).

Factors Affecting Speech Recognition Testing with Bilingual and Spanish-Speaking Patients

Speech recognition ability in all listeners is affected by numerous patient, stimulus, and environmental test factors. It is useful to discuss the research on the effect of some of these factors on speech recognition of Spanish-speaking listeners in particular.

Patient factors. Performance on word recognition tests may be influenced by several characteristics of the patient, including the age of acquisition of the second language and proficiency in the second language.

The age of language acquisition impacts speech perception in noisy and reverberant environments. A 1997 study by Mayo, Florentine, and Buus assessed the performance of Mexican-Spanish-speaking early bilinguals and late bilinguals on speech perception tests. The SPIN test was presented at varying SNR. The results indicated early bilinguals performed better in noise than late bilinguals, but both groups performed equally in quiet conditions. Also, the authors noted the possibility of the first language interfering with an early bilingual's perception of their second language in noise.

A study by Von Hapsburg and Peña (2002) supported the findings of Mayo, Florentine, and Buus (1997) concluding that bilingual listeners did not perform as well as monolingual listeners in the presence of background noise. Von Hapsburg and Peña also noted longer processing times for bilingual listeners, highlighting the effects a timed test might have on a bilingual patient. In 2003, Febo studied the effects of speech perception in early bilinguals compared to monolinguals. The speech perception abilities of monolingual English speakers and early bilingual speakers (who had acquired Spanish and English prior to six years of age) were assessed with varying levels in noisy anechoic and noisy reverberant environments. Febo (2003) learned that the early bilingual participants experienced adverse effects on their speech perception abilities in the noisy environments and scored poorer than monolingual speakers in all noise levels. Both monolingual and bilingual speakers performed similarly in quiet. Results of this study support the idea that bilingual listeners, regardless of proficiency, do not perform as well as monolingual speakers on speech recognition measures in adverse listening conditions.

Von Hapsburg, Champlin, and Shetty (2004) also investigated age of acquisition in bilingual speakers completing a speech perception task. A homogeneous group of bilingual speakers was created based on age of L2 acquisition, language function, language competency, and language history. The reception threshold for sentences (RTS) was found for each participant on the HINT with two speakers at 0 degrees azimuth and 90 degrees azimuth presenting noise. Group comparisons showed equal performance for both late bilinguals and monolinguals in noise, and that bilingual speakers needed a signal-to-noise ratio (SNR) of about 4 dB more than monolingual speakers for the HINT test. The HINT manual states that an SNR difference of 1 dB is equal to nine percentage points for sentence intelligibility, corresponding to a 36% poorer score for bilingual speakers than monolingual speakers when the L2 is used as the stimulus language. Hanks and Johnson (1998) investigated the list equivalency of the HINT for older adult listeners between the ages of 60 and 70 with a mild sensorineural hearing loss. The RTS from their study was about 10 dB greater than the RTS from von Hapsburg, Champlin, and Shetty. Based on these conclusions, von Hapsburg and colleagues suggested that bilingual listeners with normal hearing perform equally or worse than an older adult with a mild hearing loss. However, depending on azimuth of the noise and the presence of background noise, bilingual speakers and individuals with a mild hearing loss showed no differences. The authors attribute the similar scores to additional auditory processing requirements of late bilinguals.

In 2008, Weiss and Dempsey used the Latin American Spanish and English versions of the HINT to compare bilingual speakers' performance. The participants were divided into two groups based on age of second-language acquisition (early bilinguals and late bilinguals) as past studies have indicated that incomplete linguistic profiles make comparisons among studies and subjects difficult (Von Hapsburg & Peña, 2002). Weiss and Dempsey found that all bilingual participants had higher scores on the Latin American Spanish version of the HINT than on the English version in both quiet and noise conditions. The authors also reported higher scores for the late bilingual group, echoing the findings of von Hapsburg and Peña (2002). Although the explanation for these findings was inconclusive, Weiss and Dempsey caution audiologists when choosing the appropriate version of speech perception tests and interpreting the test results due to differences in performance based on the participant's L1 and L2.

Other studies have also addressed the issue of patient's English proficiency (which may be distinct from age of language acquisition) as a determinant in selection of speech audiometry test materials. Although a bilingual listener may use English daily at work or in the community, it may not be prudent to administer English-only speech perception measures during an audiologic evaluation. Shi and Sánchez (2010) recommended speech recognition testing in Spanish or in both languages; however, testing in both languages may not be practical due to busy clinician schedules and patient fatigue. The authors sought to predict the dominant language to administer speech perception tests to bilingual Spanish/English participants. Linguistic variables, such as age of acquisition and use of language were noted for each participant. The English word recognition test came from the NU-6 lists and the Spanish test material was taken from Lists 1, 2, and 4 of the bisyllabic words from Weisleder and Hodgson (1989). Shi and Sánchez learned that the age of acquisition of English, duration of immersion in the English language, self-reported Spanish listening proficiency, and language dominance had the largest impact on bilingual speakers' performance. Performance on one measure did not correlate with performance on the other, and performance may not be predicted by linguistic variables. Shi and Sánchez (2010) recommended using age of acquisition or language dominance to determine the optimal language for word recognition testing instead.

Shi (2014b) sought to replicate results of the 2010 study on predicting success on word recognition measures with bilingual subjects. Comparable results were found, validating the findings of the previous study (Shi & Sánchez, 2010). The proposed models included language dominance, language proficiency, and age of acquisition. Shi recommended the use of these models for audiologists employed in urban settings who work with large Hispanic populations.

Proficiency in a second language is highly influenced by the aforementioned linguistic variables, compelling clinicians to rely on subjective measures of language proficiency. Shi (2011) identified a method to assess a bilingual listener's proficiency in English reliably and efficiently. In the study, 125 bilingual adults were administered the NU-6 word recognition test and were asked to rate their own proficiency in listening, reading, and speaking on the Language Experience and Proficiency Questionnaire (LEAP-Q). Shi noted high sensitivity when the self-reported proficiency in listener was used as the only predictor, but also reported low specificity from overrating their listening proficiency instead of reading and speaking. About 90% of the bilingual listeners reported at least a "good" proficiency in all three domains of English. However, only 68.8% scored a 90% or better on the NU-6 test. Prediction specificity improved when language dominance and age of acquisition of English were factored in self-reported proficiency ratings. Shi concluded that, although the self-rated proficiency was convenient, it had limitations when used with more difficult measures, such as word recognition in noise and with less lenient scoring.

Table 4. Factors to consider in testing word recognition of Spanish-speaking patients.

Patient Factors	Stimulus Factors	Environmental Factors	Talker Factors
Age of second language acquisition (Mayo et al., 1997; von Hapsburg and Peña, 2002; Weiss and Dempsey, 2008)	Item complexity (Cervera and González-Alvarez, 2010	Reverberation (Rogers et al, 2006)	Clear speech (Bradlow and Bent, 2002; Smiljanić & Bradlow, 2008)
Second language proficiency (Shi, 2011, 2014b; Shi and Sánchez, 2010)	Item familiarity (Shi, 2014a; Shi and Sánchez, 2011	Noise (Cooke et al., 2008; Kilman et al., 2014)	
	Item dialect (Rogers et al., 2006; Shi and Canizalez, 2013)		
	Ease of administration by non-language-proficient clinician (Cokely and Yager, 1993)		

Stimulus factors. Characteristics of the stimulus are also likely to influence performance on word-recognition tasks by bilingual patients. These include the familiarity and complexity of test items, dialectical characteristics of test items, and ease of administration of the test by a clinician with limited language proficiency.

Cervera and González-Alvarez (2010) compiled a list of Spanish sentences that have been used in cognition and speech-processing research to study the effects context has on recognition of words, such as with elderly listeners. For example, tests like the SPIN have low-predictability and high-predictability sentences, and are useful for testing elderly patients, as those patients can present with age-related cognition changes. This cognitive decline is independent of hearing sensitivity and may result in higher performance on the high-predictability sentences than the low-predictability sentences (Pichora-Fuller, 2003). If there is no difference in performance between the high- and low-predictability sentences, cognitive processing deficits may be present. The lists Cervera and González-Alvarez chose for this compilation were controlled for length, predictability, and final word frequency. The authors chose six lists of 25 high-predictability sentences and six lists of 25 low-predictability sentences that were equivalent in all of the aforementioned properties. Cervera and González-Alvarez intended these sentences to be used in psycholinguistics, as no equivalent lists had previously existed in the Spanish language. There has been no further testing using these sentence lists.

Word familiarity should also be considered when administering speech recognition measures to bilingual participants. Unfamiliar words can lead to greater perceptual errors than familiar words when administered to both native and non-native listeners. This fact underlines the importance of familiarity in speech recognition in English and Spanish, independently. Shi and Sánchez (2011) explored the role word familiarity played on bilingual participants' performance on the English NU-6 monosyllabic words and Spanish bisyllabic words from Weisleder and Hodgson (1989). Shi and Sánchez learned that there was no difference between familiarity and word recognition scores in quiet and noise conditions. Participants also reported more unfamiliar words in their less-dominant language than in their dominant language, scoring lower on the unfamiliar words than the familiar words. Based on these findings, it is important that participants be tested in their more-dominant language and be familiar with the words used for testing. Shi (2014a) recommended further research to determine if testing should be completed in the more dominant language or in both languages, as well as conducting the measures in either language, given the varying language status in bilingual listeners.

Dialectal differences also have a significant impact on the scoring of word recognition measures. Shi and Canizales (2013) explored the effects of listeners' dialects and their variations on Spanish word recognition tests. The study's subjects included 40 native Spanish speakers with normal hearing who originated from either the Highland region (which includes the Andean regions of South America), the Caribbean, or coastal countries. The subjects were also further divided by dominant language, either English or Spanish. Canizales administered the Auditec bisyllabic Spanish word lists to the subjects in different signal-to-noise ratios (SNR+6, +3, and 0 dB). The authors found significant effects of dialect and language dominance, along with the SNR. However, it should be noted the effects of dialect were independent of those from SNR and language dominance. The results from this study are important for clinicians scoring word recognition measures, as the phonology of the Spanish language and its various dialects can affect results (Rogers, Lister, Febo, Besing, & Abrams, 2006).

Ease of administration is important for Spanish speech audiometry materials, as most clinicians are not bilingual and feel less confident scoring a test for phonemes correctly, particularly if the responses were oral. A clinician may incorrectly score a patient's speech recognition, due to lack of knowledge of the area or linguistic competency of Spanish phonemes. In 1993, Cokely and Yager assessed the scoring of two groups of judges, one group of 15 native English speakers with no knowledge of Spanish and another group of 15 native English speakers who spoke Spanish. Oral responses from the Auditec 1-4 lists were recorded and scored by both groups. Cokely and Yager (1993) found no significant differences between the groups, with both groups of judges obtaining similar word recognition scores (WRS) from oral and written responses. This difference was not deemed clinically significant, suggesting that the language of the scorer did not have an effect on the WRS in the other language. The authors also echoed the findings of Weisleder and Hodgson (1989) after observing statistically significant differences for the Spanish speakers on the Auditec lists; however, they found List 1 to be the outlier, with 13-22% higher than the means of Lists 2, 3, and 4. They suggested the need for further research of the equivalency between the Auditec lists.

Environmental factors. Environmental factors, particularly noise and reverberation as competition for the test stimuli, are also likely to influence performance. Reverberation refers to the reflected sounds from surfaces. If excessive, reverberation from the environment and noise can have adverse effects on speech understanding (Nabelek & Mason, 1981). A 2006 study by Rogers and colleagues compared the performance of monolingual English speakers and Spanish/English bilingual speakers who had learned English before the age of 6. They reported poorer scores for the bilingual participants in noise and reverberation, but equal scores for both groups in the quiet condition. Overall, all participants had lower scores for the noisy and reverberant environments (Rogers, Lister, Febo, Besing & Abrams, 2006). These results indicate that early bilingual listeners have less tolerance for acoustic degradations than monolingual listeners. This may be attributed to increased cognitive demands to process and attend to the active language and isolate the phonemes needed for speech understanding in each language.

Masking can be added to a speech perception measure to ensure the participation of only the test-ear or to simulate a real-world listening environment. There are two types of masking: energetic and informational. Energetic masking is typically used in clinical settings, where the masker's amplitude fluctuates and the stimuli can still be heard during these oscillations. Examples of energetic maskers include multi-talker babble and stationary noise. Informational masking refers to the use of sentences or words that are meaningful. These words can be heard and understood by the patient, and are therefore likely to interfere with the stimuli. Past research has demonstrated that similarity between the masker and stimuli leads to increased effort to separate them (Van Engen, 2010).

The independent contributions of energetic and informational masking in difficult listening environments may be dependent on proficiency in a non-native language. Kilman, Zekveld, Hällgren, and Rönnberg (2014) utilized energetic and informational masking to determine the influence proficiency in a non-native language had on speech perception abilities in noise. The maskers used were stationary noise, fluctuating noise, two-talker babble in Swedish, and two-talker babble in English. Twenty-three native Swedish participants between the ages of 28 years and 64 years who had normal hearing underwent speech recognition testing in the presence of background noise. Participants also underwent a test of working memory capacity, non-verbal reasoning, and English proficiency. Participants had better SRTs when the target speech was in their native language (Swedish). This improvement was also noted for target speech in the non-native language (English) for participants who reported high levels of English proficiency. However, when the masker and target speech were in the same language (i.e. Swedish masker and Swedish target speech), participants experienced more interference and lower SRTs than when the target speech was different from the language of the masker. This highlights the degree to which experience in a non-native language influences difficult speech perception.

The presence of background noise may create additional demands on attention and processing which may be ameliorated with the use of a slower rate of speech. In 2008, Cooke, Lecumberri, and Barker explored the performance of English and

Spanish speakers on the identification of keywords of sentences that were spoken by native speakers of English in the quiet and noise conditions. The noise conditions involved either stationary speech-shaped or competing noise (energetic and informational). Non-native listeners found the task more difficult when the masker level increased, especially when the masking was stationary noise. Compared to the native-speakers, non-native speakers performed worse in both noise conditions. However, when the keywords were produced slowly, the non-native speakers were able to identify more utterances.

Talker factors. Use of clear speech can improve intelligibility of spoken messages for people with hearing loss (Picheny et al., 1985 as cited in Schum, 1996). Clear speech requires the talker to speak louder and slower while decreasing his or her rate of speech, distinguishing phonemes, and increasing phoneme length. A talker may use clear speech when speaking to someone who has a hearing loss or is not native speaker of the talker's language (Smiljanić & Bradlow, 2008).

The benefit of clear speech when listening in a non-native language may be limited. Bradlow and Bent (2002) evaluated clear speech benefit in 32 non-native English speakers and 32 native English speakers with normal hearing. Sentences from a modified version of the Revised Bamford-Kowal-Bench Standard Sentence Test were read by two native speakers of American English (one female and one male), first using a conversational style of speaking and then with clear speech. The sentences were also presented in varying SNR of -4 to -8 dB. Results of the study revealed that the non-native listeners experienced a smaller benefit from clear speech, did not experience negative effects when the noise level was increased, and demographic variables did not appear to be related to speech perception ability. The effects of clear speech were greater for the female talker. Interestingly, Bradlow and Bent (2002) found that clear speech is only fully beneficial for listeners who are familiar with the phonemes and phonology of the language spoken, thereby referring to it as "native-listener oriented."

Summary

Although many tests have been developed, it is evident that further measures of validity and reliability are needed to assess those tests' clinical application. Furthermore, the complexity of the bilingual population sheds light on the need for culturally and linguistically competent clinicians to be aware of these differences when developing and administering these tests. The phonetic and semantic nuances of Spanish and English complicate the effects of sensorineural hearing loss in both pediatric and adult populations. Clinicians should be aware of what test materials exist for primarily Spanish-speaking patients and consider the effects of language dominance, age of second-language acquisition, and language used in the home when evaluating speech recognition test results.

Despite the paucity of well-validated test materials and procedures for testing the Spanish-speaking population, audiologists in all settings must be prepared to appropriately diagnose patients who cannot be assessed using standard English-language materials. While it is difficult to make broad recommendations for testing such a heterogeneous population as would be described by the term "Spanish-speaking patients," we offer the following suggestions. First, it is useful to understand that creation of Spanish-language (or other language) test stimuli directly analogous in form to English-language test stimuli presents challenges. The consonant-nucleus-consonant form of words commonly used in word recognition testing, for example, does not occur in Spanish. Spondaic words are also uncommon in Spanish; most words feature penultimate stress. The reader is referred to Table 3 for a comparison of English and Spanish stimulus types, which may inform comparison between SRT and word recognition scores obtained in both languages. Second, as with all word recognition testing, recorded stimuli are preferable to stimuli presented via live voice. This limits the potential distortion of stimuli introduced by the talker's dialect and knowledge of the language of the stimulus. Picture-pointing tasks may also help overcome these potential problems. Third, dialectical differences should be considered in the response. That is, stimulus items on most of the tests reviewed here are based on Mexican Spanish. Speakers of other Spanish dialects may make a greater number of errors than Mexican Spanish speakers based on relative unfamiliarity of words presented. Finally, conservative interpretation of scores obtained by any of the tests reviewed here is indicated until further reliability and validity studies can be conducted on these measures.

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Considerations in Speech Recognition Testing of Bilingual and Spanish-Speaking Patients, Part II: Young Children

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The rapid growth of the Spanish-speaking population of the United States presents challenges for healthcare providers to develop linguistically- and culturally- appropriate best practices. An essential need for all audiologists is language-appropriate stimuli for speech recognition testing. Unfortunately, few well-validated tests exist for this purpose. We review the timeline of development of Spanish-language speech recognition test materials and address challenges facing the audiologist in evaluating accurately the speech-recognition abilities of young children who use Spanish as their primary or only language of communication, with emphasis on picture-pointing tests. Cultural, dialectical, and educational concerns for this population are discussed.

Introduction

Part I of this two-paper series reviews environmental, stimulus, and patient considerations in evaluating speech recognition abilities of older children and adults who are bilingual Spanish speakers or speakers of Spanish alone. In part II, we review similar issues for younger children and provide an overview of Spanish-language test materials developed for pediatric patients, particularly picture-pointing tests. We refer the reader to Gaeta and John (this issue) and to Shi (2014) for an extensive discussion of issues facing audiologists in conducting speech-recognition testing with Spanish-speaking patients.

Audiology and the Spanish-Speaking Pediatric Population

Pediatric hearing loss is an important public health concern. In 2008, Ross, Holstrum, Gaffney, Green, Oyler, and Gravel found that nearly three in 1,000 babies born in the United States are born with a permanent hearing loss. The prevalence of hearing loss in Hispanic children is higher than that in other children (Mehra, Eavey, & Keamy, 2009). As the resolution of diagnostic tools improve, more children are being identified early and enrolled in the appropriate intervention programs. A comparison of reports by the Gallaudet Research Institute's Survey of Deaf or Hard of Hearing Children (2002, 2011) reveals 21.9% of students surveyed in 2009-2010 reported Spanish as the spoken/written language in the home compared to 10.3% of students in 2000-2001. Despite these growing demographics, resources for speakers of Spanish have failed to keep pace, posing a challenge for audiologists who must administer, score, and interpret results from an audiologic evaluation and provide the ensuing recommendations.

In addition to the lack of testing materials available for the Spanish-speaking pediatric population, the Hispanic population encounters social and economic barriers and is more likely to be delayed timely and appropriate health care (Escarce & Kapur, 2006). Flores, Olson, and Tomany-Korman (2005) reported both racial and ethnic disparities among Hispanic children and insurance coverage, as 31% of Hispanic children are uninsured compared to 9% of Caucasian children. The inequality may result in Hispanic children being fit with lower-end technology for amplification and receiving limited speech and language therapy services. However, some organizations and hearing aid manufacturers donate or purchase hearing aids for low-income families to address this disparity (Morrison, 2008). The selection of hearing aids may be affected by the availability for distribution as some cities have more low-income families who require assistance. Flores and colleagues also noted that Hispanic parents made fewer phone calls to healthcare providers than did their Caucasian counterparts, probably due to language barriers rising from communication with the clinical staff. Providers also made fewer referrals to specialists for this population, compounding the disparity.

Cultural and Language Issues in the Assessment of Young Children

Cultural differences play a large role in the identification and intervention of hearing loss in bilingual children. A 2003 study by Steinberg, Bain, Li, Delgado, and Ruperto explored this role by interacting with Hispanic families living in the United States who had a child who had been identified with hearing loss. Steinberg and her colleagues found that many factors impacted the family's decision, including involvement of the parents and other healthcare professionals, language differences, language preference, choice of communication, decision-making roles, and religion. In the study, the authors learned that 100% of mothers were involved in the decision-making, compared to 64% of fathers. The parents also sought recommendations mostly from healthcare professionals (96%) and the child's school district (86%). Parents in the study stated that they felt the most influence from professionals who "listened to [their] concerns." Although language barriers are typical for Spanish speakers in English-only environments, only four families in the study considered it to be a factor limiting their information. However, the majority were unable to share this experience due to the availability of interpreters, translators, and Spanish-speaking providers. Steinberg and her co-investigators reported that one parent in their study said that the material was a direct translation from English, disregarding nuances of the language and making the terminology difficult to understand. The authors reported that 63% of families hoped their child would be bilingual (Spanish/English) or trilingual (Spanish/English/sign language), with some parents stressing the need for their child to retain their Hispanic culture. In the study, 63% of families were only offered total communication by their school or school district and reported that other communication methods were not discussed. Total communication is a philosophy that involves choosing methods of communication (oral, signed/manual, written, and auditory language) that are appropriate for a child's communication needs. About half of the families interviewed described their decision-making in their child's intervention as "active," and 37% described themselves as "passive" (The authors were not able to classify three families). Lastly, 17 of the 27 families surveyed stated that religion influenced their decision-making, with four families crediting God for improvements in their child's hearing.

Similarly, Guiberson (2014) conducted a survey of parents who had children who are deaf or hard of hearing in Spain. Seventy-one parents took the online survey, which included questions about influences and inclinations of parents for a mode of communication and bilingualism for their children. Although Guiberson noted that these cultural variables are different in Spain, the results mirrored those of Steinberg and her co-investigators (2003). Guiberson found that family involvement was a major factor in the decision of a communication mode, and that the parents and grandparents were the most involved. However, unlike the Hispanic families in Steinberg and colleagues' study, Spanish families were more likely to seek advice from professionals in speech and hearing, rather than from physicians. Guiberson attributed this difference to higher parental education levels in Spanish parents of which 48% of mothers and 49% of fathers earned at least a bachelor's degree, compared to 3% of mothers in the Steinberg and colleagues group. This family support has a strong influence on the decision of a communication modality and bilingualism in children with hearing loss. Further research is needed on the role parental education has on the decision making process for children who are deaf or hard of hearing.

The results of Guiberson's 2014 study are important because they highlight the many intricate factors that can have a large impact on the decision-making process in this population. Foremost, cultural competence and sensitivity are paramount in providing services to Hispanic families to ensure satisfaction, gain trust and confidence, and ensure future involvement from both sides. Steinberg and her co-investigators emphasized the need for a "shared language", similar to that of the Deaf culture. Lastly, the authors stressed the need for Hispanic professionals who can support and advocate for this growing population.

Peyton, Ranaard, and McGinnis (2001) reported that one in four children speak a non-English language when they enter school, and eventually lose the first language as they are exposed to and learn English in school. Language can become a concern for the audiologist working with the child and his or her family when there is no common language. After a child is identified with hearing loss, it is imperative intervention occurs as soon as possible. However, the initial assessment and further assessments of progress are impeded when the audiologist does not speak the native language of the child and if the appropriate measures are not used. The U.S. Department of Education's Individuals with Disabilities Education Act (2004) requires that evaluations and assessments be "administered in the child's native language or other mode of communication and in the form most likely to yield accurate information on what the child knows and can do academically, developmentally, and functionally, unless it is clearly not feasible to provide or administer." It can be challenging for audiologists who must choose the most appropriate test for a non-English speaking child, decide the language to use for testing, and to score the child's responses. Although there are speech perception materials available in Spanish, not all of the measures have been validated and used outside of research. Additionally, there has been limited research with bilingual children. Therefore, the primary purpose of this paper is to review the current literature for speech perception measures available for assessing Spanish/English bilingual children. This review will provide additional considerations facing this growing pediatric population.

Speech Audiometry and Monolingual Children

As described in the Part I paper, clear speech has been shown to improve intelligibility of speech. Bradlow, Kraus, and Hayes (2003) examined speech perception in noise abilities in children with learning disabilities (with and without a diagnosis) and children without learning disabilities. The subjects were 63 school-age children with learning disabilities and 36 children for the control group. The children underwent testing similar to that of Bradlow and Bent (2002) (see Part I), including the Revised Bamford-Kowal-Bench (BKB) (Bench, Kowal, & Bamford, 1979) sentences spoken by a male and female speaker in both conversational and clear speech styles in varying signal-to-noise ratios (SNR). Bradlow, Kraus, and Hayes concluded that speech perception in noise highlights deficits in children with learning disabilities. These children performed worse than the control group and experienced greater adverse effects when the SNR was increased. The study results also reveal additional factors such as background noise, reverberation, and hearing loss can increase difficulties with speech perception. However, clear speech was shown to benefit both groups of children in spite of the decreasing SNR. This discovery, Bradlow and colleagues suggested, is the basis for encouraging clear speech for these children. As seen in the 2002 study by Bradlow and Bent, the observed clear speech effect was greater for the female talker, leading to an increase in benefit for the female talker. Bradlow and her colleagues recommended that parents, clinicians, and teachers use clear speech to speak to children in environments with poor SNR.

The adverse effects in noise are exacerbated as hearing loss increases. Blamey and colleagues (2001) studied the relation between speech perception and hearing loss, along with speech production, spoken language, and age. The researchers also explored differences in these skills for children with hearing aids and cochlear implants. Using the information from this study, Blamey and his co-investigators designed a model of language acquisition and speech perception for children with hearing loss, and considered the development of these skills when they enter secondary school. For the study, the researchers enrolled 78 children (4-12 years old) who had hearing loss of at least 40 dB HL and a cochlear implant and/or hearing aid. All of the children were enrolled in classes with normal hearing children and participated in an aural/oral rehabilitation program. The children underwent a series of measures to assess their abilities in the aforementioned areas. Speech perception ability was measured with the Consonant-Nucleus-Consonant (CNC) test (Peterson & Lehiste, 1962) and Bench-Kowal-Bamford (BKB) test. Two lists from both measures were presented in an auditory-visual condition and two lists in an auditory-only condition. Blamey and his colleagues found that speech production and language level had a large impact on speech perception. Speech perception scores declined 5% for every 10 dB of the child's hearing loss for the auditory-only conditions. However, the researchers concluded that when the child's language scores reach that of a seven-year-old with normal hearing, his or her sentence recognition scores are expected to exceed 90% in an auditory-visual condition, which the authors identify as representative of the child's daily communication modes.

As the numbers of bilingual children continue to increase, concerns have risen about introducing a second language to children with hearing loss. These arise from concerns that the child will become confused and will be unable to separate the two languages, in spite of research demonstrating otherwise. A 2013 study by Bunta and Douglas explored this notion by comparing language abilities in bilingual and monolingual children with hearing loss and assessing the bilingual children's language scores in both English and Spanish. The study involved 40 children who wore a cochlear implant and/or hearing aids before the age of five and who had been enrolled in oral communication classes for at least one year. The children underwent a test battery consisting of auditory comprehension, expressive communication, and total language scores from the Preschool Language Scale (PLS-4) (Zimmerman, Steiner, & Pond, 2002). Based on the results of their study, Bunta and Douglas concluded that learning two languages, in this case, English and Spanish, had no adverse effects on language development. The bilingual children performed comparably to their monolingual peers. Banta and Douglas supported these findings by underscoring the role of the audiologist, speech-language pathologist, and educator to enable this dual-language use and proficiency. It is also noteworthy that the children in the study received language support in Spanish and English. The authors of this study underscored the role of a home language as well as speech and language development in both languages.

Speech Audiometry and Bilingual Children

Although there exists a selection of speech perception materials in Spanish for adults and older children, a review of the literature for speech perception measures for bilingual children does not yield many results (see Gaeta and John, this issue). Adolescents and older children may be tested with speech perception measures designed for adults. However, these measures are not appropriate for use with younger children or those with developmental delays. There have been many attempts to create measures for the pediatric population (see Table 1); however, some have been not validated and/or have not had their clinical use and feasibility reported. Five major picture-pointing tests for evaluating speech recognition of Spanish-speaking children were identified in our review and are summarized below.

Table 1. Picture-Pointing Word-Recognition Tests for Spanish-Speaking Pediatric Patients

Author	Stimulus Type	Number of Lists / Stimuli	Example Stimuli
Martin and Hart (1978)	nouns chosen based on stress pattern, simplicity, and ease of representation	12 lists (English), 12 lists (Spanish)	carro, casa, leche, libro, llave
Spitzer (1980)	words chosen from lists of common Spanish words (objects, animals, body parts, etc)	51 bisyllabic words	niño, toro, perro, suéter, sofá
Comstock and Martin (1984)	bisyllabic CVCV words within the vocabulary of Spanish-speaking preschool children	4 lists of 25 words	mala, boca, lloro, ocho, cama
Mendel et al (2013)	bisyllabic trochaic words without definite article	4 lists of 25 words	mano, ojo, puerta, cama,libro
Calandruccio et al (2014)	bisyllabic words (in both English and Spanish) from Dolch word list (1948) and common words expected to be part of a five-year-old child's vocabulary	30 words	papel, pollo, agua, mesa, niños

Picture Identification Tests

Bilingual children and audiologists may encounter a language barrier when administering speech audiometry materials (see Gaeta and John, this issue). Martin and Hart (1978) explored the use of a recorded speech reception threshold test in the form of a picture-pointing task for use with Spanish-speaking children. The use of the picture-pointing task was to allow a non-Spanish-speaking practitioner to administer the closed-set test without any knowledge of Spanish. The words for the English recordings were selected from the most familiar words for testing by Conn, Dancer, and Ventry (1975), and the Spanish words were chosen based on simplicity, stress pattern, and ease of representation in picture form (see Figure 1). Twelve phonetically-dissimilar words were selected and preceded by the carrier phrase, "¿Dónde está…" (In English, "Where is ...?"), for the task. Martin and Hart evaluated the resulting test stimuli with 16 normal hearing Spanish/English bilingual adults and 16 normal hearing Spanish/English bilingual children from Texas (age 3-6). Test stimuli were found to have good homogeneity in terms of audibility, equivalent to that of English spondees. In addition, good agreement was found between the Spanish speech threshold and the pure-tone average, with the mean of the Spanish speech threshold and the pure-tone average differing by 4 dB. Based on these findings, the authors recommended the use of the test with older patients who speak Spanish but have little to no knowledge of English. The picture-pointing task can also be easily developed and/or modified into other languages and regions.

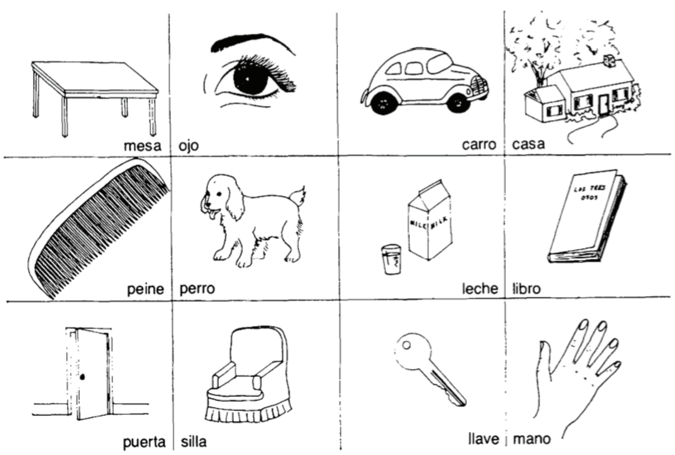

Figure 1. Sample response card for Martin and Hart picture-pointing test (from Martin and Hart, 1978)

In 1980, Spitzer sought to develop a Spanish word picture-pointing task, designed for use with Spanish speakers from diverse backgrounds. Similar to Martin and Hart (1978), the test was intended for use by non-Spanish-speaking clinicians. Spitzer cited the speech reception threshold (SRT) and picture-pointing task by Martin and Hart (1978) as having Spanish vocabulary that was "insufficient" for clinical purposes. The test items were chosen from a frequently used list of Spanish words, consisting of body parts, animals, common objects, food, clothing, and people. The carrier phrase "Muéstrame…" (In English, "Show me…") was presented before the word. No definite articles preceded the word, such as "Muéstrame niño" instead of "Muéstrame el niño," in order to avoid unintentional information (i.e. gender) influencing the word choices. The child would then point to a picture on the card, which was marked with numbers corresponding to the word's location (see Figure 2). To determine the SRT, stimuli were presented in descending 5-dB steps with three correct responses needed to proceed. Although not validated in a laboratory setting, Spitzer stated that audiologists using the test reported good agreement between the SRT and the pure-tone average without any difficulty.

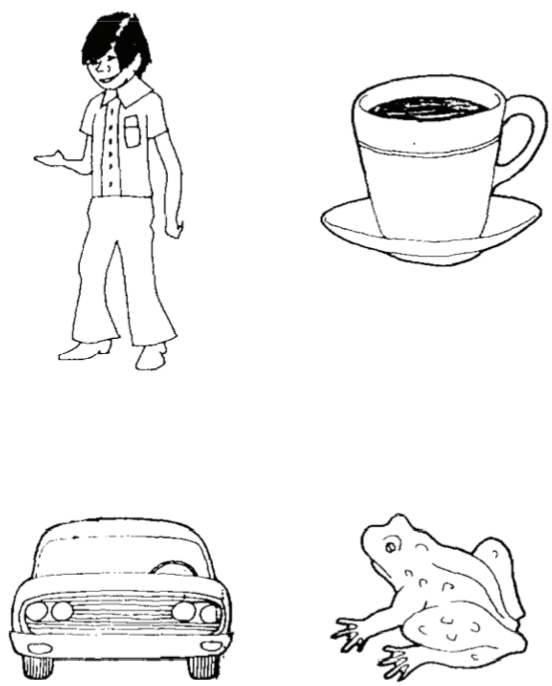

Figure 2. Sample response card for Spitzer picture-pointing test (from Spitzer, 1980)

Comstock and Martin (1984) developed a picture-pointing word discrimination test that could be administered to Spanish-speaking children by English-speaking clinicians who had no knowledge of Spanish. The authors compiled four lists of 25 words, which were recorded by a native speaker from Texas who was also fluent in Spanish. A carrier phrase, "Apunta con el dedo…" (In English "Point with your finger"), was presented prior to the stimulus. The words were illustrated by black and white drawings on six tiles on an 8 x 11 plate (see Figure 3). The pictures included four stimuli words and two foils. Comstock and Martin included two experiments within this study. The first experiment involved 15 adults with normal hearing who were native Spanish speakers and who grew up in Texas. The second experiment was comprised of 20 children (between the ages of three and eight) who lived in central Texas and who identified Spanish as their dominant language. The first experiment revealed equivalent word lists and a performance-intensity (PI) function slope of 2.9%/dB. The average PI function for the PB-50 lists is 2.5%/dB. Experiment 2 showed an increase in discrimination score as age increased. Most of the words that the children missed were due to limited vocabulary, which, Comstock and Martin noted, should be assessed for any speech discrimination measure. Results from experiment 2 demonstrated that the test was useful in assessing word discrimination. Because the carrier phrase does not require the audiologist to review any instructions in Spanish, it may also be an effective assessment for English-speaking clinicians. At the time of publication, the authors were investigating the effect of hearing loss on word discrimination ability. However, a recent review of the literature returned no results of a follow-up study.

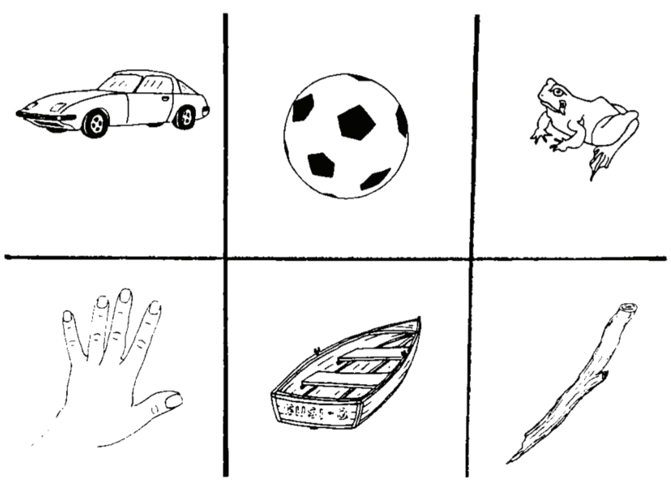

Figure 3. Sample response card for Comstock and Martin picture-pointing test (from Comstock and Martin, 1984)

In a 2013, Mendel, Elkins, McNiece, Lane, Carter, and Taylor developed and validated a Spanish SRT test that used picture pointing for Spanish-speaking children between the ages of two and five. This test included bisyllabic trochaic words and did not include an article, which in Spanish, provides information about a word's gender. The words were easily illustrated and were considered very familiar to Spanish speakers (see Figure 4). The first part of their study consisted of two sections. The first section involved 12 adult Spanish speakers in order to determine the most familiar words to young children. The second section included 25 Spanish-speaking children who were between the ages of three and eleven. The child was asked to point to the picture that matched the stimulus heard. Mendel and colleagues found that the children responded more accurately (95%) to illustrations of the words rather than photos. The second part of the study reported the initial normative data obtained from Spanish-speaking children with normal hearing. At the time of presentation, the validation process was noted as ongoing, but the authors have expanded the test to include quiet and competing message conditions.

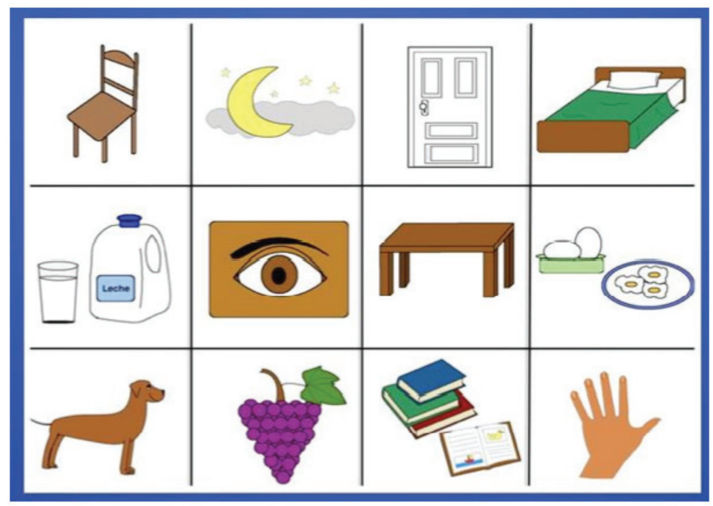

Figure 4. Sample response card for Mendel picture-pointing test (from Mendel et al, 2013)

Most recently, in 2014, Calandruccio, Gomez, Buss, and Leibold developed a speech perception task for use with bilingual Spanish/English children. The authors chose to use a four-alternative forced-choice picture identification format based on a study by Jerger, Speaks, and Trammell (1968) that found that since closed set formats have limited possible answer choices, they are appropriate for non-native speakers of English. The picture-pointing format allows the audiologist to accurately score the responses without knowledge of the Spanish language, and is commonly used with other clinical measures such as the Word Intelligibility by Picture Identification (WIPI) (Ross & Lerman, 1970) and Northwestern University- Children's Perception of Speech (NU-CHIPS) (Elliot & Katz, 1980). The speech perception task was designed for use with three main pediatric populations: monolingual English speakers, monolingual Spanish speakers, and bilingual Spanish/English speakers. This permits flexibility for the audiologist to choose the most appropriate task depending on the L1 (first language) and L2 (second/foreign language) of the child. Calandruccio and her co-investigators chose to develop the task to be conducted in the presence of a masker or noise as most speech perception measures available for the pediatric population are conducted in quiet conditions. The authors selected 30 words from the Dolch word list (Dolch, 1948) and common words in children's literature that are expected to be part of the vocabulary of a typically developing five-year-old. Words selected were bisyllabic in both English and Spanish (e.g., feath-er and plu-ma) and easily illustrated for clear identification (see Figure 5). The target words and speech used in the masker were recorded from bilingual Spanish/English speakers to minimize any potential for temporal and spectral differences. The masker was passages from the English and Spanish versions of Jack and the Beanstalk and Juan y los Frijoles Mágicos, respectively. For the study, 16 children between the ages of 4.9 and 16.4, consisting of eight bilingual Spanish/English speakers and eight monolingual English speakers, were selected. Six children were considered simultaneous bilinguals and two children acquired English after learning Spanish. The bilingual Spanish/English children performed better in English than Spanish in the presence of competing speech, but performed similarly in a competing noise condition. Calandruccio and colleagues concluded the pediatric speech perception measures were easy to administer and addressed the need for a test available in English or Spanish.

Figure 5. Sample response card for Calandruccio picture-pointing test (from Calandruccio et al, 2014)

Considerations when Testing Speech Recognition of Spanish-Speaking Monolingual or Bilingual Children

The following review studies the impact of various factors on speech perception in bilingual children. Though the studies involved children with normal hearing, the effects are exacerbated by a hearing loss. These effects of hearing loss result in a compromise of speech perception compared to children with normal hearing, requiring additional considerations.

It is important to evaluate (or examine previous evaluations of) the language comprehension and production capabilities of a child in the language to be used for speech recognition testing. Carrow (1972) compared auditory comprehension of English in bilingual and monolingual children. Two groups of 30 Mexican-American children were given the Auditory Test for Language Comprehension (Carrow, 1968), which assesses oral language comprehension for both English and Spanish. The test includes black and white drawings of various parts of speech such as nouns, verbs, adjectives, demonstratives, pronouns, etc. The child was instructed to point to the picture for each word. Carrow found that the children might first experience a language delay around preschool ages, which progresses as they become older. The bilingual children made more errors than their monolingual counterparts on adjectives, nouns, pronouns, and noun phrases that had adjective modifiers. Carrow attributed this to the challenge that bilingual listeners may encounter with nouns and not with syntax and functional words. The results of the study support the position of adequate assessment of a bilingual child's language ability as it may be delayed. This delay can be further intensified as the child enters school learning two languages, leading to academic difficulties.

Ferullo (1983) used a case illustration to provide guidelines for the use of assessing pre-school bilingual Spanish/English children. Ferullo explained the process of assessing "Wanda," a three year old who was seen because she was not responding and talking in neither Spanish nor English, raising concerns for her mother. Based on behavioral measures (Wanda's behavior prevented objective measures from being obtained), the clinician diagnosed Wanda as having a severe-to-profound hearing loss. The recommendation was to follow Wanda for future audiologic evaluations and to enroll her in speech-language therapy in English. Subsequent audiologic evaluations supported the initial diagnosis of a severe-to-profound bilateral hearing loss. Wanda was enrolled in a public school program for preschool children who had hearing loss. Later, Wanda was making unsatisfactory progress with her speech and language therapy, likely due to the 76 absences from preschool she logged. After psychological testing, Wanda obtained a score of 98 on the Wechsler Preschool and Primary Scale of Intelligence and Performance Scale at 4;3. Later evaluations deemed oral-auditory communication was not appropriate for Wanda's communication needs and that it be supplemented with a total communication program.

Ferullo used the case of Wanda to create guidelines for preschool bilingual children, citing the family environment, Hispanic culture, Wanda's mother's overbearingness, inconsistent language exposure, and variation of recommendations as sources of Wanda's identification and intervention. Based on these "mis-steps" as Ferullo refers to them, the following guidelines were developed: 1. Avoiding "premature, monoprofessional recommendations" favoring the involvement of a team of clinicians, 2. Avoiding "the defense of a specific philosophy" as each family and child is different, 3. Avoiding "transgressing from the professional role" as rapport between clinician and family is important in determining the next step, and 4. Being "aware of the impact of a child's hearing impairment, not only on the child, but on the family" as the hearing loss is only one aspect and other areas like the child's academic performance and social interaction should not be overlooked. Ferullo concluded that these guidelines allow for objectivity in evaluating non-native English-speaking children.

An evaluation conducted in the child's non-native language may yield inaccurate test results. Smyk, Restrepo, Gorin, and Gray (2013) sought to address this concern by developing and validating an oral language proficiency scale for Spanish/English sequential children between the ages of four and eight years old to assess L2 proficiency. Using the above definition of language proficiency, Smyk and colleagues designed the Spanish-English Language Proficiency Scale (SELPS) as a criterion-reference rating scale to be used with a story-retelling task that would provide a language sample. The authors chose to use a story-retell task as previous studies have shown that sequential bilinguals produce longer utterances and more complex syntactical structures than other tasks like spontaneous conversation. Two stories were used for the retell task to avoid memory effects and allow for test-retest within the assessment. The study consisted of two parts: evaluating the reliability of the new scale and determining its suitability for measuring language proficiency in English. For the first part, Smyk and colleagues found that the SELPS yielded similar results on the story-retelling task in bilingual children. However, the authors cautioned that all of the participants had experience with storytelling, an awareness that could affect results for children who did not. For the second part, the authors used the SELPS to assess sequential bilingual children who identified English as their L2 in English-only schools in Arizona, as well as teacher ratings of the child's language proficiency in English. Results showed significant correlation between the score on the SELPS and language sample, indicating comparable assessment of language ability between the two scores. It should be noted that the SELPS provides an overall view of language proficiency in the L2 and should, therefore, be utilized as a screener. Teacher ratings and scores on the SELPS were significantly moderately correlated, meaning higher scores on the SELPS correlated to higher ratings on the teacher's scales. Smyk and colleagues cautioned that the measure should not be used to identify language impairments as it was developed based on the milestones normally achieved by children. Based on these findings, the SELPS may be a valid measure for assessing L2 proficiency in sequential bilingual children.

In addition to evaluating a child in his or her non-native language, there are other factors that influence a bilingual child's word recognition ability, including maternal education, socioeconomic status, and other environmental factors. In 2007, Hurtado, Marchman, and Fernald studied children learning Spanish as their first language and how low socioeconomic status affected speech recognition and processing. The study involved 49 children between 1;3 and 3;6 years who had recently immigrated to the United States from Mexico. The majority of the children were born in the United States, but 92% of their parents were born in Mexico. None of the parents reported developmental delays or hearing loss for their children. In a satellite laboratory, the children underwent assessments of their expressive vocabulary and eye-movements during a listening task. Hurtado and her co-investigators learned that there was a positive correlation between speech processing ability and age, as older children were quicker to respond than younger children, and that their spoken language ability was also correlated to the size of their vocabulary. Other associations include maternal education and socioeconomic status. The authors attributed these associations to mothers who contribute to their child's language abilities by using labeling (e.g., "the naming game") and their level of talking to their children. The families in the study were in the bottom 20% of the education and income levels of the United States population, which may explain the poorer performance in children of low socioeconomic backgrounds who required more time and scored more poorly on the tasks. Hurtado and her co-investigators concluded vocabulary size and speech processing efficiency are adversely affected by the child's socioeconomic status. The results from this study are crucial in the assessment of speech perception in bilingual children from low socioeconomic backgrounds as they may experience lower understanding of spoken language and have limited vocabulary, especially younger children. Familiarization for speech recognition threshold measures is, therefore, imperative to ensure the score obtained is accurate.

Challenges for Assessment and Treatment of Bilingual Children in Educational Settings

The implications of speech perception testing are especially important for children as classrooms tend to be noisy and reverberant environments. Background noise has greater adverse effects on speech perception for children than adults (Nelson, Kohnert, Sabur, & Shaw, 2005).

Speech testing in noise is of particular interest to audiologists working with children to estimate how the child performs in a classroom, an environment where noise and reverberation occur naturally and can negatively affect speech perception, even for children with normal hearing. The American National Standards Institute (ANSI), U.S. Access Board, and the Acoustical Society of America sought to formulate guidelines for creating an optimal environment for speech understanding in the classroom (ANSI S12.60-2010). ANSI S12.60-2010 is endorsed by the American Academy of Audiology and the American Speech-Language-Hearing Association. This standard has recommended criteria for permanent school buildings (ANSI S12.60-2010/Part 1) and portable classrooms (ANSI S12.60-2009/Part 2). These criteria include recommendations for background noise and reverberation time, dependent on the size of the room and the type of classroom. Portable classrooms have higher allowances for background noise compared to permanent classrooms, 41 dBA and 35 dBA, respectively, for rooms less than 10,000 cubic feet and rooms between 10,000 and 20,000 cubic feet. Background noise levels of 40 dBA are permissible in both permanent and portable classrooms with room volumes greater than 20,000 cubic feet. Reverberation time in portable classrooms should not exceed 0.5 seconds and 0.6 seconds for rooms less than 10,000 cubic feet and rooms between 10,000 and 20,000 cubic feet, respectively. This allowance is slightly higher for permanent classrooms that have recommended reverberation times of 0.6 seconds and 0.7 seconds for rooms less than 10,000 cubic feet and rooms between 10,000 to 20,000 cubic feet. In 1996, Crandell and Smaldino sought to investigate the speech perception ability in bilingual Spanish/English children. The subjects were 20 children who were native speakers of English and 20 children who were learning English as a second language. Crandell and Smaldino used the Bamford-Kowal-Bench (BKB) sentence test presented in the presence of 12-speaker babble from Auditec (Etymotic Research, 2005). To simulate a typical classroom environment, Crandell and Smaldino presented the stimuli at varying signal-to-noise-ratios (SNR) of +6, +3, 0, -3, and -6 dB. The authors found that the children learning English as a second language had poorer speech perception scores in noise than the native English speakers. The differences between groups became more evident as the SNR decreased. However, in quiet conditions, both groups obtained similar scores. The results of this study are two-fold. Firstly, academic difficulties typically encountered by children learning English as a second language may be attributed to the poor classroom acoustic environment. Secondly, classroom acoustics, both noise and reverberation, can create an unfavorable environment for listening, especially for children whose first language is not English. Crandell and Smaldino suggested the use of assistive technology such as a personal FM (frequency modulation) or sound-field FM system to improve the SNR to observe any improvements by children learning English as a second language in a classroom setting.

In 2005, Nelson, Kohnert, Sabur, and Shaw explored the effects that classroom noise had on bilingual children's attention and speech perception compared to monolingual children. This involved the observation of behavioral changes prior to and following the addition of amplification in the classroom. Then, a word recognition measure, similar to that of Crandell and Smaldino (1996), was used. The majority of the 22 second-grade students who participated in the study spoke Spanish at home. The school chosen by Nelson and colleagues had a bilingual education program, which allowed students to spend half of the school day learning in English and the second half of the day in Spanish. The teachers and speech-language pathologist at the school reported high levels of noise from a busy street outside of the classroom in spite of renovations. These noise levels were found to range between 54 and 67 dBA. Nelson and her co-investigators found no differences when observing behavior before and after adding amplification. However, the authors reported a decline in word recognition scores for both monolingual and bilingual children when the test was presented in the noise condition. This decline was greater for the bilingual children. The results from this study supported the findings of Crandell and Smaldino. Nelson and colleagues recommended that those working in the school first recognize any noise and try to remove it. Examples of this include turning off computers, adding tennis balls to the legs of chairs, and closing open doors and windows. The authors also suggested that educational audiologists work with teachers to identify these noise sources and work to increase the signal's level. Results of this study further support the concept of increasing the signal over the noise, especially for those learning a second language, as research has shown they experience greater deficits in speech perception in poor SNR environments.

Reverberation and noise can cause bilingual listeners to experience deficits in speech perception. Tabri, Chacra, and Pring (2010) noted that these deficits are especially important to address in children who are multilingual and are learning in classrooms with poor acoustics. In the study, Tabri and colleagues recruited monolingual, bilingual, and trilingual adult listeners who were "highly fluent" in English and had normal hearing. Participants underwent the Speech Perception in Noise (SPIN) test (Kalikow, Stevens, & Elliott, 1977) with varying levels of noise. The results of the study supported the indication that although monolingual speakers and bilingual speakers may perform similarly in quiet conditions, bilingual speakers have declines in their speech perception abilities when the SNR is poor. Trilingual listeners' performance was similar to that of bilingual listeners. Tabri and her co-investigators extended these results to non-native children in classrooms who may struggle with speech perception. The authors recommended that teachers and school administrators focus on improving the listening environment in classrooms for these students.

Synthesized speech is utilized by electronic communication devices, such as augmentative and alternative communication (AAC) systems, for the purpose of providing individuals with severe communicative disabilities with a means to express themselves (Axmear, Reichle, Alamsaputra, Kohnert, Drager, & Sellnow, 2005). Children from diverse linguistic backgrounds may benefit from increased use of synthesized speech devices (Harrison-Harris, 2002). Because it is electronically created, synthesized speech is considered less intelligible than natural speech and is generated by a computer. Digitized speech uses pre-recorded human speech, so the voice output is more natural. Given the growing number of linguistically diverse children who now use devices with synthesized speech and the disadvantages they can pose, Axmear and her co-investigators sought to compare synthesized speech and live speech with monolingual and bilingual children. In the study, 10 monolingual children and 10 sequentially bilingual children underwent testing with the SPIN test, which was presented twice, once by a female speaker from the Midwest United States, and then via Perfect Paul, an application that uses text-to-speech for synthesis. Axmear and colleagues found that both groups of children performed comparably when the stimuli were presented with live speech. However, the monolingual group (84%) outperformed the bilingual group (61%) when the Perfect Paul application was used. Previous research has shown that exposure to synthetic speech like that produced by the Perfect Paul led to improved performance with speech intelligibility in monolingual children (McNaughton, Fallon, Tod, Weiner, & Neisworth, 1994). Based on these findings, Axmear and her colleagues concluded that although bilingual children may need synthesized speech in noisy classroom environments, they are likely to encounter difficulties with understanding. Therefore, audiologists and interventionists in the schools may have to implement external speakers and find ways to decrease classroom noise levels.

In order to rectify the challenges bilingual children with hearing loss face in the classrooms, Walker-Vann (1998) proposed a model for educational systems that include Hispanic students with hearing loss. After collecting demographic information from Hispanic and non-Hispanic students at the Texas School for the Deaf, Walker-Vann learned of some differences between the groups. First, 27% of the Hispanic students surveyed had a hearing loss attributable to genetics, compared to 35% of non-Hispanic students. Secondly, although the ratio of males to females with hearing loss is higher for the former, Walker-Vann found that 64% of the Hispanic students were male and 58% of the non-Hispanic students were female. The author attributed this discrepancy to research by Schildroth and Hotto (1993) that found that "males… *are reported* [emphasis in original] to have significantly higher rates of emotional/behavioral problems and learning disabilities than females." In Walker-Vann's study, about half (44%) of the students reported Spanish as the preferred language in the home. Similarly, 52% of the households used a form of signed language for communication, even if the parents were hearing. In this case, the child is introduced to trilingualism, which includes signed language, English, and Spanish. Walker-Vann commented that this can be "frustrating and stressful" and that the educational system should work with these students to alleviate these feelings. Using the results from this study combined with results from a 1985 study by Christensen, Walker-Vann proposed the use of videotaped lessons for families to receive instruction or who are unable to attend sign language classes. Lastly, the author noted that these lessons would allow children and their parents to participate actively in language learning at home.

Finally, when screening for hearing loss, an accurate case history can provide the pediatric/educational audiologist with essential information for diagnosis and treatment of children who speak Spanish primarily. A literature review by Muñoz, Caballero, and White (2014) examined studies published between 1980 and 2013 in either English or Spanish for the use of questionnaires. The authors found seven studies that used parent or teacher-completed questionnaires as a means of identifying children who may require additional hearing evaluations. Of those seven studies, only one was deemed effective in screening for permanent hearing loss. Based on these results, Muñoz and colleagues recommended that further research needs to be performed on questionnaires to ensure that they are effective tools for screening hearing. The findings of this study are especially important for audiologists working with culturally diverse populations. Morrison (2008) suggested the inclusion of small-talk prior to obtaining a case history in order to build rapport and impart confidence. In addition to showing respect, Morrison advised that the audiologist allow the family to ask questions and to explain any new terminology. This also includes being aware of the family's cultural and belief system and any influences they may have on hearing loss (Talamantes, Lindeman, & Mouton, 2001; Warda, 2000 as cited in Morrison, 2008).

Future Research and Clinical Implications

After a review of the literature, it is evident that more research with bilingual children is needed. Goldstein and Kohnert (2005) direct future research to include interactions with the Hispanic family and culture, given its influence within the population. As the Hispanic population continues to grow, the fields of audiology and speech-language pathology will require materials that have been validated and have had normative values obtained in order to ensure that bilingual children with hearing loss are receiving appropriate services and to address any hearing healthcare disparities. In addition to the development of additional test materials appropriate for Spanish-speaking pediatric patients, considerable work is needed to assess the validity and reliability of these tests that are already available and in use.

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Pilot Study of Transient Hearing Loss in Children from a Low Income Urban Setting

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Socioeconomic status is a risk factor for hearing impairment. Any type or degree of hearing loss in early childhood will affect educational achievement. This pilot study sought to examine the prevalence of middle ear pathologies in an urban, low income, primary school setting. Forty four second-grade students from a diverse immigrant community were recruited. Pure-tone hearing screenings and tympanometry were performed on those who consented to the test. However, the consent form return rate was only 40%. This may be a reflection of the community from which the data was collected. Additionally, students in low-income urban settings tend to exhibit higher than normal amounts of middle ear pathology, as indicated by study findings. Future research should expand methods to evaluate hearing in the school setting and incorporate tests of the middle ear. Parent and teacher education about minimal hearing loss and its subsequent effects on learning may also improve outcomes for high-risk children.

Introduction

The auditory system develops through sound exposure (Kilgard & Merzenich, 1998; Nakahara, Zhang, & Merzenich, 2004; Norena, Gourévitch, Aizawa, & Eggermont, 2006; Sanes & Constantine-Paton, 1985; Zhang, Bao, & Merzenich, 2001). Any form or degree of auditory deprivation during development can lead to changes in auditory processing (Sharma, Dorman, & Spahr, 2002; Syka, 2002; Xu, Kotak, & Sanes, 2007). For many children, otitis media is a recurrent and persistent problem (Roush, 2001; Teele, Klein, & Rosner, 1984). Fluid accumulation in the middle ear, which accompanies otitis media, impedes sound transmission to the auditory cortex and often results in a mild-to-moderate conductive hearing loss (Bluestone & Klein, 2001).

The fluctuating nature of a fluid-induced hearing loss results in an inconsistent transfer of sound energy, and may lead to persistent central auditory deficits (Whitton & Polley, 2011). For example, significant changes in the temporal properties of auditory cortex synapses and spikes were observed when researchers induced a conductive hearing loss in gerbils during the postnatal period (Xu et al., 2007). There were also significant deficits in membrane and inhibitory synaptic properties in these gerbils during the critical period of development. Yet, when the conductive hearing loss was reversed prior to the end of the critical period, most membrane properties recovered to normal values. However, when the hearing loss was treated and reversed a few days after the end of the critical period, the deficits persisted for several months. These findings suggest that long-lasting deficits may result from untreated hearing loss (Xu et al., 2007).

Changes in the auditory cortex that result from these deficits likely contribute to auditory processing difficulties observed in those with mild to moderate hearing loss and may contribute to the observed behavioral delays following a hearing loss in childhood (Johnson, Nicol, & Kraus, 2005; Whitton & Polley, 2011). Additional evidence suggests that elevated thresholds during development result in a child's continued difficulty locating sounds and may explain a child's difficulty detecting signals in background noise (Hall & Grose, 1994; Hall, Grose, & Pillsbury, 1995; Hogan, Meyer, & Moore, 1996; Wilmington, Gray, & Jahrsdoerfer, 1994). Restoration of hearing is, therefore, essential for normal development in the auditory cortex (Mowery, Kotak, & Sanes, 2014). In humans, an earlier age of hearing loss identification and restoration is positively correlated with improved auditory skills performance (May-Mederakeet et al., 2010; Svirsky, Teoh, & Neuburger, 2004). However, if auditory deprivation extends beyond the critical period of development, the amount of recovery is significantly reduced (Mowery et al., 2014).

Newborn hearing screening programs have significantly improved the diagnosis and subsequent treatment of infants with moderate to profound hearing losses. However, current screening protocols are not sensitive enough to identify hearing losses less than 30 dB HL (Norton, Gorga, Widen, Folsom, Sininger, Cone-Wesson, Vohr, Mascher, & Fletcher, 2000). Additionally, it is estimated that almost 15% of school-aged children have some degree of hearing loss that was either missed by universal newborn hearing screening programs or developed later in infancy and early childhood (Niskar, Kieszak, Holmes, Esteban, Rubin, & Brody, 1998). Unfortunately, after newborn hearing screening there are no government-mandated hearing screening programs in place.

However, the American Speech-Language-Hearing Association (ASHA) recommends that children be screened for hearing loss at 20 dB HL at 1.0, 2.0, and 4.0 kHz upon school entry, annually from kindergarten to third grade, and in the seventh and eleventh grades (ASHA, 1997). ASHA also recommends that children be screened if they exhibit risk factors or upon teacher or parental concern. The American Academy of Audiology (AAA) additionally recommends the use of tympanometry for younger children in grades preschool to first (AAA, 2011). The AAA also recommends otoacoustic emission (OAE) screening for preschool and school-aged children for whom pure tone screening is not developmentally appropriate. New York State, where the study was conducted, recommends that children be screened at 20 dB HL for the frequencies 1.0, 2.0, and 3.0 kHz. New York State also recommends tympanometry if it is available (The University of the State of New York, State Education Department, 2008). Unfortunately, despite the above recommendations, New York

City no longer offers school-based hearing assessment (New York City Department of Education, Office of School Health, 2016). In the New York City school system, teacher observation and recommendation are the primary means of referring children for hearing evaluations.

New York City's decision to suspend school-based hearing screening programs is unfortunate because a large number of the students served by the New York City Board of Education come from challenged socio-economic backgrounds (American Community Survey 5-Year 2006-2010 Estimates, 2010). These children are at a greater risk for middle ear disorder (Auinger, Lanphear, Kalkwarf, & Mansour, 2003) and would, therefore, benefit from hearing screening programs and follow-up treatment.

Tympanometry is a quick and objective means for screening middle ear disorders. ASHA and AAA criteria for abnormal tympanometry include flat, type B tympanograms or tympanic peak pressures (TPPs) beyond -200 daPa. However, studies have indicated that the air-bone gap increases with increasing negative middle ear pressure beyond -50 daPa (Cooper, Langley, Meyerhoff, & Gates, 1977). Additionally, OAEs, an objective test of outer hair cell function and sensitive indicator of hearing health (Lonsbury-Martin, & Martin, 1990), are adversely affected by negative middle ear pressures of -50 daPa and beyond (Marshall, Heller, & Westhusin, 1997; Prieve, Calandruccio, Fitzgerald, Mazevski, & Georgantas, 2008; Thompson, Henin, & Long, 2015).

The children tested in this pilot study came from a low-income population in Queens, NY. Due to their backgrounds, these children are at a higher risk for middle ear pathologies. Testing was performed in the teacher's lounge, as the school did not have a nurse's office or library. Following New York State guidelines, pure tone screening was performed at 20 dB HL for 1.0, 2.0, and 3.0 kHz. Due to this population's risk for middle ear pathologies, tympanometry was held to strict criteria, namely TPPs beyond -50 daPa were considered abnormal.

Methods

Participants

Data were collected from second grade students (age 7-8 years) at a parochial school in Queens, NY. The demographic estimates for the school were reported as follows (www.greatschools.com): 75% of the students were Black, 11% Asian, 11% Hispanic, and 3% White. Children who met the classification of Black were mainly from the West Indies (i.e. Haiti, Jamaica, Trinidad, Antiga). Children who met the classification for Asian were primarily from South East Asia. Additionally, 78% of the children qualified for the free lunch program but only 34% applied. As reported by the school principal, the children were immigrants or children of immigrants and tended to be highly transient. For example, 15 to 20% of the student population enters or leaves the school each year.

Procedure

Consent forms requesting that the child have his or her hearing tested in the school by a state-licensed audiologist were sent home to the child's guardian in English only. Following New York State guidelines, students' hearing was screened. Pass criteria of 20 dB HL was used for the screen at 1.0, 2.0, and 3.0 kHz bilaterally. To evaluate middle ear health, tympanometry was performed, and TPPs were recorded. Pure tone audiometry and tympanometry were performed using an Interacoustics AA22 portable audiometer and middle ear analyzer (Interacoustics A/S, Denmark).

Testing was done in a quiet corner of the teachers' lounge during class time. The students verbally assented to the hearing test and were given erasers for their participation. The St. John's University Office of the Institutional Review Board approved this study.

Results

Forty-four (44) consent forms were sent home. Eighteen (18) were completed and returned. Thirteen (13) families consented to have their child's hearing evaluated and were present on the day of testing; one child was absent. Four parents did not consent to the hearing test. The consent form return rate was 40.1%, and approximately 30% of the second grade students had their hearing tested. Of the 13 students tested, 26 ears, passed the pure-tone screen. Pure-tone screening and TPPs for each subject are shown in Table 1.

Table 1. *Pure Tone Screening Results (left) and TPPs (right) for each subject*

	Pure Tone Screening (20 dB HL) (Pass/Fail)		Tympanometric Peak Pressure (daPa)	
Subjects	PT Right	PT Left	TPP Right	TPP Left
N1	Pass	Pass	CNT	-90
N2	Pass	Pass	-40	-25
N3	Pass	Pass	-31	-49
N4	Pass	Pass	CNT	CNT
N5	Pass	Pass	-15	-13
N6	Pass	Pass	5	14
N7	Pass	Pass	-7	-70
N8	Pass	Pass	CNT	-15
N9	Pass	Pass	-297	-285
N10	Pass	Pass	CNT	-50
N11	Pass	Pass	-40	flat
N12	Pass	Pass	-74	-8
N13	Pass	Pass	-390	-283

As shown in Table 2, TPP results were as follows: 13 ears had TPPs between 0 and -50 daPa, three ears fell between -50 and -100 daPa, four ears had TPPs beyond -200 daPa, and one ear had a flat type B tympanogram. Five ears could not be tested (see Table 2).

Table 2. *TPPs for Each Ear (N=26) Grouped in 50 daPa Blocks.*

TPP (daPa)	N
$0 < TPP \leq -50$	13
$-50 < TPP \leq -100$	3
$-100 < TPP \leq -150$	0
$-150 < TPP \leq -200$	0
$-200 < TPP$	4
Flat type B	1
CNT	5

Discussion

Unfortunately, almost sixty percent (60%) of the consent forms were not returned. The poor return rate could be related to the consent form, written only in English. Alternately, the poor return rate may be a reflection of the effects low socio-economic status has on health care access and knowledge (Adler, Boyce, Chesney, Cohen, Folkman, Kahn, & Syme, 1994). It may also be an additional indicator that this population, which consists of mostly immigrant parents, is overwhelmed by other childcare and work related responsibilities.

Low socio-economic status is a risk factor for middle ear pathology, and any type or degree of hearing loss may affect educational achievement (Bess, Dodd-Murphy, & Parker, 1998; Davis, Elfenbein, Schum, & Bentler, 1986). Based on the strict criteria used for this study, 30% of the ears tested had some degree of negative middle ear pressure and possible middle ear pathology. Additionally, though all the children passed the pure-tone hearing screen, New York State guidelines only required that the hearing be screened at three frequencies at a threshold of 20 dB HL. It is possible that some of children tested had minimal hearing loss, which was not identified by the pure-tone screen (Wake et al., 2006).

Undetected hearing loss in early elementary school is an important problem because this is a critical time in the child's development (Sharma et al., 2002; Syka, 2002; Xu et al., 2007). Minimal or unilateral hearing loss has implications for a child's ability to listen to and understand auditory information, a child's speech and language development, and a child's behavior (Bess, et al., 1998; Bess, Klee, & Culbertson, 1986; Brackett, Maxon, & Blackwell, 1993; Oyler, Oyler, & Matkin, 1988). Additionally, school-age children with minimal or unilateral hearing losses are at an elevated risk for developmental delays (Bess, et al., 1998; Bess, et al., 1986; Oyler, et al., 1988).

A child's hearing thresholds should be at least 15 dB HL (Bess et al., 1998; Brackett et al., 1993; Davis et al., 1986). This lower threshold is recommended because research indicates that children between 6 and 16 years of age with minimal or unilateral hearing loss are twice as likely to score two standard deviations below the norm on standardized arithmetic and reading tests (Niskar et al., 1998). Future research could include follow-up hearing threshold tests in the third grade with a comparison to achievement test scores, as third graders with minimal hearing loss have been found to exhibit significantly lower scores in reading, language mechanics, word analysis, and science (Bess et al., 1998).

This pilot study highlights the need for more thorough testing and follow-up care in low-income urban settings. The low consent form return rate indicates that parents may not fully understand the importance hearing has on development and academic success. Additionally, as New York City relies solely on teacher referral, teachers should be more formally educated about the warning signs of hearing loss and be informed of classroom modifications that would make the environment most conducive for learning. Accommodating students appropriately in the classroom to compensate for deficits that result from minimal or unilateral hearing, possibly caused by middle ear disorders, would improve educational outcomes (Johnson et al., 2005).

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