

# Effects of noise and a speaker's impaired voice quality on spoken language processing in school-aged children: a systematic review and meta-analysis\*

#### Introduction

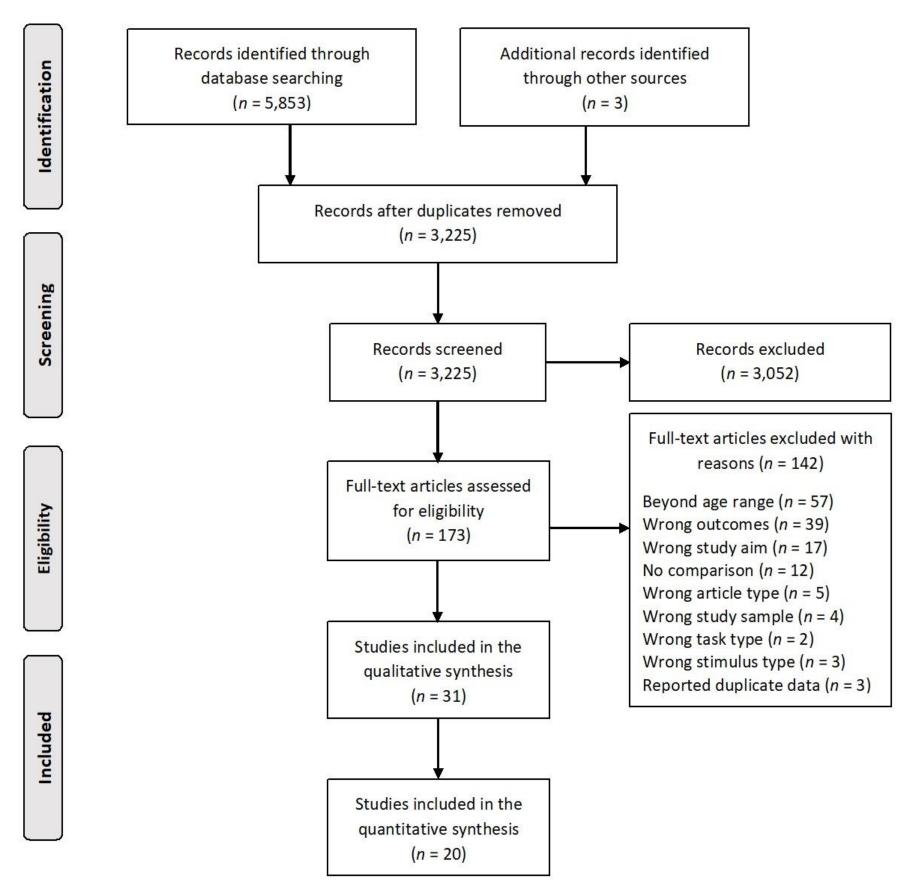
- Classroom noise levels ~70 dB(A) (recommended: ≤55 dB(A)) [1]
- Intensive voice use among teachers to increase intelligibility [2]
- ~50% of teachers develop voice disorders [3]
- Poor listening conditions affect children's processing of spoken language [4]

## **Objective**

To review and quantify the effects of noise and impaired voice on spoken language processing in school-aged children

### Methods

- Systematic review and meta-analysis reported using PRISMA [5]
- Eligibility: Studies examining 6-18-year-old children's accuracy and response times (RT) in listening tasks presented in noise and/or impaired voice
- Study search: PsycINFO/Ovid, Medline/Ovid, Eric/Ovid, and Scopus (up to 11/2019)
- Systematic review: Classification and synthesis of noise and impaired-voice effects regarding speech perception, listening comprehension, and auditory working memory
- Meta-analysis: Quantification of noise and impaired-voice effects
- Quality assessment: Tool for Observational Cohort and Cross-Sectional Studies of the National Heart, Lung, and Blood Institute [6]



**Figure 1.** Flow diagram illustrating study selection process

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Bradley et al. (2008)	YES C	D	NR	NO	NO	YES	NO	YES	NR	YES	FAIR
Brännström, Kastberg, et al. (2018)	YES Y	ES	YES	YES	YES	NA	CD	YES	NR	CD	GOOD
Brännström, von Lochow, et al. (2018)	YES N	IO	NR	NR	NO	NA	CD	YES	NR	CD	FAIR
Chui & Ma (2018)	YES Y	ES	NR	YES	NO	YES	CD	CD	NR	YES	GOOD
Crandell & Smaldino (1996)	YES N	IO	NR	NO	NO	YES	YES	YES	NR	YES	GOOD
Howard et al. (2010)	YES N	10	NR	NR	NO	YES	NO	YES	NR	NO	GOOD
Hurtig et al. (2016)	YES Y	ES	YES	NO	YES	NA	YES	CD	NR	YES	GOOD
Jamieson et al. (2004)	YES N	IO	NR	CD	NO	YES	CD	NO	NR	CD	FAIR
Klatte et al. (2007)	YES N	10	NR	NO	NO	YES	YES	CD	NR	NO	FAIR
Lyberg-Åhlander, Haake, et al. (2015)	YES Y	ES	YES	YES	YES	NA	CD	YES	NR	YES	GOOD
Lyberg-Åhlander, Holm, et al. (2015)	YES N	IO	YES	NO	YES	NA	CD	YES	NR	CD	GOOD
McCreery & Stelmachowicz (2013)	YES Y	ES	NR	CD	YES	YES	YES	YES	NR	NO	GOOD
McGarrigle et al. (2017)	YES N	IO	NR	NO	CD	NA	YES	CD	NR	NO	FAIR
Morsomme et al. (2011)	YES N	IO	NR	NR	NO	NA	CD	CD	NR	YES	FAIR
Morton & Watson (2001)	YES N	Ю	NR	YES	NO	NA	CD	NO	NR	CD	FAIR
Nakeva von Mentzer et al. (2017)	YES N	10	YES	NO	YES	NA	CD	YES	NR	YES	GOOD
Nelson et al. (2005)	YES Y	TES	YES	CD	YES	NA	NO	NO	NR	CD	GOOD
Nirme et al. (2018)	YES Y	ES	YES	YES	NO	NA	YES	YES	NR	CD	GOOD
Osman et al. (2014)	YES Y	ES	NR	CD	NO	YES	YES	YES	NR	YES	GOOD
Peng & Jiang (2016)	YES N	10	NR	NO	NO	YES	YES	YES	NR	NO	GOOD
Peng et al. (2016)	YES N	10	NR	NO	NO	NA	YES	YES	NR	NO	FAIR
Peng & Wu (2018)	YES N	10	NR	NO	NO	YES	YES	YES	NR	NO	GOOD
Picou et al. (2019)	YES N	IO	NR	CD	YES	YES	YES	CD	NR	NO	GOOD
Prodi, Visentin, Borella, et al. (2019)	YES Y	ES	NR	CD	NA	NO	YES	CD	NR	YES	GOOD
Prodi, Visentin, Peretti, et al. (2019)	YES Y	ES	NR	CD	NA	NO	YES	YES	NR	CD	GOOD
Rogerson & Dodd (2005)	YES C	D	NR	NO	NO	YES	NO	CD	NR	YES	FAIR
Sahlén et al. (2017)	YES N	10	NR	NO	YES	NA	CD	YES	NR	CD	GOOD
Sullivan et al. (2015)	YES Y	ES	YES	CD	YES	NA	NO	YES	NR	CD	GOOD
von Lochow et al. (2018)	YES Y	ES	YES	NO	YES	YES	CD	CD	NR	NO	GOOD
Yacullo & Hawkins (1987)	YES Y	ES	NR	YES	NO	NA	YES	CD	NR	NO	GOOD
Zhang et al. (2019)	YES N	IO	NR	NO	YES	YES	NO	NO	NR	CD	FAIR

Figure 2. Quality assessment of included studies using shortened NIH tool [5] NR = not reported; NA = not applicable; CD = cannot determine

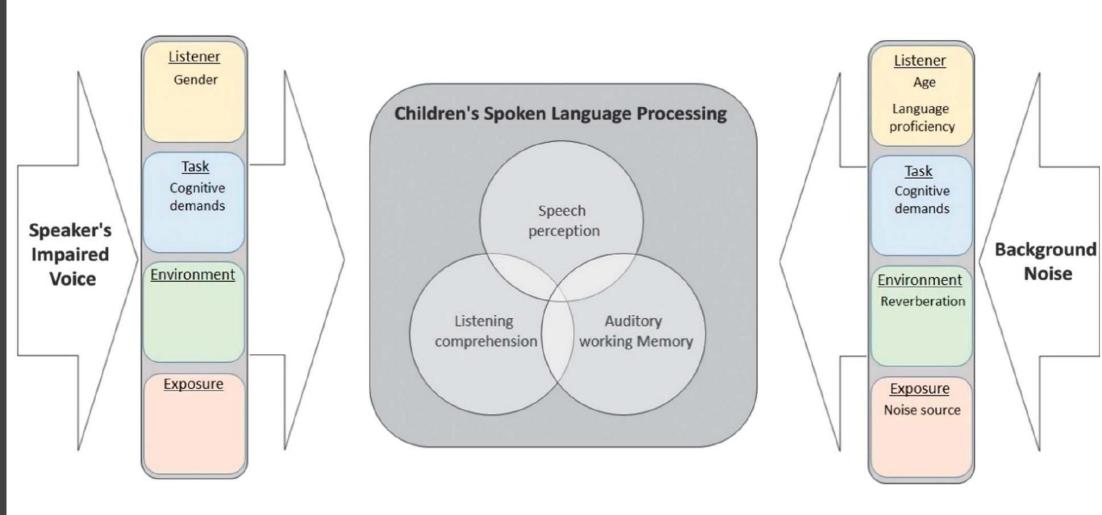


Figure 3. Speech Processing under Acoustic DEgradations (SPADE) Framework illustrates: impaired voice and noise can disrupt children's spoken language processing regarding speech perception, listening comprehension, and auditory working memory. Based on reviewed studies, factors concerning the listener, task, environment, and exposure can moderate these effects.

#### Results

- 31 studies reviewed (Figure 1; 21 = noise; 8 = impaired voice; 2 = combined effect)
- Good study quality in 71% and fair quality in 29% of studies (Figure 2)
- Qualitatively, noise and impaired voice impede speech perception, listening comprehension, and auditory working memory (Figure 3)
- Quantitatively, moderate-severe effects of noise (Table 1) and mild-moderate effects of impaired voice on response accuracy (Table 2); effects on RT inconclusive

Stur	Studies	Children	Main	Heterogeneity test			
Predictor	N		Cohen's <i>d</i> [95% CI]	z value	p value	ľ	p value
Noise (SNR bins)							
+6 to +10 dB	5	130	-0.67 [-0.92, -0.42]	-5.24	< .01**	0%	.93
+1 to +5 dB	5	156	-1.20 [-2.00, -0.40]	-2.94	< .01**	90%	< .01**
0 dB	7	371	-1.74 [-2.60, -0.88]	-3.96	< .01**	95%	< .01**
–1 to –5 dB	5	131	-2.24 [-3.82, -0.65]	-2.77	< .01**	96%	< .01**
–6 to –12 dB	3	70	-2.65 [-4.10, -1.21]	-3.60	< .01**	89%	< .01**

Note. SNR = signal-to-noise ratio.

\*\*p < .01.

Table 2. Effects of impaired voice on answer accuracy in listening comprehension and auditory working memory tasks

	Studies	Children	Main	Heterogeneity test			
Predictor	N N		Cohen's <i>d</i> [95% Cl]	z value	p value	l <sup>2</sup>	p value
Impaired voice							
Listening comprehension	9	545	-0.35 [-0.59, -0.11]	-2.82	< .01**	73%	< .01**
Auditory working memory	2	81	-0.13 [-0.72, 0.46]	-0.42	.67	67%	.08

*Note.* The dimension of speech perception is not featured as it was assessed in only one study (Morsomme et al.). \*\*p < .01.

#### Conclusions

- Noise and impaired voice may disrupt children's spoken language processing from very early up to highly complex processing stages.
- Further research on combined effects of noise and impaired voice required
- Study quality generally good, but more rigorous reporting needed

#### Recommendations

- Improving classroom listening conditions (e.g., classroom management techniques, noise insulation, and voice amplification for teachers)
- Investigating combined effects and potential interactions of noise and speaker's impaired voice
- Enhancing study quality (e.g., reporting participation rate, effect estimates, and blinding methods)

#### References

[1] Silva LT et al. (2016). Appl Acoust 106:2–9. [2] Remacle A et al. (2014). JSLHR 57(2):406–415. [3] Roy N et al. (2004). JSLHR 47:2–551. [4] Johnson CE. (2000). JLSHR 43(1):144–157. [5] Moher D, et al. (2009). PLOS Med 6(7). [6] NIH National Heart, Lung and Blood Institute. (retrieved 12 Jan 2022). From www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.

