BMJ open

Validation of a questionnaire measuring preschool children's reactions to and coping with noise in a repeated measurement design.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2012-002408
Article Type:	Research
Date Submitted by the Author:	28-Dec-2012
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Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Public health
Keywords:	EPIDEMIOLOGY, Community child health < PAEDIATRICS, PUBLIC HEALTH

Summary

Study Focus:

- ✓ Only a few studies have been performed on how noise affects preschool children.
- ✓ A prerequisite to do so is a method to measure perception, emotional and bodily reaction and coping with noise in the preschool situation.
- ✓ This study explored the reliability and validity of such an instrument based on data derived from a before after intervention study which was carried out at seven preschools in Sweden.

Key Messages:

- ✓ The results show that preschool children can indeed make a clear distinction between perception of and reaction to different types of noise and bodily reactions.
- ✓ Visual representation of emotional reactions and the location of bodily reactions is a good and reliable way to measure reactions in young children.
- ✓ More work on larger samples will need to be done to further develop a standard instrument to be used in preschool aged children.

Strength and weaknesses

- ✓ The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language".
- ✓ A major limitation is the relatively small sample size.

INTRODUCTION

Background

Earlier studies show that the sound environment at preschools may be a serious occupational and public health problem. Voss [1] measured eight hour equivalent noise exposure levels of 80 dB L_{Aeq} in daycare centers in Denmark. Maxwell and Evans [2] report four hour L_{Aeq} levels of 76 and peak levels of 96 dBC in preschools in the USA.

Dominant noise sources in preschools are sounds from children's activities indoors. In contrasts to elementary schools, the sound environment in preschools is highly intermittent, uncontrollable and characterized by peak levels of high spectrum frequency, originating from voices and children's activities. Acoustical improvements in preschools and schools are most often made by fitting walls and ceiling with sound absorption panels. The calculated direct effects are a reduction of the reverberation time -the time it takes for a sound to decay 60 dB from its original intensity- and moderate reduction of sound level. [3, 4] Few studies have evaluated the effects of reducing contact sounds such as rolling, sliding or impact sounds resulting from the interaction between surfaces of e.g. chairs and the floor or table wares and the table top..

Noisy preschool environments could lead to reduced understanding of speech and as a consequence impaired reading and writing abilities. [2] Exposures at a young age might also effect other aspects of later life functioning and the development of disease. Effects described in the literature indicating such a mechanism pertain to

hearing impairment [5, 6] and increased levels of cortisol in children attending day care centers.[7, 8, 9] Studies in older children have confirmed effects on reading comprehension and memory [10], performance [11], coping, wellbeing and stress [12, 13], and behavior and mental health. [14]

Reactions to and coping with environmental noise have been studied extensively in the past 30-40 years for adults.[15] Several recent studies also addressed annoyance and coping in school children, [16, 17, 12, 18, 19, 20, 11] while only a handful of studies addressed this issue in younger (preschool) children. [2, 21, 22, 23] In comparison with adults, children in general and preschool children in specific may be particularly susceptible to the effects of noise because they have less capacity to anticipate, understand and cope with stressors [19] and because they are in a crucial and sensitive phase of their development. [5, 10]

Instruments to investigate young children's reactions to noise are not available. In order to fill this gap a qualitative study was performed in 2006 among 36 preschool children in Mölndal (Sweden), aged 4-6 years [24] using the constructivist-grounded theory as qualitative approach. [25] The children were asked about their perception of sound in the preschool situation, their understanding of the source and their perceived reactions at emotional and bodily level. Also, the degree of familiarity and comprehensibility of the sounds, manageability/control as well as disturbance and distress by the sounds were addressed. Finally, several coping strategies came forward, subdivided in avoidance (getting away, covering ears etc) and problem-oriented coping (complain to teacher). The method employed was in broad lines comparable to that used by Haines et al.[11] in children aged 10-13. She concluded that noise annoyance in children pertains to the same construct as in adults, and this was later confirmed by others .[11, 16, 15] It is uncertain whether younger children are also

able to make such distinctions and thus show a comparable pattern to older children and adults, nor whether they are capable to answer questions during a structured interview regarding their sound environment and the way they emotionally and physically are affected by it in a consistent way.

Objectives

This paper explores and describes the reliability and validity of the key questions of a standardized interview protocol- the Inventory of Noise and Children's Health (INCH) -developed on the base of focus group interviews among 4-6 year old preschool children. The questions pertain to preschool children's perception of noise when at school, their bodily and emotional reaction to it, non-specific (stress related) symptoms and their coping strategies used to diminish detrimental effects of the noise. Aspects related to perceived control and behavioral reactions were left out of the interview, since it was felt that observational methods to measure these aspects would be more suitable to apply in this age group. Bodily reactions to noise in general as well as noise specific reactions were used to examine the external validity of the children's responses.

MATERIALS AND METHODS

Selection and recruitment

In the period between October 2006 to October 2009 children aged 4-5 and their parents were recruited from seven preschools where interventions were undertaken with the purpose to improve the acoustical qualities in the preschools in Mölndal, Sweden. In total, 63 children and 59 parents filled out the questionnaire before and after the intervention. A control group of twenty three parents from three preschools where no interventions were undertaken was also included in the study. Parental data

will be reported elsewhere. Due to external circumstances no children were selected for the control group from preschools where no intervention took place. The response rates ranged from 80% in the parents to 98% in the children. Of the children two fell outside the age range of 4-5 years and were excluded from further analysis, resulting in a study population of 61 children.

Procedure

One month before and three months after the intervention the children were interviewed. In order to diminish the risk of inter-rater variance as much as possible the interviews were performed by two trained persons. The children were asked questions in a structured way and presented with visual representations of scales on show cards. When the child was not able to answer the question they were not prompted to do so. For the core set of questions see Appendix 1. For information about the full protocol please contact the first author.

Noise exposure assessment and interventions

Acoustic interventions included changes of floor mats, felt cushions under chairs and sound absorbing tiles on ceilings and walls. Table tops had been changed to acoustically soft material before the intervention. The expected effect of the absorbents was a moderate reduction of the sound level in the range of 3 dBA, while the change of table tops, felt cushions and change of floor maths were hypothesised to mainly lead to less contact sounds from e.g. plates and glasses being placed on the table or chairs pulled over the floor. These types of sounds would normally not be of large importance for the overall sound level in a preschool, but the high frequency characteristics of such sounds could be perceived as highly unpleasant.

Noise was measured one month before the interventions and three months after using stationary measurements and personal dosimeters worn by personnel and children in seven preschools. [26, 27] Similar measurements were also undertaken in the three control preschools. Stationary measurements during activity in the various rooms showed a significant lower equivalent A-weighted level after the intervention as compared to before. For the playroom an average reduction was measured from 69 to 66 dB $_{LAeq}$, giving a difference of 2.9 dB (95%CI: 1.3-4.5). For the eating room an average reduction was measured from 69 to 68 dB $_{LAeq}$, giving a difference of 1.2 dB (95%CI: 0.6-1.8). In the play halls the intervention did not alter the equivalent sound levels significantly from 69 to 66 (a difference of 3.8 dB, 95%CI: -0.8-7.6). Significantly lower maximum levels of 4.6dB$_{AFmax}$ (95%CI: 0.7-8.4) were found after the intervention in the play-halls and up to 2.0 dB$_{AFmax}$ in the playroom (95%CI 0.8-3.3). The sound levels in the control preschools did not change during the same time period, being on average 67-68 dB$_{LAeq}$ and 82-83 dB$_{AFmax}$ for the various rooms and for both measurement occasions.

Children's dosimeters showed that personal average exposures were higher compared to stationary measurements and in the range of 83-85 dB $_{LAeq}$ and 117-118 dB$_{AFmax}$, both at the intervention preschools and the control schools and before and after the intervention, hence the intervention did not affect personal levels in a measurable way.

Noise perception

Noise perception was measured by means of standard questions. Children were asked how frequently they heard noise from three relevant noise sources in the preschool

situation: yelling and angry children, strong and loud sounds and scraping and screeching sounds. Answers were indicated on a five -point Likert scale (ranging from 'almost never to very often') presented as 5 circles increasing in size and including 1 to 5 dots.

The percentage of children who indicated that they never heard the sound was 17% and 19% for the yelling sounds, 22% and 22% for loud sounds and 35% and 52 % for the scraping and screeching sounds in the before and after condition respectively.

Reaction to noise

Aspects of reaction were measured using the following wording: '*How do you feel when* you hear the [sounds of angry, yelling children][load and strong sounds] scraping and screeching sounds]*. Answers were indicated on a bipolar visual scale representing drawn figures with different facial and bodily expressions ranging from glad/safe to sad/afraid and from kind/friendly to angry/irritated respectively.

The reaction was recoded to neutral position (code 3) for those children who indicated on the previous question on perception, that they did not hear the sound.Figure 1 Here

Coping strategies

For noise experienced at preschool, coping strategies were investigated by asking the children what they did when there was a lot of noise and if they coped, how often that was. The phrasing was as follows: '*When there is a lot of noise what do you do' [go away], [put your hands over your ears][tell your teacher] [raise your voice]and if so how often [almost never to all the time]*. Again visual representations were used.

Bodily reactions to noise and symptoms

In order to measure bodily reactions to the three different sounds, the children were asked to indicate per sound source whether they could feel the sounds in their body and if so where they felt it (Figure 2) *('when you hear [yelling and screams], [strong and loud sounds],[scraping and screeching sounds] can you feel it inside you or in your body and if so please point out in the figure where you feel it'*). The answers were recoded into location *[head] [neck] [arms] [heart] [belly] [legs] [feet]* as well as in number of locations (none versus 1 or more).

Figure 2 Here

Nonspecific symptoms were inventoried by asking the children what symptoms they had experienced in the past few days at preschool: headache, tummy ache and hoarse voice. Finally a question was asked about general wellbeing, making use of a similar figures used for reaction to noise ['*in the last days at preschool*' *have you felt like any of these children in this picture*] which was recoded into a 1 to 5 scale.

Data analysis

In order to test the convergent and divergent validity of the different indices, as a first step, confirmative factor analysis (CFA) was carried out using SAS for Windows (version 9.3) on the reaction and coping questions and perceived health questions. Bodily sensation and health symptoms were included, in order to determine whether children could distinguish between emotional and bodily responses and nonspecific symptoms/ health complaints. Also the items on the questions regarding coping strategies were included in the analysis. A high correlation was expected between reactions (both bodily and emotional) to different noise sources, between symptoms and the different coping strategies. CFA is a special form of factor analysis which is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct (or factor) and therefore suitable for our purpose. The degree of consistency is expressed by several statistical quantities determining the adequacy of model fit to the data, including the standardized root mean square residual (SRMSR) and the adjusted goodness of fit (AGFI). Acceptable model fit is indicated by a SRMSR value of 0.08 or less [28] and a AGFI value of 0.95 or more. [29] The contribution of each item to a factor is expressed in factor loadings. Due to small sample size and departure from normality, diagonally weighted least squares were used to estimate the parameters of the factor model.

In order to test the internal consistency of the components, Cronbach's alphas were calculated on the grouped items. Indices were composed by simply summing the separate items. These indices were further tested on their concurrent validity by comparing groups with one or more symptoms due to the different noise sources to a group who reported no symptoms. This was performed for the before and after condition separate by means of a t-test assuming unequal variances. Additional

analyses were performed on some relevant single items, which were excluded from CFA using nonparametric methods such as Spearman and Mann-Whitney.

RESULTS

Table 1 shows the general characteristics of the children included in the analysis. The 61/59 children respectively included in the before – after study are reasonably well distributed over gender and age groups. The number of interviewed children per preschool ranged from 4 to 15. The prevalence of noise perception is presented per noise source as percentage of children scoring in the highest two categories, while reaction, total coping strategies and symptoms are presented as the percentage of children scoring in the highest two categories per sum-score.

Table 1: General characteristics of the children (Before and After intervention).

Characteristic	Before	After
Number of Respondents (n)	61	59
Gender		
girls	48%	49%
boys	52%	51%
Age		
4 years	52%	32%
5 years	48%	49%
6 years	-	8%
Perception noise source (score 4, 5)		
Angry and screams: Source 1	67%	58%
Loud and strong: Source 2	57%	51%
Scraping and Screeching: Source 3	35%	18%
Angry reaction (>11)	13.1%	4.8.%
Prevalence Symptoms (>11)	6.8%	3.8%
Coping(>15)	13.0%	16.3%
Location bodily reaction		
At least 1 location	70%	80%
Source 1	54%	49%
Source 2	54%	56%
Source 3	51%	49%

Reaction and coping in children: construct validity

Confirmatory factor analyses (CFA) with categorical indicators were carried out to verify the a-priori structure pertaining to perception, emotional reaction, symptoms and coping strategies in the before and after condition. The perception scales [*How often do you hear screaming and angry children, strong and loud sounds and scraping and screeching sounds*] as well as the sad reaction scales showed to be too instable to consider for further analysis. Likewise, the items pertaining to noise perception per source and unwell-being, were too unstable or loaded on many factors and therefore were treated as single items in further analysis (see Table 2). A three factor model was fitted to the remaining ten items pertaining to angry reactions, symptoms and coping. The model fit was good with a SRMSR of .08 and an AGFI of .97 in the before condition, but weaker in the after condition with a SRMSR of .12 and an AGFI of .91. For the before condition the loading are in the ranges .58 to .77, .41 to .78 and .51 to .71 for the three factors respectively. It was decided to take the before analysis as a point of departure and to test the reliability of the scales based on the measurements in the before and after condition.

Table 2: Factor Loadings, Goodness of Fit, internal consistency and interrelations

	Components/Before			Components/After		
	I	**II**	**III**	**I**	**II**	**III**
Source1_angry	.63			.33		
Source2_angry	.77			.55		
Source3_angry	.58			.73		
go away		.78			.32	
cover ears		.52			.46	
tell teacher		.41			.62	
raise voice		.57			.72	
headache			.71			.53
tummy ache			.67			.18
hoarse voice			.51			.61
Cronbach's alpha	.63	.65	.67	.56	.54	.52
SRMSR	.08			.12		
AGFI	.97			.91		

BEFORE	a	b	c	d	e	f	g
a. Perception yelling children	1	.48*	.19	.09	.11	.23*	-.12
b. Perception loud and strong sounds		1	30*	.24*	.25*	.33*	.00
c. Perception scraping and screeching sounds			1	.23*	.37*	.25*	.23*
d. Angry reaction				1	.33*	.15	.22*
e. Symptoms					1	34*	.56*
f. Coping strategies						1	-.10
f. Unwell-being							1

* Significant at .05 level/missing values pairwise deletion

Reliability in terms of internal consistency

Three groups of variables pertaining to Angry Reaction, Coping and Symptoms were tested on their internal consistency expressed in alpha for the two measurements (Table 2 row 11). The analysis yielded homogeneous scales with comparable alpha's over the measurements ranging from .56 to .75. Subsequently, three indices were composed by simply summing the scores on the separate items within each factor and distributions were tested on normality. Deviations of normality were slight and most pronounced in the symptom scales.

Correlation analyses between these indices and items related to perception of noise and unwell-being were studied (Table 2) and showed moderate to weak associations between perception and outcomes, but mostly in line with our expectations. Perception of scraping and screeching sounds was most strongly associated with angry reactions, coping, symptoms as well as unwell-being followed by perceived loud sounds. Coping strategies were associated most strongly with symptoms and the highest association was found between symptoms and unwell-being. Since items referring to sad reactions to the different sounds did not form one factor and the bipolar items do not allow for correlational analysis, separate analysis was performed after dichotomizing the scores on sad reaction items. Mann-Whitney analysis showed that sadness due to loud noises was associated with symptoms (Z-value=2.3/p=.021) and sad reaction due to scraping/screeching sounds with symptoms (Z-value=3.4/ p=.001) and coping strategies (Z-value=2.7/p=.008), while sadness due to yelling sounds was found not to be associated with any of the indices on angry reaction, symptoms or coping.

Concurrent validity

As a last step in the psychometric evaluation, the associations between bodily reactions to noise and the three indices and the single item un unwell-being were analyzed to explore the concurrent validity. This refers to the accuracy of the relevant test scores to estimate an individual state on a criterion, in this case bodily reaction (general and noise source specific).

The rationale behind this analysis is that angry reaction, amount of coping strategies (number and frequency) and symptoms as well as unwell-being are expected to be associated with bodily reactions. The associations between bodily reactions to noise with these relevant test-scores were studied by means of t-test. Hereby dichotomous groups were formed based on respectively any bodily reaction, and bodily reactions per noise source versus none. Distributions were checked per group and angry reaction was dropped from the analysis because the majority of data points in the group with no bodily reaction contained only children who had indicated they did not hear the sound. Subsequently, the mean scores on the remaining indices and the unwell-being item were compared between groups.

Table 3 presents the results

Table 3: T-test on bodily reaction and children's coping, symptoms and unwell-being

	Any source	Yelling sounds	Loud sounds	Scraping and screeching sounds
Symptom before	**-4.67/0.000**	**-2.18/0.033**	**-2.34/0.023**	**-2.69/0.009**
Coping strategies before	**-2.62/0.012**	**-2.58/0.012**	-1.53/0.131	**-2.04/0.045**
Unwell-being before	-1.97/0.056	**-2.34/0.023**	-1.05/0.297	-1.50/0.140
Symptom after	**-3.20/0.003**	-1.40/0.167	-1.06/0.294	-0.30/0.766
Coping strategies after	-0.14/0.894	-0.66/0.510	-1.99/0.052	-0.87/0.385
Unwell-being after	**-2.77/0.010**	-0.79/0.433	-1.91/0.062	-1.36/0.178

Observed t-statistic/p-value with significant results on level 0.05 marked as bold

T-test yielded significant differences in means on symptoms before for groups based on presence of any bodily reactions as well as presence of bodily reaction to the separate sources. The same pattern was found for coping with the exception of loud sounds. Unwell-being when at school in the before condition, measured with a single item, showed to be associated significantly with bodily reaction to loud sounds only, while any bodily reaction just failed significance. In the after condition this pattern was only partly confirmed for symptoms with any bodily reaction and unwell-being with any bodily reaction. Since t-test assumes normal distribution, in addition non parametric tests were applied. Further analysis showed that each hypothesis with p-value <0.05 for the t-test had Mann-Whitney p-values not exceeding 0.08.

DISCUSSION

The results of the psychometric evaluation show that preschool children are able to make a distinction between reactions to noises and emotional and bodily reactions as measured by means of visual representations of reactions and representation of the location of bodily reactions. As in adults [30], the interrelations between angry reactions

to different sounds and noises were relatively high, while the relation between angry reactions and symptom related aspects was lower: in other words reaction and symptoms can be considered as separate dimensions. This is also consistent with the findings among school children (9-11 years) in the RANCH study [17] and a survey among 207 children (aged 13-14 years). [31, 33] Furthermore, the results are in agreement with the results of a RANCH sub-study [32] in which it was found that children were capable to reliably index complex soundscapes and to provide perceptual scales that were in striking agreement with the perceptual scales provided by adults. We also found that angry reactions to noise could be distinguished from coping strategies. Comparing the elements of the correlation matrix in the before condition for perceptions of the different sound sources and its effects we conclude that scraping and screeching sounds play a prominent role, with significant associations for angry reaction, coping and symptoms. Whilst coping was significantly associated with all sounds, angry and loud sounds were not associated with angry reaction nor symptoms. Based on the pattern we hypothesize that there is a pathway from perception of scraping and screeching sounds via angry reactions and coping to symptoms and via symptoms to unwell-being.

An important finding is that children compared to adults seem to have a tendency to describe reaction to noise in a somatic way: they literary feel the noise in their body, especially in the head, heart and tummy, with a prevalence varying between 15-20%.

Both the (angry) reaction and symptoms indices are significantly associated with general unwell-being while at school and these responses tend to be sound specific. Where loud and screaming sounds are only associated with coping, the perception of scraping and screeching sounds is significantly associated with angry

reactions, coping as well as symptoms. This finding is important in view of future interventions at preschools as scraping and screeching sounds mainly originate from contact sounds between surfaces.

The four coping items included in the questionnaire pertain to active and avoidant behavior, a distinction which is confirmed in studies among older children and adults, but also came forward from the focus group discussions with children. [24] Results of CFA analysis showed a high inter correlation between the different coping strategies, with a slight tendency for a two sub-factors structure, pertaining to problem oriented coping and avoidance. This has implications for the interpretation of the coping index: it refers to the number and frequency of strategies employed rather than more or less effective strategies to cope with environmental noise. Future work should attempt to expand the number of items related to these different strategies which young children employ to cope with classroom noise.

A comparison between the before and after data shows a consistent pattern for symptoms and coping, but is somewhat less clear for angry reactions. Explorative comparison of children's symptom report and bodily reactions reveal a reasonable consistent pattern and indicate satisfactory concurrent validity of most of the indices in particular for the before situation. There is no explanation for much weaker associations in the after situation, but a link with the intervention cannot be excluded.

The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language". A major limitation is the relatively small sample size. Future research on larger groups of preschool children will be needed to further refine the questions in particular the questions pertaining to well-being. Such an instrument will allow for

studying development in reaction over time as well as the evaluation of noise reducing measurements in preschool in an unobtrusive and playful manner.

Previous studies suggest that children have fewer possibilities for controlling noise or have a less developed coping repertoire than adults.[19 24] Development of coping strategies would be an important target for future research in this group: noise induced behaviors at a young age (e.g. learned helplessness) might affect other aspects of later life functioning and the development of disease. Furthermore, this study shows that emotional reaction (angry and sad) is not the only relevant indicator of the effects of community noise in children, also bodily reactions, symptoms, coping behavior and wellbeing show to be important.

CONCLUSION

The main conclusion to be drawn from this study is that young children's angry reaction and bodily reactions to and coping with noise can be reliably measured with a structured interview, including visual representation questions. In accordance with what was found in adults [30] and children aged 9-11 [17] we found that also younger children are able to distinguish between reaction/annoyance and symptoms and coping. Compared to adults, younger children tend to describe their reactions to noise in a somatic way. After further development of the instrument discussed in this paper we foresee studies into young children's reactions to and coping with noise on a larger scale.

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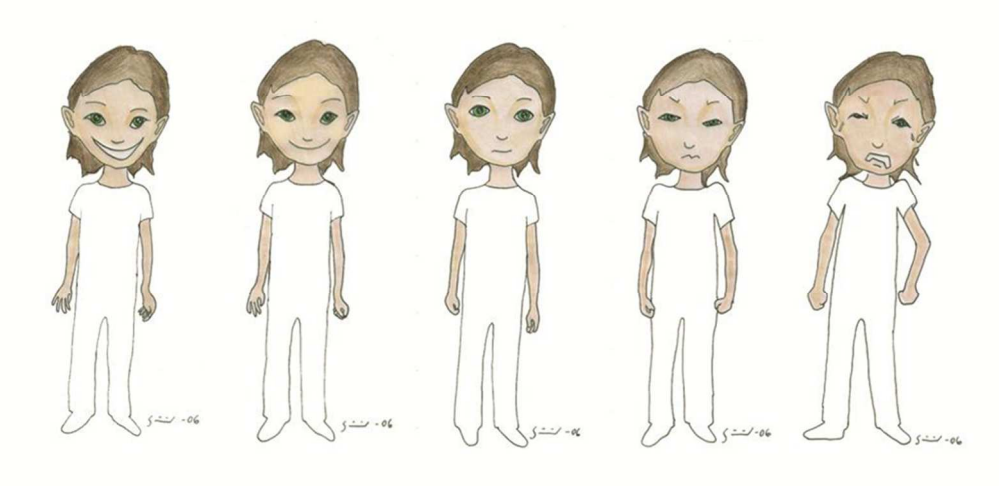
Figure 1: Visual representation with point scale ranging from kind/friendly to angry/irritated

Figure 2: Visual representation of body location



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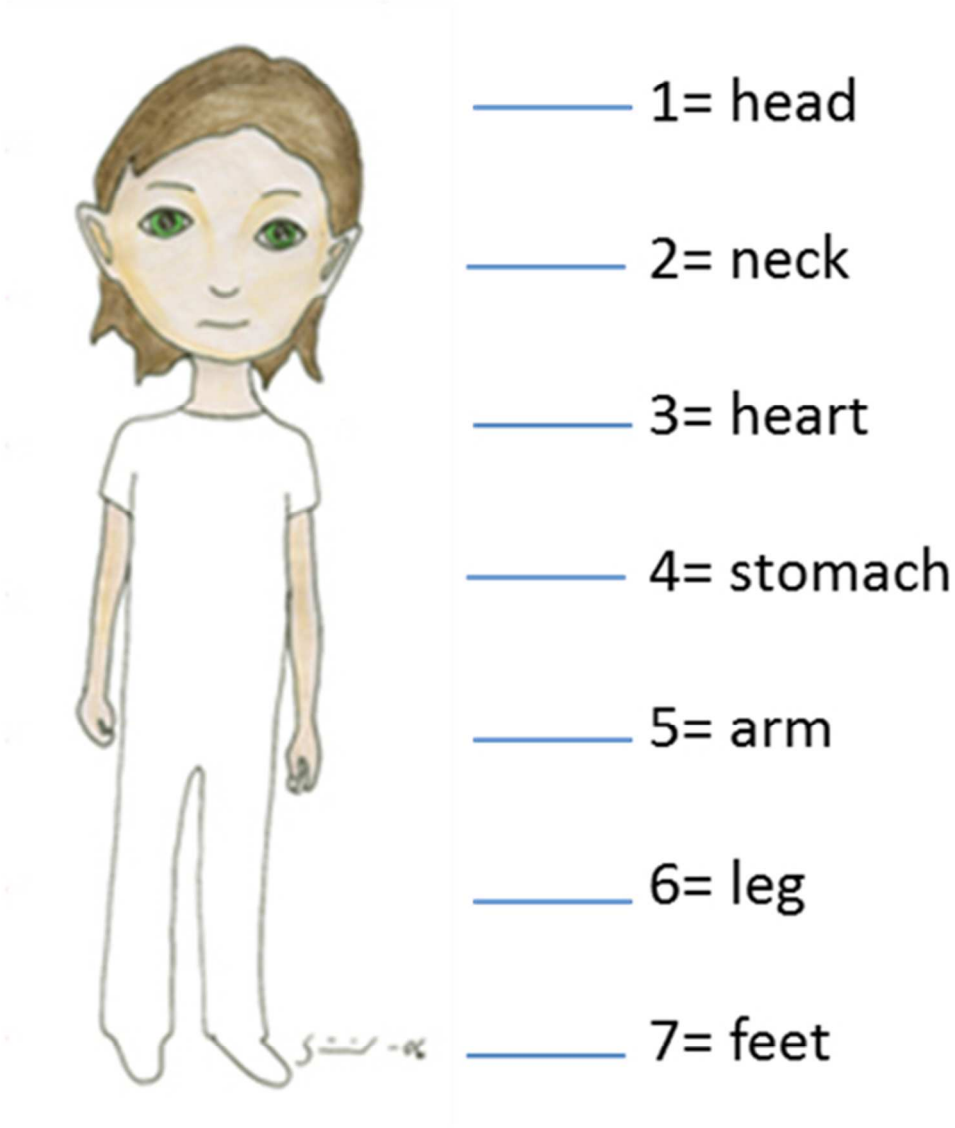


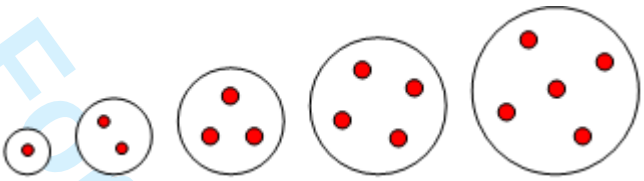
87x102mm (150 x 150 DPI)

Inventory of Noise and Children's Health
INCH

10. How often do you hear other children at preschool being angry and yelling?

12. How often do you hear loud and strong sounds at preschool – like shouting, screaming or banging?

14. How often do you hear scraping and screeching sounds?



Almost never Very often

Repeat for 10, 12, 14

11a. When you hear other children being angry and yelling, do you feel it inside you or in your body?

13a. When you hear loud, strong sounds, do you feel it inside you or in your body?

15a. When you hear scraping and screeching sounds, do you feel it inside you or in your body?

☐ If No, go to Question 16. ☐ If Yes, point out in the picture where you feel it.

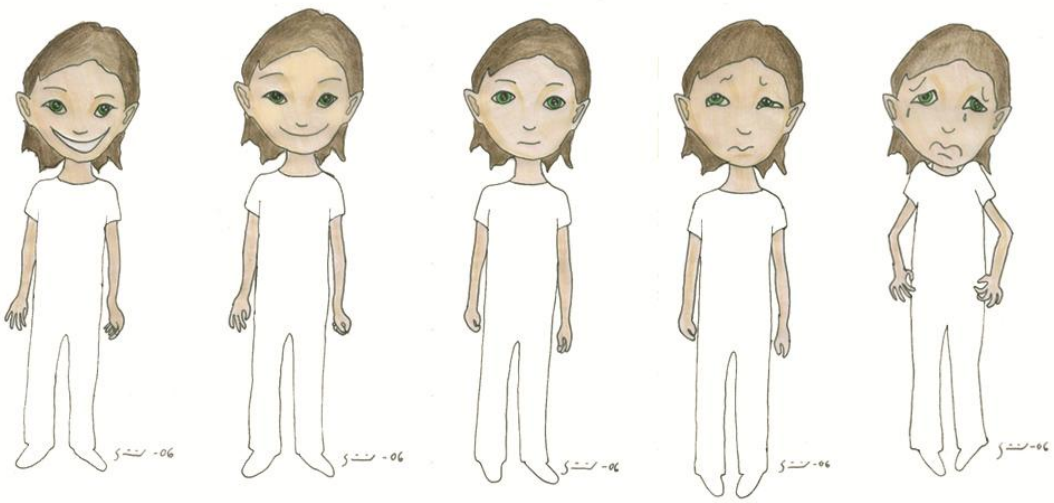
Repeat for 11a, 13a, 15a

11c. Sometimes when you hear children being angry and yelling, you might feel like one of the children in this picture.

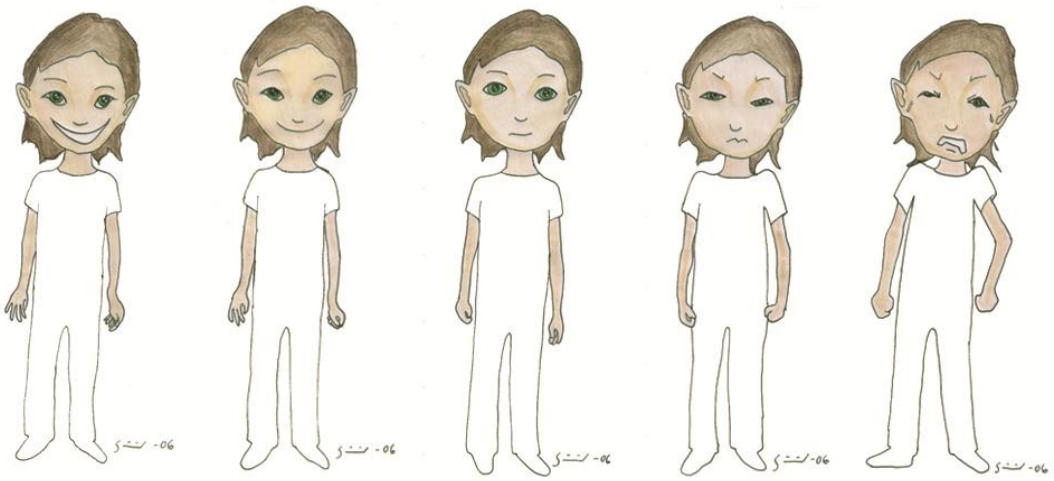
13c. Sometimes when you hear loud, strong sounds, you might feel like one of the children in this picture.

15c. Sometimes when you hear scraping and screeching sounds, you might feel like one of the children in this picture.

Point to the child that looks most like how you feel when you hear these sounds.



glad/safe sad/afraid



kind/friendly angry/irritated

Repeat for 11c, 13c, 15c

16. When there's a lot of noise, what do you do?

a) Do you go away?

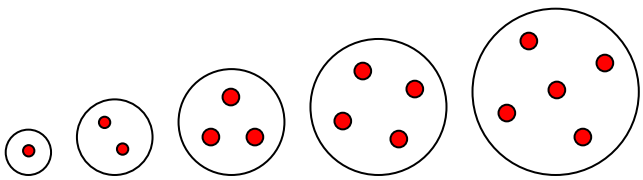
b) Put your hands over your ears?

c) Tell the teacher?

d) Do you need to raise your voice in order to be heard?

□ No, go to next question

□ if Yes How often do you do that?



Almost never Always

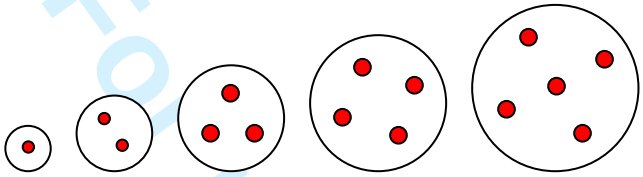
Repeat for 16a, 16b, 16c and16 d

18. The questions I am going to ask now are about how you have been feeling at preschool <u>in the past few days</u>.

    a) Have you had a headache?

    b) Have you had a tummy ache?

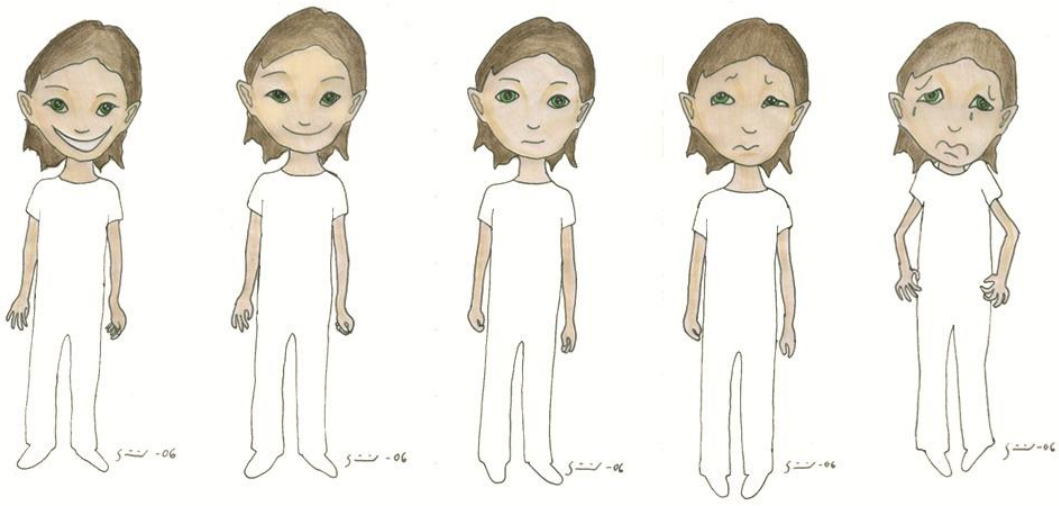
    c) Have your voice been hoarse?



Never Often

Repeat for 18a, 18b, 18c

19. In the past few days, have you felt like any of the children in this picture? Can you point at the one you felt like?



UNIVERSITY OF GOTHENBURG

Procedure for use of the Questionnaire: **INCH**

These questions are part of a questionnaire which was developed within the Sound Environment Research Unit at Gothenburg University under the leadership of Kerstin Persson Waye www.amm.se/soundenvironment

The full questionnaire can be obtained by contacting the first author.

The questionnaire can be used under the following conditions:

- The source should be mentioned e.g. this article.
- Manuscripts and articles dealing with results obtained with the questionnaire should be sent to kerstin.persson.waye@amm.gu.se
- Part of the research data should be made available to the author of the questionnaire (in consultation with the author) for further validation.

STARD checklist for the reporting of studies of diagnostic accuracy

Section and Topic	Item #		On page #
TITLE/ABSTRACT/ KEYWORDS	1	Identify the article as a study of diagnostic accuracy (recommended MeSH heading 'sensitivity and specificity')	I-II
INTRODUCTION	2	State the research questions or study aims, such as estimating diagnostic accuracy or comparing accuracy between tests or across participant groups	1-2
METHODS			
Participants	3	Describe the study population: The inclusion and exclusion criteria, setting and locations where the data were collected	4-5
	4	Describe participant recruitment: Was recruitment based on presenting symptoms, results from previous tests, or the fact that the participants had received the index tests or the reference standard?	4-5
	5	Describe participant sampling: Was the study population a consecutive series of participants defined by the selection criteria in items 3 and 4? If not, specify how participants were further selected	As defined in 3 and 4
	6	Describe data collection: Was data collection planned before the index test and reference standard were performed (prospective study) or after (retrospective study)?	Befor-after study
Test methods	7	Describe the reference standard and its rationale	na
	8	Describe technical specifications of material and methods involved including how and when measurements were taken, and/or cite references for index tests and reference standard	5
	9	Describe definition of and rationale for the units, cutoffs and/or categories of the results of the index tests and the reference standard	6-9
	10	Describe the number, training and expertise of the persons executing and reading the index tests and the reference standard	5
	11	Describe whether or not the readers of the index tests and reference standard were blind (masked) to the results of the other test and describe any other clinical information available to the readers	na
Statistical methods	12	Describe methods for calculating or comparing measures of diagnostic accuracy, and the statistical methods used to quantify uncertainty (e.g. 95% confidence intervals)	9
	13	Describe methods for calculating test reproducibility, if done	9
RESULTS			
Participants	14	Report when study was done, including beginning and ending dates of recruitment	4
	15	Report clinical and demographic characteristics of the study population (e.g. age, sex, spectrum of presenting symptoms, comorbidity, current treatments, recruitment centers	10
	16	Report the number of participants satisfying the criteria for inclusion that did or did not undergo the index tests and/or the reference standard; describe why participants failed to receive either test (a flow diagram is strongly recommended)	10
Test results	17	Report time interval from the index tests to the reference standard, and any treatment administered between	5
	18	Report distribution of severity of disease (define criteria) in those with the target condition; other diagnoses in participants without the target condition	na
	19	Report a cross tabulation of the results of the index tests (including indeterminate and missing results) by the results of the reference standard; for continuous results, the distribution of the test results by the results of the reference standard	na
	20	Report any adverse events from performing the index tests or the reference standard	na
Estimates	21	Report estimates of diagnostic accuracy and measures of statistical uncertainty (e.g. 95% confidence intervals)	12-15
	22	Report how indeterminate results, missing responses and outliers of the index tests were handled.	7, 9
	23	Report estimates of variability of diagnostic accuracy between subgroups of participants, readers or centers, if done.	na
	24	Report estimates of test reproducibility, if done	12-13
DISCUSSION	25	Discuss the clinical applicability of the study findings	15-18

This checklist is found at:www.consort-statement.org/checklist_test.pdf

BMJ open

Validation of a questionnaire measuring preschool children's reactions to and coping with noise in a repeated measurement design.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2012-002408.R1
Article Type:	Research
Date Submitted by the Author:	15-Mar-2013
Complete List of Authors:	Persson Waye, Kerstin; Sahlgrenska academy, Gothenburg University, Department of Occupational and Environmental Medicine van Kamp, Irene; National Institute for Public Health and the Environment, Centre for Environmental Health Research Dellve, Lotta; Royal Institute of Technology, Ergonomics
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Public health
Keywords:	EPIDEMIOLOGY, Community child health < PAEDIATRICS, PUBLIC HEALTH

Summary

Study Focus:

- ✓ Only a few studies have been performed on how noise affects preschool children.
- ✓ A prerequisite to do so is a method to measure perception, emotional and bodily reaction and coping with noise in the preschool situation.
- ✓ This study explored the reliability and validity of such an instrument based on data derived from a before after intervention study which was carried out at seven preschools in Sweden.

Key Messages:

- ✓ The results show that preschool children can indeed make a clear distinction between perception of and reaction to different types of noise and bodily reactions.
- ✓ Visual representation of emotional reactions and the location of bodily reactions is a good and reliable way to measure reactions in young children.
- ✓ More work on larger samples will need to be done to further develop a standard instrument to be used in preschool aged children.

Strength and weaknesses

- ✓ The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language".
- ✓ A major limitation is the relatively small sample size.

INTRODUCTION

Background

Earlier studies show that the sound environment at preschools may be a serious occupational and public health problem. Voss [1] measured eight hour equivalent noise exposure levels of 80 dB L_{Aeq} in daycare centers in Denmark. Maxwell and Evans [2] report four hour L_{Aeq} levels of 76 dB and peak levels of 96 dBC in preschools in the USA. The World Health Organization (WHO) recommends a A-weighted equivalent noise level of 35 dB (L_{Aeq}) at preschools in order not to disturb communication.[3] Dominant noise sources in preschools are sounds from children's activities indoors. In contrasts to elementary schools, the sound environment in preschools is highly intermittent, uncontrollable and characterized by peak levels of high spectrum frequency, originating from voices and children's activities. In order to describe the sound environment the equivalent noise level L_{Aeq} is used to represent an average sound pressure level over a given time, while the highest sound pressure levels of the intermittent sounds are better described by their maximum noise levels (L_{AFmax}) or peak levels (L_{Cpeak}).

Acoustical improvements in preschools and schools are most often made by fitting walls and ceiling with sound absorption panels. The calculated direct effects are a reduction of the reverberation time -the time it takes for a sound to decay 60 dB from its original intensity- and moderate reduction of sound level.[4, 5]

Noisy preschool environments could lead to reduced understanding of speech and as a consequence impaired reading and writing abilities.[2] Exposures at a young age might also affect other aspects of later life functioning and the development of disease. Effects described in the literature indicating such a mechanism pertain to

hearing impairment [3, 6] and increased levels of cortisol in children attending day care centers. [7, 8, 9] In preschool children also an association was found between noise levels at school and observed hoarseness, breathy voice and vocal hyperfunction.[10] Studies in older children have confirmed effects on reading comprehension and memory [11], performance [12], coping, wellbeing and stress [13, 14], and behavior and mental health.[15]

Reactions to and coping with environmental noise have been studied extensively in the past 30-40 years for adults.[16] Several recent studies also addressed annoyance and coping in school children, [12, 13, 17, 18, 19, 20 ,21] while only a handful of studies addressed this issue in younger (preschool) children. [2, 22, 23, 24] In comparison with adults, children in general and preschool children in specific may be particularly susceptible to the effects of noise because they have less capacity to anticipate, understand and cope with stressors [20] and because they are in a crucial and sensitive phase of their development. [3, 11]

Instruments to investigate young children's reactions to noise are not available. In order to fill this gap and in preparation of the development of such an instrument a qualitative study was performed in 2006 among 36 preschool children in Mölndal (Sweden), aged 4-6 years [25] using the constructivist-grounded theory as qualitative approach. [26] The children were asked about their perception of sound in the preschool situation, their understanding of the source and their perceived reactions at emotional and bodily level. Also, the degree of familiarity and comprehensibility of the sounds, manageability/control as well as disturbance and distress by the sounds were addressed. Finally, several coping strategies came forward, subdivided in avoidance (getting away, covering ears etc) and problem- oriented coping (complain to teacher). The method employed was in broad lines comparable to that used by

Haines et al.[12] in children aged 10-13. She concluded that noise annoyance in children pertains to the same construct as in adults, and this was later confirmed by others. [13, 16, 17, 18] It is uncertain whether younger children are also able to make such distinctions and thus show a comparable pattern to older children and adults, nor whether they are capable to answer questions during a structured interview regarding their sound environment and the way they emotionally and physically are affected by it in a consistent way.

Objectives

This paper aims to describe and explore the reliability and validity of the key questions of a structured interview developed for preschool children. The questions pertain to preschool children's perception of noise when at school, their bodily and emotional reaction to it, non-specific (stress related) symptoms and their coping strategies used to diminish detrimental effects of the noise. Aspects related to perceived control and behavioral reactions were left out of the interview, since it was felt that observational methods to measure these aspects would be more suitable to apply in this age group. Bodily reactions to noise in general as well as noise specific reactions were used to examine the external validity of the children's responses.

MATERIALS AND METHODS

Selection and recruitment

In the period between October 2006 to October 2009 children aged 4-5 and their parents were recruited from seven preschools where interventions were undertaken with the purpose to improve the acoustical qualities in the preschools in Mölndal, Sweden. In total, 63 children and 59 parents filled out the questionnaire before and

after the intervention. The response rates ranged from 80% in the parents to 98% in the children. Of the children two fell outside the age range of 4-5 years and were excluded from further analysis, resulting in a study population of 61 children. Parents signed an informed consent for their children according to the Declaration of Helsinki. The study was approved by the Ethics Committee of Göteborg, Sweden.

Procedure

One month before and three months after the intervention the children were interviewed. In order to diminish the risk of inter-rater variance the interviews were performed by two trained persons. The interview took on average 20 minutes and the form was filled in directly by the interviewer. The children were asked questions in a structured way and presented with visual representations of scales on show cards. The answers were filled in by the interviewer directly. When the child was not able to answer the question they were not prompted to do so. For the core set of questions see Appendix 1. For information about the full protocol please contact the first author.

Study population

Table 1 shows the distribution of age and gender of the children included in the analysis. The 61/59 children respectively included in the before – after study are reasonably well distributed over gender and age groups. All children aged 4 to 6 years were asked to participate in the interview, the number of children that took part in the interview per preschool ranged from 4 to 15.

Table 1: General characteristics of the children (Before and After intervention).

Characteristic	Before	After
Number of Respondents (n)	61	59
Gender		
girls	48%	49%
boys	52%	51%
Age		
4 years	52%	32%
5 years	48%	49%
6 years	-	8%

Noise exposure assessment and interventions

Noise was measured one month before and three months after the intervention using stationary noise level meter (Bruel and Kjaer 2261) with the microphone hanging 0.5 meters from the ceiling and personal dosimeters (Larson and Davies Sparks 705+) mounted on the left shoulder of personnel and children in seven preschools. The methods are described in more details elsewhere. [27,28] Stationary measurements during activity in the various rooms showed a moderate reduction of equivalent A-weighted level. The average reduction after the intervention as compared to before varied between 1.2 to 3.8 dB (L_{Aeq}) depending on the room. Children's dosimeters showed that personal average exposures were high and in the range of 83-85 dB (L_{Aeq}) and 117-118 dB (L_{AFmax}) both before and after the intervention, hence the intervention did not affect personal levels in a measurable way.

Noise perception

Noise perception was measured by means of standard questions. Children were asked how frequently they heard noise from three relevant noise sources in the preschool situation: angry and yelling children, strong and loud sounds and scraping and screeching sounds. Answers were indicated on a five -point Likert scale (ranging from *'almost never to very often'*) presented as 5 circles increasing in size and including 1 to 5 dots.

Reaction to noise

Aspects of reaction were measured using the following wording: '*How do you feel when* you hear the [sounds of angry, yelling children][loud and strong sounds] [scraping and screeching sounds]*. Answers were indicated on a bipolar visual scale representing drawn figures with different facial and bodily expressions ranging from glad/safe to sad/afraid and from kind/friendly to angry/irritated respectively. The reaction was recoded to neutral position (code 3) for those children who indicated on the previous question on perception, that they did not hear the sound.

Figure 1 Here

Coping strategies

For noise experienced at preschool, coping strategies were investigated by asking the children what they did when there was a lot of noise and if they coped, how often that was. The phrasing was as follows: '*When there is a lot of noise what do you do' [go away], [put your hands over your ears][tell your teacher] [raise your voice]and if so how often [almost never to all the time]*. First the answers No or Yes could be given. If the answer was Yes, they were asked to indicate how often on a five -point Likert

scale (ranging from *'almost never to very often'*) presented as 5 circles increasing in size and including 1 to 5 dots.

Bodily reactions to noise and symptoms

In order to measure bodily reactions to the three different sounds, the children were asked to indicate per sound source whether they could feel the sounds in their body and if so where they felt it (Figure 2) *('when you hear [angry and yelling sounds], [strong and loud sounds],[scraping and screeching sounds] can you feel it inside you or in your body and if so please point out in the figure where you feel it'*). The answers were recoded into location *[head] [neck] [arms] [heart] [belly] [legs] [feet]* as well as in number of locations (none versus 1 or more).

Figure 2 Here

Nonspecific symptoms were inventoried by asking the children what symptoms they had experienced in the past few days at preschool: headache, tummy ache and hoarse voice. Finally a question was asked about general wellbeing, making use of a similar figures used for reaction to noise ['*in the last days at preschool*' *have you felt like any of these children in this picture*] which was recoded into a 1 to 5 scale.

Data analysis

In order to test the convergent and divergent validity of the different indices, as a first step, confirmative factor analysis (CFA) was carried out using SAS for Windows (version 9.3) on the reaction and coping questions and perceived health questions. Bodily sensation and health symptoms were included, in order to determine whether children could distinguish between emotional and bodily responses and nonspecific symptoms/ health complaints. Also the items on the questions regarding coping strategies were included in the analysis. A high correlation was expected between reactions (both bodily and emotional) to different noise sources, between symptoms and the different coping strategies. CFA is a special form of factor analysis which is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct (or factor) and therefore suitable for our purpose. The degree of consistency is expressed by several statistical quantities determining the adequacy of model fit to the data, including the standardized root mean square residual (SRMSR) and the adjusted goodness of fit (AGFI). Acceptable model fit is indicated by a SRMSR value of 0.08 or less [29] and an AGFI value of 0.95 or more. [30] The contribution of each item to a factor is expressed in factor loadings. Due to small sample size and departure from normality, diagonally weighted least squares were used to estimate the parameters of the factor model.

In order to test the internal consistency of the components, Cronbach's alphas were calculated on the grouped items. Indices were composed by simply summing the separate items. These indices were further tested on their concurrent validity by comparing groups with one or more symptoms due to the different noise sources to a group who reported no symptoms. This was performed for the before condition only by means of a t-test assuming unequal variances. Additional analyses were performed on some relevant single items, which were excluded from CFA using nonparametric

methods such as Spearman and Mann-Whitney. Limiting factor for all analysis is the relatively small sample size. Traditional psychometrics advises that there should be at least 10 respondents per item, but sample sizes between 50 and 100 subjects are usually considered adequate to evaluate the psychometric properties of measures of social constructs. [31]

RESULTS

Table 2 shows the prevalence of noise perception, presented per noise source, and emotional reaction, total coping strategies and symptoms.

Table 2: Prevalence of noise perception, reaction, symptoms and coping

Characteristic	Before (n=61)	After (n=59)
Perception noise source *		
Angry and yelling: Source 1	67%	58%
Loud and strong: Source 2	57%	51%
Scraping and Screeching: Source 3	35%	18%
Location bodily reaction		
At least 1 location	70%	80%
Source 1	54%	49%
Source 2	54%	56%
Source 3	51%	49%
Angry reaction (score over 11)**	13%	5%
Prevalence of symptoms (score over 11)**	7%	4%
Coping (score over 15)* *	13%	16%

* percentage of percentage of children scoring in the highest two categories
** percentage of children scoring in the highest two categories per sum-score

The percentage of children indicating they never heard the sound was 17% and 19% for the angry and yelling sounds, 22% and 22% for loud sounds and 35% and 52 % for the scraping and screeching sounds in the before and after condition respectively.

Reaction and coping in children: construct validity

Confirmatory factor analyses (CFA) with categorical indicators were carried out to verify the a-priori structure pertaining to perception, emotional reaction, symptoms and coping strategies in the before and after condition. The perception scales [*How often do you hear angry and yelling children, strong and loud sounds and scraping and screeching sounds*] as well as the sad reaction scales showed to be too unstable to consider for further analysis. Likewise, the items pertaining to noise perception per source and low wellbeing were too unstable or loaded on many factors and were therefore treated as single items in further analysis (see Table 3). A three factor model was fitted to the remaining ten items pertaining to angry reactions, symptoms and coping. The model fit was good with a SRMSR of .08 and an AGFI of .97 in the before condition, but weaker in the after condition with a SRMSR of .12 and an AGFI of .91. For the before condition the loading are in the ranges .58 to .77, .41 to .78 and .51 to .71 for the three factors respectively. It was decided to take the before analysis as a point of departure and to test the reliability of the scales based on the measurements in the before and after condition.

Table 3: Factor Loadings, Goodness of Fit, internal consistency and interrelations

	Components/Before			Components/After		
	Reaction	Coping	Symptom	Reaction	Coping	Symptom
Source1_angry	.63			.33		
Source2_angry	.77			.55		
Source3_angry	.58			.73		
go away		.78			.32	
cover ears		.52			.46	
tell teacher		.41			.62	
raise voice		.57			.72	
headache			.71			.53
tummy ache			.67			.18
hoarse voice			.51			.61
Cronbach's alpha	.63	.65	.67	.56	.54	.52
SRMSR	.08			.12		
AGFI	.97			.91		

BEFORE	a	b	c	d	e	f	g
a. Perception yelling children	1	.48*	.19	.09	.11	.23*	-.12
b. Perception loud and strong sounds		1	30*	.24*	.25*	.33*	.00
c. Perception scraping and screeching sounds			1	.23*	.37*	.25*	.23*
d. Angry reaction				1	.33*	.15	.22*
e. Symptoms					1	34*	.56*
f. Coping strategies						1	-.10
g. Low wellbeing							1

* Significant at .05 level/missing values pairwise deletion

Reliability in terms of internal consistency

Three groups of variables pertaining to Angry Reaction, Coping and Symptoms were tested on their internal consistency expressed in alpha for the two measurements (Table 3 row 11). The analysis yielded homogeneous scales with comparable alpha's over the measurements ranging from .56 to .75. The relatively low alpha's in the after condition are partly due to test length and imply the risk to underestimate/attenuate the relationships between the variables and other variables. [32] However, based on the findings in the before condition it was considered justified to compose three indices by summing the scores on the separate items within each factor and to test distributions on normality. Deviations of normality were slight and most pronounced in the symptom scales.

Correlation analyses between these indices and items related to perception of noise and low wellbeing were studied for the before situation only (Table 3) and showed moderate to weak associations between perception and outcomes, but mostly in line with our expectations. Perception of scraping and screeching sounds was most strongly associated with angry reactions, coping, symptoms as well as low wellbeing followed by perceived loud sounds. Coping strategies were associated most strongly with symptoms and the highest association was found between symptoms and low wellbeing. Since items referring to sad reactions to the different sounds did not form one factor and the bipolar items do not allow for correlational analysis, separate analysis was performed after dichotomizing the scores on sad reaction items. Mann-Whitney analysis showed that sadness due to loud noises was associated with symptoms (Z-value=2.3/p=.021) and sad reaction due to scraping/screeching sounds with symptoms (Z-value=3.4/ p=.001) and coping strategies (Z-value=2.7/p=.008),

while sadness due to yelling sounds was found not to be associated with any of the indices on angry reaction, symptoms or coping.

Concurrent validity

As a last step in the psychometric evaluation, the associations between bodily reactions to noise and the three indices and the single item low wellbeing were analyzed to explore the concurrent validity. This refers to the accuracy of the relevant test scores to estimate an individual state on a criterion, in this case bodily reaction (general and noise source specific).

The rationale behind this analysis is that angry reaction, amount of coping strategies (number and frequency) and symptoms as well as low wellbeing are expected to be associated with bodily reactions. The associations between bodily reactions to noise with these relevant test-scores were studied by means of t-test. Hereby dichotomous groups were formed based on respectively any bodily reaction, and bodily reactions per noise source versus none. Distributions were checked per group and angry reaction was dropped from the analysis because the majority of data points in the group with no bodily reaction contained only children who had indicated they did not hear the sound. Subsequently, the mean scores on the remaining indices and the low wellbeing item were compared between groups. Table 4 presents the results.

Table 4. Bodily reaction and children's coping, symptoms and low wellbeing (before condition)

	Bodily reaction to any source	Bodily reaction to yelling sounds	Bodily reaction to loud sounds	Bodily reaction to scraping and screeching sounds
Symptom	-4.67**	-2.18*	-2.34*	2.69*
Coping strategies	-2.62*	-2.58*	-1.53	-2.04*
Low wellbeing	-1.97	-2.34*	-1.05	-1.50

Observed t-statistic/p-value < 0.05 marked as * and p<0.001 marked as **

T-test yielded significant differences in means on symptoms before for groups based on presence of any bodily reactions as well as presence of bodily reaction to the separate sources. The same pattern was found for coping with the exception of loud sounds. Low wellbeing when at school in the before condition, measured with a single item, showed to be associated significantly with bodily reaction to loud sounds only, while any bodily reaction just failed significance. In the after condition this pattern was only partly confirmed for symptoms with any bodily reaction and low wellbeing with any bodily reaction. Since t-test assumes normal distribution, in addition non parametric tests were applied. Further analysis showed that each hypothesis with p-value <0.05 for the t-test had Mann-Whitney p-values not exceeding 0.08.

DISCUSSION

The results of the psychometric evaluation indicate that preschool children are able to make a distinction between reactions to noises and emotional and bodily reactions as measured by means of visual representations of reactions and representation of the location of bodily reactions. As in adults [33], the interrelations between angry reactions to different sounds and noises were relatively high, while the relation between angry

reactions and symptom related aspects was lower: in other words reaction and symptoms can be considered as separate dimensions. This is also consistent with the findings among school children (9-11 years) in the RANCH study [18] and a survey among 207 children (aged 13-14 years). [34, 36] Furthermore, the results are in agreement with the results of a RANCH sub-study [35] in which it was found that children were capable to reliably index complex soundscapes and to provide perceptual scales that were in striking agreement with the perceptual scales provided by adults. We also found that angry reactions to noise could be distinguished from coping strategies. Comparing the elements of the correlation matrix in the before condition for perceptions of the different sound sources and its effects we conclude that scraping and screeching sounds play a prominent role, with significant associations for angry reaction, coping and symptoms. Whilst coping was significantly associated with all sounds, angry and loud sounds were not associated with angry reaction or symptoms. Based on the pattern we hypothesize that there is a pathway from perception of scraping and screeching sounds via angry reactions and coping to symptoms and via symptoms to low wellbeing.

An important finding is that children compared to adults seem to have a tendency to describe reaction to noise in a somatic way: they literary feel the noise in their body, especially in the head, heart and tummy.

Both the (angry) reaction and symptoms indices are significantly associated with general low wellbeing while at school and these responses tend to be sound specific. While loud and yelling sounds are only associated with coping, the perception of scraping and screeching sounds is significantly associated with angry reactions, coping as well as symptoms. This finding is important in view of future interventions at preschools as scraping and screeching sounds mainly originate from

friction between surfaces, such as chairs being pulled across the floor or table wares moved on the table top. To our knowledge no standards exist that give guidance on how to predict these sounds, which makes them problematic to systematically address. The four coping items included in the questionnaire pertain to active and avoidant behavior, a distinction which is confirmed in studies among older children and adults, but also came forward from the focus group discussions with children. [24] Results of CFA analysis showed a high inter correlation between the different coping strategies, with a slight tendency for a two sub-factors structure, pertaining to problem oriented coping and avoidance. This has implications for the interpretation of the coping index: it refers to the number and frequency of strategies employed rather than more or less effective strategies to cope with environmental noise. Future work should attempt to expand the number of items related to these different strategies which young children employ to cope with classroom noise.

Explorative comparison of children's symptom report and bodily reactions reveal a reasonable consistent pattern and indicate satisfactory concurrent validity of most of the indices for the before situation.

The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language". A major limitation is the relatively small sample size. Future research on larger groups of preschool children will be needed to further refine the questions in particular the questions pertaining to well-being and coping. Such an instrument will allow for studying development in reaction over time as well as the evaluation of noise reducing measurements in preschool in an unobtrusive and playful manner.

Previous studies suggest that children have fewer possibilities for controlling noise or have a less developed coping repertoire than adults.[20, 23] Development of

coping strategies would be an important target for future research in this group: noise induced behaviors at a young age (e.g. learned helplessness) might affect other aspects of later life functioning and the development of disease. Furthermore, this study shows that emotional reaction (angry and sad) is not the only relevant indicator of the effects of community noise in children, also bodily reactions, symptoms, coping behavior and wellbeing show to be important.

CONCLUSION

The main conclusion to be drawn from this study is that young children's angry reaction and bodily reactions to and coping with noise can be reliably measured with a structured interview, including visual representation questions. In accordance with what was found in adults [33] and children aged 9-11 [18, 21] we found that also younger children are able to distinguish between emotional reactions, symptoms, coping and wellbeing. Compared to adults, younger children tend to describe their reactions to noise in a somatic way. After further development of the instrument discussed in this paper we foresee studies into young children's reactions to and coping with noise on a larger scale.

Acknowledgements

We are grateful to Agneta Agge and Lena Samuelsson for their competence in carrying out the interviews. We also want to thank the participating children and their parents. The study was funded by the Swedish Council for Working Life and Social research.

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Figure 1: Visual representation with point scale ranging from kind/friendly to angry/irritated

Figure 2: Visual representation of body location

Summary

Study Focus:

- ✓ Only a few studies have been performed on how noise affects preschool children.
- ✓ A prerequisite to do so is a method to measure perception, emotional and bodily reaction and coping with noise in the preschool situation.
- ✓ This study explored the reliability and validity of such an instrument based on data derived from a before after intervention study which was carried out at seven preschools in Sweden.

Key Messages:

- ✓ The results show that preschool children can indeed make a clear distinction between perception of and reaction to different types of noise and bodily reactions.
- ✓ Visual representation of emotional reactions and the location of bodily reactions is a good and reliable way to measure reactions in young children.
- ✓ More work on larger samples will need to be done to further develop a standard instrument to be used in preschool aged children.

Strength and weaknesses

- ✓ The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language".
- ✓ A major limitation is the relatively small sample size.

INTRODUCTION

Background

Earlier studies show that the sound environment at preschools may be a serious occupational and public health problem. Voss [1] measured eight hour equivalent noise exposure levels of 80 dB L_{Aeq} in daycare centers in Denmark. Maxwell and Evans [2] report four hour L_{Aeq} levels of 76 dB and peak levels of 96 dBC in preschools in the USA. The World Health Organization (WHO) recommends a A-weighted equivalent noise level of 35 dB (L_{Aeq}) at preschools in order not to disturb communication.[3] Dominant noise sources in preschools are sounds from children's activities indoors. In contrasts to elementary schools, the sound environment in preschools is highly intermittent, uncontrollable and characterized by peak levels of high spectrum frequency, originating from voices and children's activities. In order to describe the sound environment the equivalent noise level L_{Aeq} is used to represent an average sound pressure level over a given time, while the highest sound pressure levels of the intermittent sounds are better described by their maximum noise levels ($L_{AF,max}$) or peak levels (L_{Cpeak}).

Acoustical improvements in preschools and schools are most often made by fitting walls and ceiling with sound absorption panels. The calculated direct effects are a reduction of the reverberation time -the time it takes for a sound to decay 60 dB from its original intensity- and moderate reduction of sound level.[4, 5]

Noisy preschool environments could lead to reduced understanding of speech and as a consequence impaired reading and writing abilities.[2] Exposures at a young age might also affect other aspects of later life functioning and the development of disease. Effects described in the literature indicating such a mechanism pertain to

hearing impairment [3, 6] and increased levels of cortisol in children attending day care centers. [7, 8, 9] In preschool children also an association was found between noise levels at school and observed hoarseness, breathy voice and vocal hyperfunction.[10] Studies in older children have confirmed effects on reading comprehension and memory [11], performance [12], coping, wellbeing and stress [13, 14], and behavior and mental health.[15]

Reactions to and coping with environmental noise have been studied extensively in the past 30-40 years for adults.[16] Several recent studies also addressed annoyance and coping in school children, [12, 13, 17, 18, 19, 20 ,21] while only a handful of studies addressed this issue in younger (preschool) children. [2, 22, 23, 24] In comparison with adults, children in general and preschool children in specific may be particularly susceptible to the effects of noise because they have less capacity to anticipate, understand and cope with stressors [20] and because they are in a crucial and sensitive phase of their development. [3, 11]

Instruments to investigate young children's reactions to noise are not available. In order to fill this gap and in preparation of the development of such an instrument a qualitative study was performed in 2006 among 36 preschool children in Mölndal (Sweden), aged 4-6 years [25] using the constructivist-grounded theory as qualitative approach. [26] The children were asked about their perception of sound in the preschool situation, their understanding of the source and their perceived reactions at emotional and bodily level. Also, the degree of familiarity and comprehensibility of the sounds, manageability/control as well as disturbance and distress by the sounds were addressed. Finally, several coping strategies came forward, subdivided in avoidance (getting away, covering ears etc) and problem- oriented coping (complain to teacher). The method employed was in broad lines comparable to that used by

Haines et al.[12] in children aged 10-13. She concluded that noise annoyance in children pertains to the same construct as in adults, and this was later confirmed by others. [13, 16, 17, 18] It is uncertain whether younger children are also able to make such distinctions and thus show a comparable pattern to older children and adults, nor whether they are capable to answer questions during a structured interview regarding their sound environment and the way they emotionally and physically are affected by it in a consistent way.

Objectives

This paper aims to describe and explore the reliability and validity of the key questions of a structured interview developed for preschool children. The questions pertain to preschool children's perception of noise when at school, their bodily and emotional reaction to it, non-specific (stress related) symptoms and their coping strategies used to diminish detrimental effects of the noise. Aspects related to perceived control and behavioral reactions were left out of the interview, since it was felt that observational methods to measure these aspects would be more suitable to apply in this age group. Bodily reactions to noise in general as well as noise specific reactions were used to examine the external validity of the children's responses.

MATERIALS AND METHODS

Selection and recruitment

In the period between October 2006 to October 2009 children aged 4-5 and their parents were recruited from seven preschools where interventions were undertaken with the purpose to improve the acoustical qualities in the preschools in Mölndal, Sweden. In total, 63 children and 59 parents filled out the questionnaire before and

after the intervention. The response rates ranged from 80% in the parents to 98% in the children. Of the children two fell outside the age range of 4-5 years and were excluded from further analysis, resulting in a study population of 61 children. Parents signed an informed consent for their children according to the Declaration of Helsinki. The study was approved by the Ethics Committee of Göteborg, Sweden.

Procedure

One month before and three months after the intervention the children were interviewed. In order to diminish the risk of inter-rater variance the interviews were performed by two trained persons. The interview took on average 20 minutes and the form was filled in directly by the interviewer. The children were asked questions in a structured way and presented with visual representations of scales on show cards. The answers were filled in by the interviewer directly. When the child was not able to answer the question they were not prompted to do so. For the core set of questions see Appendix 1. For information about the full protocol please contact the first author.

Study population

Table 1 shows the distribution of age and gender of the children included in the analysis. The 61/59 children respectively included in the before – after study are reasonably well distributed over gender and age groups. All children aged 4 to 6 years were asked to participate in the interview, the number of children that took part in the interview per preschool ranged from 4 to 15.

Table 1: General characteristics of the children (Before and After intervention).

Characteristic	Before	After
Number of Respondents (n)	61	59
Gender		
girls	48%	49%
boys	52%	51%
Age		
4 years	52%	32%
5 years	48%	49%
6 years	-	8%

Noise exposure assessment and interventions

Noise was measured one month before and three months after the intervention using stationary noise level meter (Bruel and Kjaer 2261) with the microphone hanging 0.5 meters from the ceiling and personal dosimeters (Larson and Davies Sparks 705+) mounted on the left shoulder of personnel and children in seven preschools. The methods are described in more details elsewhere. [27,28] Stationary measurements during activity in the various rooms showed a moderate reduction of equivalent A-weighted level. The average reduction after the intervention as compared to before varied between 1.2 to 3.8 dB (L_{Aeq}) depending on the room. Children's dosimeters showed that personal average exposures were high and in the range of 83-85 dB (L_{Aeq}) and 117-118 dB (L_{AFmax}) both before and after the intervention, hence the intervention did not affect personal levels in a measurable way.

Noise perception

Noise perception was measured by means of standard questions. Children were asked how frequently they heard noise from three relevant noise sources in the preschool situation: angry and yelling children, strong and loud sounds and scraping and screeching sounds. Answers were indicated on a five -point Likert scale (ranging from *'almost never to very often'*) presented as 5 circles increasing in size and including 1 to 5 dots.

Reaction to noise

Aspects of reaction were measured using the following wording: '*How do you feel when* you hear the [sounds of angry, yelling children][loud and strong sounds] [scraping and screeching sounds]*. Answers were indicated on a bipolar visual scale representing drawn figures with different facial and bodily expressions ranging from glad/safe to sad/afraid and from kind/friendly to angry/irritated respectively. The reaction was recoded to neutral position (code 3) for those children who indicated on the previous question on perception, that they did not hear the sound.

Figure 1 Here

Coping strategies

For noise experienced at preschool, coping strategies were investigated by asking the children what they did when there was a lot of noise and if they coped, how often that was. The phrasing was as follows: '*When there is a lot of noise what do you do' [go away], [put your hands over your ears][tell your teacher] [raise your voice]and if so how often [almost never to all the time]*. First the answers No or Yes could be given. If the answer was Yes, they were asked to indicate how often on a five -point Likert

scale (ranging from *'almost never to very often'*) presented as 5 circles increasing in size and including 1 to 5 dots.

Bodily reactions to noise and symptoms

In order to measure bodily reactions to the three different sounds, the children were asked to indicate per sound source whether they could feel the sounds in their body and if so where they felt it (Figure 2) *('when you hear [angry and yelling sounds], [strong and loud sounds],[scraping and screeching sounds] can you feel it inside you or in your body and if so please point out in the figure where you feel it'*). The answers were recoded into location *[head] [neck] [arms] [heart] [belly] [legs] [feet]* as well as in number of locations (none versus 1 or more).

Figure 2 Here

Nonspecific symptoms were inventoried by asking the children what symptoms they had experienced in the past few days at preschool: headache, tummy ache and hoarse voice. Finally a question was asked about general wellbeing, making use of a similar figures used for reaction to noise ['*in the last days at preschool*' *have you felt like any of these children in this picture*] which was recoded into a 1 to 5 scale.

Data analysis

In order to test the convergent and divergent validity of the different indices, as a first step, confirmative factor analysis (CFA) was carried out using SAS for Windows (version 9.3) on the reaction and coping questions and perceived health questions. Bodily sensation and health symptoms were included, in order to determine whether children could distinguish between emotional and bodily responses and nonspecific symptoms/ health complaints. Also the items on the questions regarding coping strategies were included in the analysis. A high correlation was expected between reactions (both bodily and emotional) to different noise sources, between symptoms and the different coping strategies. CFA is a special form of factor analysis which is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct (or factor) and therefore suitable for our purpose. The degree of consistency is expressed by several statistical quantities determining the adequacy of model fit to the data, including the standardized root mean square residual (SRMSR) and the adjusted goodness of fit (AGFI). Acceptable model fit is indicated by a SRMSR value of 0.08 or less [29] and an AGFI value of 0.95 or more. [30] The contribution of each item to a factor is expressed in factor loadings. Due to small sample size and departure from normality, diagonally weighted least squares were used to estimate the parameters of the factor model.

In order to test the internal consistency of the components, Cronbach's alphas were calculated on the grouped items. Indices were composed by simply summing the separate items. These indices were further tested on their concurrent validity by comparing groups with one or more symptoms due to the different noise sources to a group who reported no symptoms. This was performed for the before condition only by means of a t-test assuming unequal variances. Additional analyses were performed on some relevant single items, which were excluded from CFA using nonparametric

methods such as Spearman and Mann-Whitney. Limiting factor for all analysis is the relatively small sample size. Traditional psychometrics advises that there should be at least 10 respondents per item, but sample sizes between 50 and 100 subjects are usually considered adequate to evaluate the psychometric properties of measures of social constructs. [31]

RESULTS

Table 2 shows the prevalence of noise perception, presented per noise source, and emotional reaction, total coping strategies and symptoms.

Table 2: Prevalence of noise perception, reaction, symptoms and coping

Characteristic	Before (n=61)	After (n=59)
Perception noise source *		
Angry and yelling: Source 1	67%	58%
Loud and strong: Source 2	57%	51%
Scraping and Screeching: Source 3	35%	18%
Location bodily reaction		
At least 1 location	70%	80%
Source 1	54%	49%
Source 2	54%	56%
Source 3	51%	49%
Angry reaction (score over 11)**	13%	5%
Prevalence of symptoms (score over 11)**	7%	4%
Coping (score over 15)* *	13%	16%

* percentage of percentage of children scoring in the highest two categories
** percentage of children scoring in the highest two categories per sum-score

The percentage of children indicating they never heard the sound was 17% and 19% for the angry and yelling sounds, 22% and 22% for loud sounds and 35% and 52 % for the scraping and screeching sounds in the before and after condition respectively.

Reaction and coping in children: construct validity

Confirmatory factor analyses (CFA) with categorical indicators were carried out to verify the a-priori structure pertaining to perception, emotional reaction, symptoms and coping strategies in the before and after condition. The perception scales [*How often do you hear angry and yelling children, strong and loud sounds and scraping and screeching sounds*] as well as the sad reaction scales showed to be too unstable to consider for further analysis. Likewise, the items pertaining to noise perception per source and low wellbeing were too unstable or loaded on many factors and were therefore treated as single items in further analysis (see Table 3). A three factor model was fitted to the remaining ten items pertaining to angry reactions, symptoms and coping. The model fit was good with a SRMSR of .08 and an AGFI of .97 in the before condition, but weaker in the after condition with a SRMSR of .12 and an AGFI of .91. For the before condition the loading are in the ranges .58 to .77, .41 to .78 and .51 to .71 for the three factors respectively. It was decided to take the before analysis as a point of departure and to test the reliability of the scales based on the measurements in the before and after condition.

Table 3: Factor Loadings, Goodness of Fit, internal consistency and interrelations

	Components/Before			Components/After		
	Reaction	Coping	Symptom	Reaction	Coping	Symptom
Source1_angry	.63			.33		
Source2_angry	.77			.55		
Source3_angry	.58			.73		
go away		.78			.32	
cover ears		.52			.46	
tell teacher		.41			.62	
raise voice		.57			.72	
headache			.71			.53
tummy ache			.67			.18
hoarse voice			.51			.61
Cronbach's alpha	.63	.65	.67	.56	.54	.52
SRMSR	.08			.12		
AGFI	.97			.91		

BEFORE	a	b	c	d	e	f	g
a. Perception yelling children	1	.48*	.19	.09	.11	.23*	-.12
b. Perception loud and strong sounds		1	30*	.24*	.25*	.33*	.00
c. Perception scraping and screeching sounds			1	.23*	.37*	.25*	.23*
d. Angry reaction				1	.33*	.15	.22*
e. Symptoms					1	34*	.56*
f. Coping strategies						1	-.10
g. Low wellbeing							1

* Significant at .05 level/missing values pairwise deletion

Reliability in terms of internal consistency

Three groups of variables pertaining to Angry Reaction, Coping and Symptoms were tested on their internal consistency expressed in alpha for the two measurements (Table 3 row 11). The analysis yielded homogeneous scales with comparable alpha's over the measurements ranging from .56 to .75. The relatively low alpha's in the after condition are partly due to test length and imply the risk to underestimate/attenuate the relationships between the variables and other variables. [32] However, based on the findings in the before condition it was considered justified to compose three indices by summing the scores on the separate items within each factor and to test distributions on normality. Deviations of normality were slight and most pronounced in the symptom scales.

Correlation analyses between these indices and items related to perception of noise and low wellbeing were studied for the before situation only (Table 3) and showed moderate to weak associations between perception and outcomes, but mostly in line with our expectations. Perception of scraping and screeching sounds was most strongly associated with angry reactions, coping, symptoms as well as low wellbeing followed by perceived loud sounds. Coping strategies were associated most strongly with symptoms and the highest association was found between symptoms and low wellbeing. Since items referring to sad reactions to the different sounds did not form one factor and the bipolar items do not allow for correlational analysis, separate analysis was performed after dichotomizing the scores on sad reaction items. Mann-Whitney analysis showed that sadness due to loud noises was associated with symptoms (Z-value=2.3/p=.021) and sad reaction due to scraping/screeching sounds with symptoms (Z-value=3.4/ p=.001) and coping strategies (Z-value=2.7/p=.008),

while sadness due to yelling sounds was found not to be associated with any of the indices on angry reaction, symptoms or coping.

Concurrent validity

As a last step in the psychometric evaluation, the associations between bodily reactions to noise and the three indices and the single item low wellbeing were analyzed to explore the concurrent validity. This refers to the accuracy of the relevant test scores to estimate an individual state on a criterion, in this case bodily reaction (general and noise source specific).

The rationale behind this analysis is that angry reaction, amount of coping strategies (number and frequency) and symptoms as well as low wellbeing are expected to be associated with bodily reactions. The associations between bodily reactions to noise with these relevant test-scores were studied by means of t-test. Hereby dichotomous groups were formed based on respectively any bodily reaction, and bodily reactions per noise source versus none. Distributions were checked per group and angry reaction was dropped from the analysis because the majority of data points in the group with no bodily reaction contained only children who had indicated they did not hear the sound. Subsequently, the mean scores on the remaining indices and the low wellbeing item were compared between groups. Table 4 presents the results.

Table 4. Bodily reaction and children's coping, symptoms and low wellbeing (before condition)

	Bodily reaction to any source	Bodily reaction to yelling sounds	Bodily reaction to loud sounds	Bodily reaction to scraping and screeching sounds
Symptom	-4.67**	-2.18*	-2.34*	2.69*
Coping strategies	-2.62*	-2.58*	-1.53	-2.04*
Low wellbeing	-1.97	-2.34*	-1.05	-1.50

Observed t-statistic/p-value < 0.05 marked as * and p<0.001 marked as **

T-test yielded significant differences in means on symptoms before for groups based on presence of any bodily reactions as well as presence of bodily reaction to the separate sources. The same pattern was found for coping with the exception of loud sounds. Low wellbeing when at school in the before condition, measured with a single item, showed to be associated significantly with bodily reaction to loud sounds only, while any bodily reaction just failed significance. In the after condition this pattern was only partly confirmed for symptoms with any bodily reaction and low wellbeing with any bodily reaction. Since t-test assumes normal distribution, in addition non parametric tests were applied. Further analysis showed that each hypothesis with p-value <0.05 for the t-test had Mann-Whitney p-values not exceeding 0.08.

DISCUSSION

The results of the psychometric evaluation indicate that preschool children are able to make a distinction between reactions to noises and emotional and bodily reactions as measured by means of visual representations of reactions and representation of the location of bodily reactions. As in adults [33], the interrelations between angry reactions to different sounds and noises were relatively high, while the relation between angry

reactions and symptom related aspects was lower: in other words reaction and symptoms can be considered as separate dimensions. This is also consistent with the findings among school children (9-11 years) in the RANCH study [18] and a survey among 207 children (aged 13-14 years). [34, 36] Furthermore, the results are in agreement with the results of a RANCH sub-study [35] in which it was found that children were capable to reliably index complex soundscapes and to provide perceptual scales that were in striking agreement with the perceptual scales provided by adults. We also found that angry reactions to noise could be distinguished from coping strategies. Comparing the elements of the correlation matrix in the before condition for perceptions of the different sound sources and its effects we conclude that scraping and screeching sounds play a prominent role, with significant associations for angry reaction, coping and symptoms. Whilst coping was significantly associated with all sounds, angry and loud sounds were not associated with angry reaction or symptoms. Based on the pattern we hypothesize that there is a pathway from perception of scraping and screeching sounds via angry reactions and coping to symptoms and via symptoms to low wellbeing.

An important finding is that children compared to adults seem to have a tendency to describe reaction to noise in a somatic way: they literary feel the noise in their body, especially in the head, heart and tummy.

Both the (angry) reaction and symptoms indices are significantly associated with general low wellbeing while at school and these responses tend to be sound specific. While loud and yelling sounds are only associated with coping, the perception of scraping and screeching sounds is significantly associated with angry reactions, coping as well as symptoms. This finding is important in view of future interventions at preschools as scraping and screeching sounds mainly originate from

friction between surfaces, such as chairs being pulled across the floor or table wares moved on the table top. To our knowledge no standards exist that give guidance on how to predict these sounds, which makes them problematic to systematically address.

The four coping items included in the questionnaire pertain to active and avoidant behavior, a distinction which is confirmed in studies among older children and adults, but also came forward from the focus group discussions with children. [24] Results of CFA analysis showed a high inter correlation between the different coping strategies, with a slight tendency for a two sub-factors structure, pertaining to problem oriented coping and avoidance. This has implications for the interpretation of the coping index: it refers to the number and frequency of strategies employed rather than more or less effective strategies to cope with environmental noise. Future work should attempt to expand the number of items related to these different strategies which young children employ to cope with classroom noise.

Explorative comparison of children's symptom report and bodily reactions reveal a reasonable consistent pattern and indicate satisfactory concurrent validity of most of the indices for the before situation.

The strength of this study lies in the fact that the questions posed to the children were based on focus group discussion and worded in their own "language". A major limitation is the relatively small sample size. Future research on larger groups of preschool children will be needed to further refine the questions in particular the questions pertaining to well-being and coping. Such an instrument will allow for studying development in reaction over time as well as the evaluation of noise reducing measurements in preschool in an unobtrusive and playful manner.

Previous studies suggest that children have fewer possibilities for controlling noise or have a less developed coping repertoire than adults.[20, 23] Development of

coping strategies would be an important target for future research in this group: noise induced behaviors at a young age (e.g. learned helplessness) might affect other aspects of later life functioning and the development of disease. Furthermore, this study shows that emotional reaction (angry and sad) is not the only relevant indicator of the effects of community noise in children, also bodily reactions, symptoms, coping behavior and wellbeing show to be important.

CONCLUSION

The main conclusion to be drawn from this study is that young children's angry reaction and bodily reactions to and coping with noise can be reliably measured with a structured interview, including visual representation questions. In accordance with what was found in adults [33] and children aged 9-11 [18, 21] we found that also younger children are able to distinguish between emotional reactions, symptoms, coping and wellbeing. Compared to adults, younger children tend to describe their reactions to noise in a somatic way. After further development of the instrument discussed in this paper we foresee studies into young children's reactions to and coping with noise on a larger scale.

Acknowledgements

We are grateful to Agneta Agge and Lena Samuelsson for their competence in carrying out the interviews. We also want to thank the participating children and their parents. The study was funded by the Swedish Council for Working Life and Social research.

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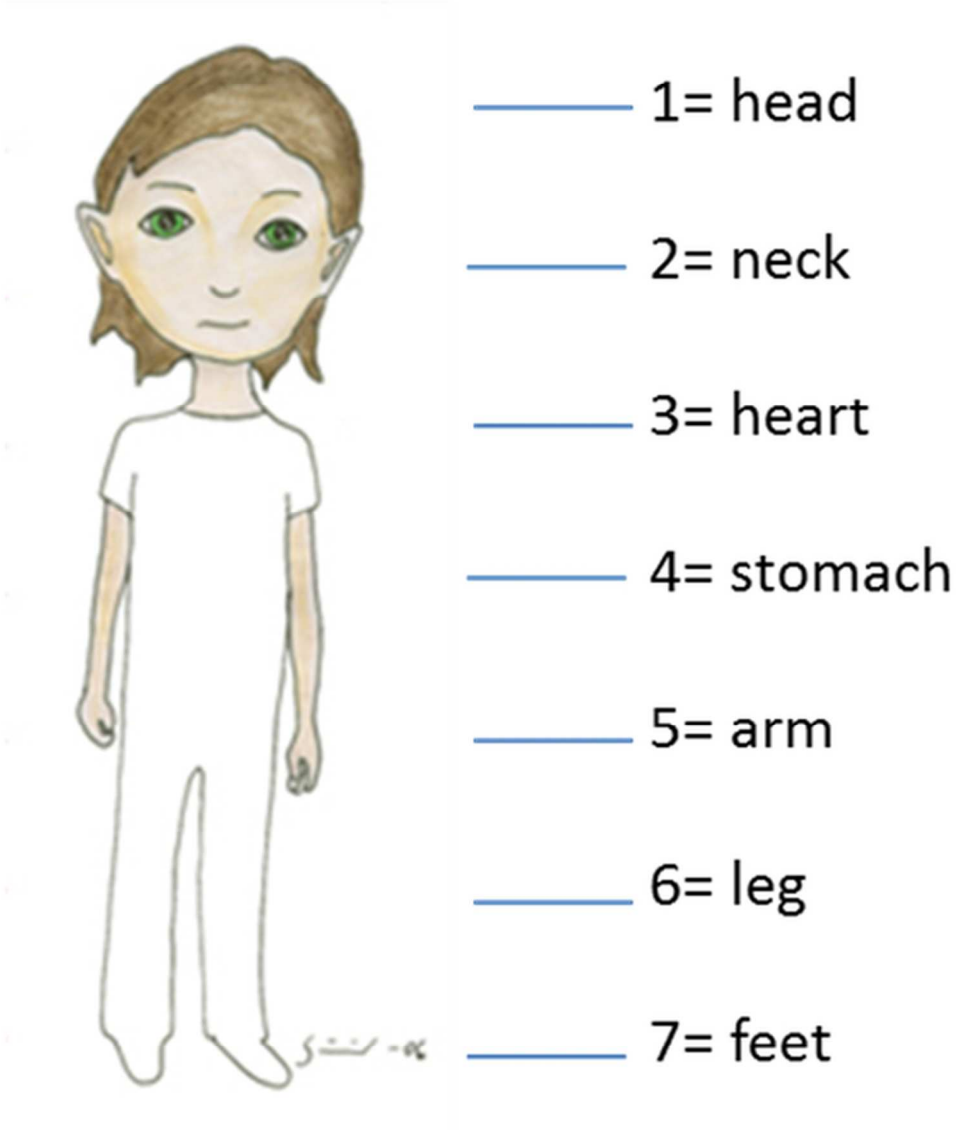
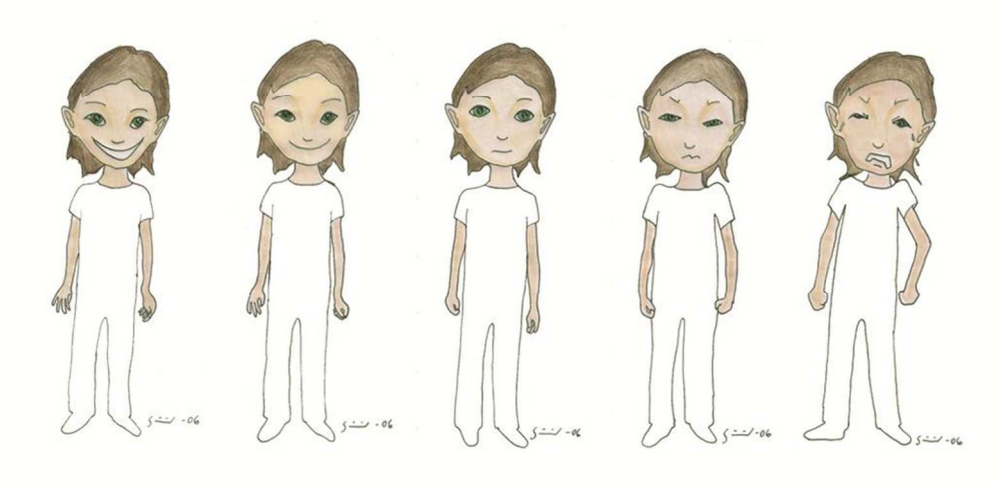
Figure 1: Visual representation with point scale ranging from kind/friendly to angry/irritated

Figure 2: Visual representation of body location



90x105mm (300 x 300 DPI)



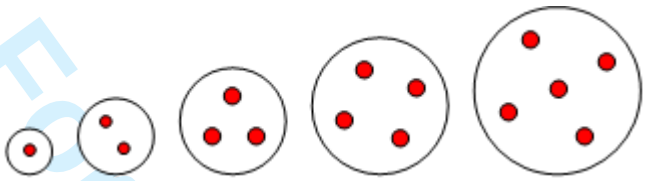
183x90mm (300 x 300 DPI)

Inventory of Noise and Children's Health
INCH

10. How often do you hear other children at preschool being angry and yelling?

12. How often do you hear loud and strong sounds at preschool – like shouting, screaming or banging?

14. How often do you hear scraping and screeching sounds?



Almost never Very often

Repeat for 10, 12, 14

11a. When you hear other children being angry and yelling, do you feel it inside you or in your body?

13a. When you hear loud, strong sounds, do you feel it inside you or in your body?

15a. When you hear scraping and screeching sounds, do you feel it inside you or in your body?

☐ If No, go to Question 16. ☐ If Yes, point out in the picture where you feel it.

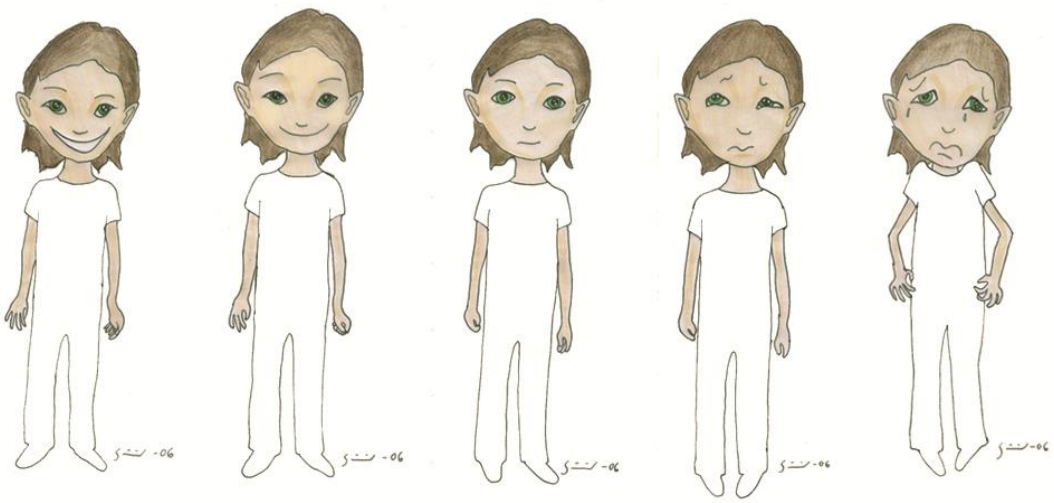
Repeat for 11a, 13a, 15a

11c. Sometimes when you hear children being angry and yelling, you might feel like one of the children in this picture.

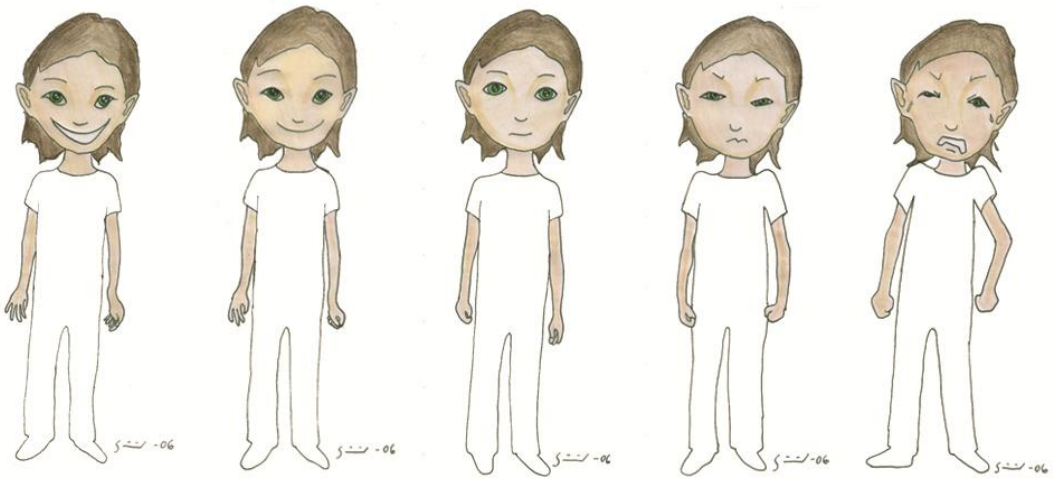
13c. Sometimes when you hear loud, strong sounds, you might feel like one of the children in this picture.

15c. Sometimes when you hear scraping and screeching sounds, you might feel like one of the children in this picture.

Point to the child that looks most like how you feel when you hear these sounds.



glad/safe sad/afraid



kind/friendly angry/irritated

Repeat for 11c, 13c, 15c

16. When there's a lot of noise, what do you do?

a) Do you go away?

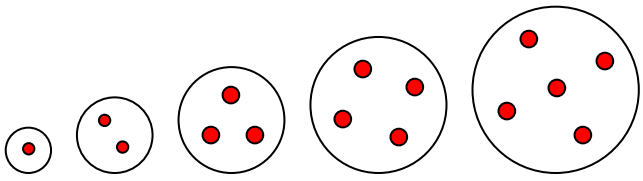
b) Put your hands over your ears?

c) Tell the teacher?

d) Do you need to raise your voice in order to be heard?

□ No, go to next question

□ if Yes How often do you do that?



Almost never Always

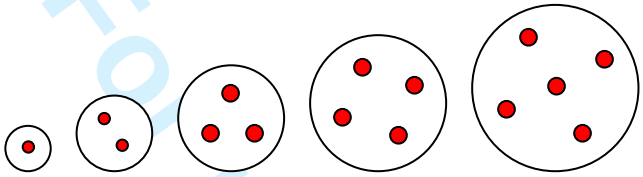
Repeat for 16a, 16b, 16c and16 d

18. The questions I am going to ask now are about how you have been feeling at preschool <u>in the past few days</u>.

    a) Have you had a headache?

    b) Have you had a tummy ache?

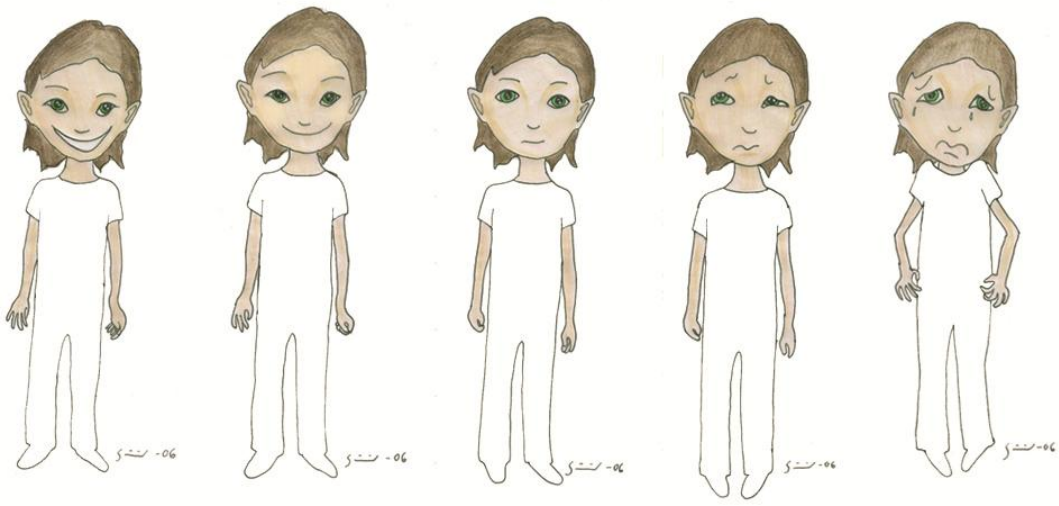
    c) Have your voice been hoarse?



Never Often

Repeat for 18a, 18b, 18c

19. In the past few days, have you felt like any of the children in this picture? Can you point at the one you felt like?



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Procedure for use of the Questionnaire: **INCH**

These questions are part of a questionnaire which was developed within the Sound Environment Research Unit at Gothenburg University under the leadership of Kerstin Persson Waye www.amm.se/soundenvironment

The full questionnaire can be obtained by contacting the first author.

The questionnaire can be used under the following conditions:

- The source should be mentioned e.g. this article.
- Manuscripts and articles dealing with results obtained with the questionnaire should be sent to kerstin.persson.waye@amm.gu.se
- Part of the research data should be made available to the author of the questionnaire (in consultation with the author) for further validation.

STARD checklist for the reporting of studies of diagnostic accuracy

Section and Topic	Item #		On page #
TITLE/ABSTRACT/ KEYWORDS	1	Identify the article as a study of diagnostic accuracy (recommended MeSH heading 'sensitivity and specificity')	I-II
INTRODUCTION	2	State the research questions or study aims, such as estimating diagnostic accuracy or comparing accuracy between tests or across participant groups	1-2
METHODS			
Participants	3	Describe the study population: The inclusion and exclusion criteria, setting and locations where the data were collected	4-5
	4	Describe participant recruitment: Was recruitment based on presenting symptoms, results from previous tests, or the fact that the participants had received the index tests or the reference standard?	4-5
	5	Describe participant sampling: Was the study population a consecutive series of participants defined by the selection criteria in items 3 and 4? If not, specify how participants were further selected	As defined in 3 and 4
	6	Describe data collection: Was data collection planned before the index test and reference standard were performed (prospective study) or after (retrospective study)?	Befor-after study
Test methods	7	Describe the reference standard and its rationale	na
	8	Describe technical specifications of material and methods involved including how and when measurements were taken, and/or cite references for index tests and reference standard	5
	9	Describe definition of and rationale for the units, cutoffs and/or categories of the results of the index tests and the reference standard	6-9
	10	Describe the number, training and expertise of the persons executing and reading the index tests and the reference standard	5
	11	Describe whether or not the readers of the index tests and reference standard were blind (masked) to the results of the other test and describe any other clinical information available to the readers	na
Statistical methods	12	Describe methods for calculating or comparing measures of diagnostic accuracy, and the statistical methods used to quantify uncertainty (e.g. 95% confidence intervals)	9
	13	Describe methods for calculating test reproducibility, if done	9
RESULTS			
Participants	14	Report when study was done, including beginning and ending dates of recruitment	4
	15	Report clinical and demographic characteristics of the study population (e.g. age, sex, spectrum of presenting symptoms, comorbidity, current treatments, recruitment centers	10
	16	Report the number of participants satisfying the criteria for inclusion that did or did not undergo the index tests and/or the reference standard; describe why participants failed to receive either test (a flow diagram is strongly recommended)	10
Test results	17	Report time interval from the index tests to the reference standard, and any treatment administered between	5
	18	Report distribution of severity of disease (define criteria) in those with the target condition; other diagnoses in participants without the target condition	na
	19	Report a cross tabulation of the results of the index tests (including indeterminate and missing results) by the results of the reference standard; for continuous results, the distribution of the test results by the results of the reference standard	na
	20	Report any adverse events from performing the index tests or the reference standard	na
Estimates	21	Report estimates of diagnostic accuracy and measures of statistical uncertainty (e.g. 95% confidence intervals)	12-15
	22	Report how indeterminate results, missing responses and outliers of the index tests were handled.	7, 9
	23	Report estimates of variability of diagnostic accuracy between subgroups of participants, readers or centers, if done.	na
	24	Report estimates of test reproducibility, if done	12-13
DISCUSSION	25	Discuss the clinical applicability of the study findings	15-18

This checklist is found at:www.consort-statement.org/checklist_test.pdf