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Classroom noise and its effect on learning

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THE PROBLEM AREA

The acoustical conditions in a classroom may severely impair listening, which in turn impairs learning.

To safe-guard against inferior listening conditions government agencies and professional societies have established building codes and recommendations for acceptable signal-to-noise ratios (SNR) and reverberation times (RT) in classrooms. These codes and recommendations are based on conditions required for speech intelligibility and correct identification of spoken words and isolated sentences.

Recommended background noise levels, excluding activity sounds in the room, generally lie between 30 and 40 dB(A) and recommended RT between 0.4 and 0.8 s.

See the Table for examples!

Country	Reverberation time (s)	Background noise dB(A)
Denmark	≤ 0.6	30-33
Finland	0.5 – 0.6	28
Iceland	≤ 0.9	35
Norway	≤ 0.9	32
Sweden	0.5 – 0.6	30-35

Table: Examples of recommendations in the Nordic countries for reverberation times and background noise levels in rooms for teaching.

Examples of varying RT and SNR

Examples RT: 0.3 0.6 0.9 1.2 2.0

Words with a RT of 0.3 or 1.2 s played back against a background of broadband noise, with SNRs of +3 or +12 dB

English, RT = 0.3 s – SNR = +12 dB
Swedish, RT = 1.2 s – SNR = +3 dB
English, RT = 1.2 s – SNR = +12 dB
Swedish, RT = 0.3 s – SNR = +3 dB

THE PROBLEM AREA (cont)

Speech intelligibility is only a necessary criterion for memory and learning, but it is not a sufficient criterion!

How well founded then are the recommendations when the target is learning and memory rather than speech intelligibility?

One critical issue is whether it can be shown that acoustical conditions that are sufficient in terms of SNR and RT for speech intelligibility, still impair memory and learning.

Another critical issue is whether the effects of SNR and RT on memory and learning are additive or if they interact with each other.

A practical issue is to establish the magnitudes of these effects. Are they too small or big enough to be of practical importance in class room?

THE PROBLEM AREA (cont)

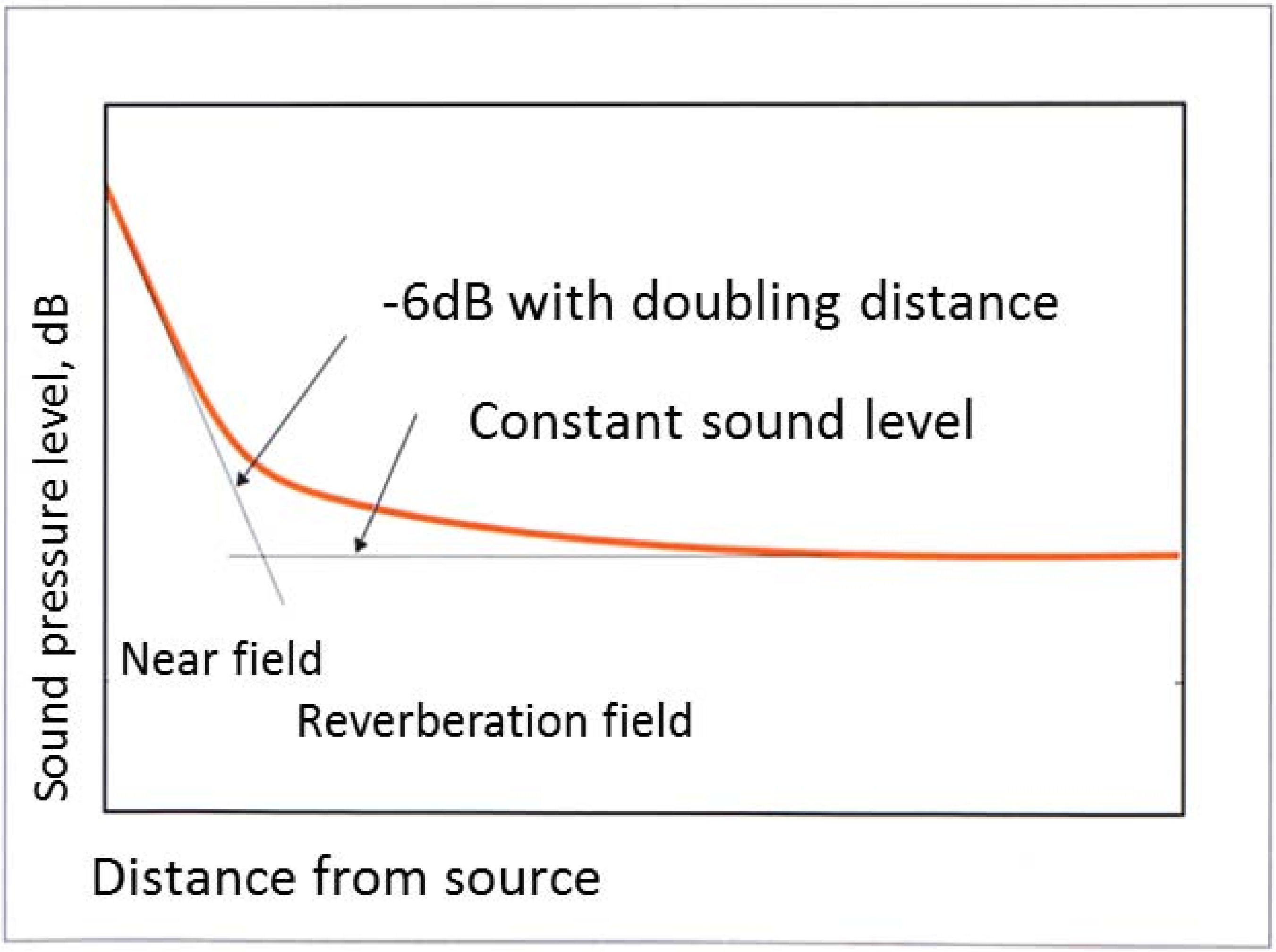


Figure: Example of decrease in speech sound level in a classroom

THE PROBLEM AREA (cont)

When a teacher speaks at a level of 65 dB(A) (raised voice) in the front of an ordinary classroom with ordinary sound reflections from the surfaces, that level will drop to ≈52 dB(A) 6 m out in the classroom.

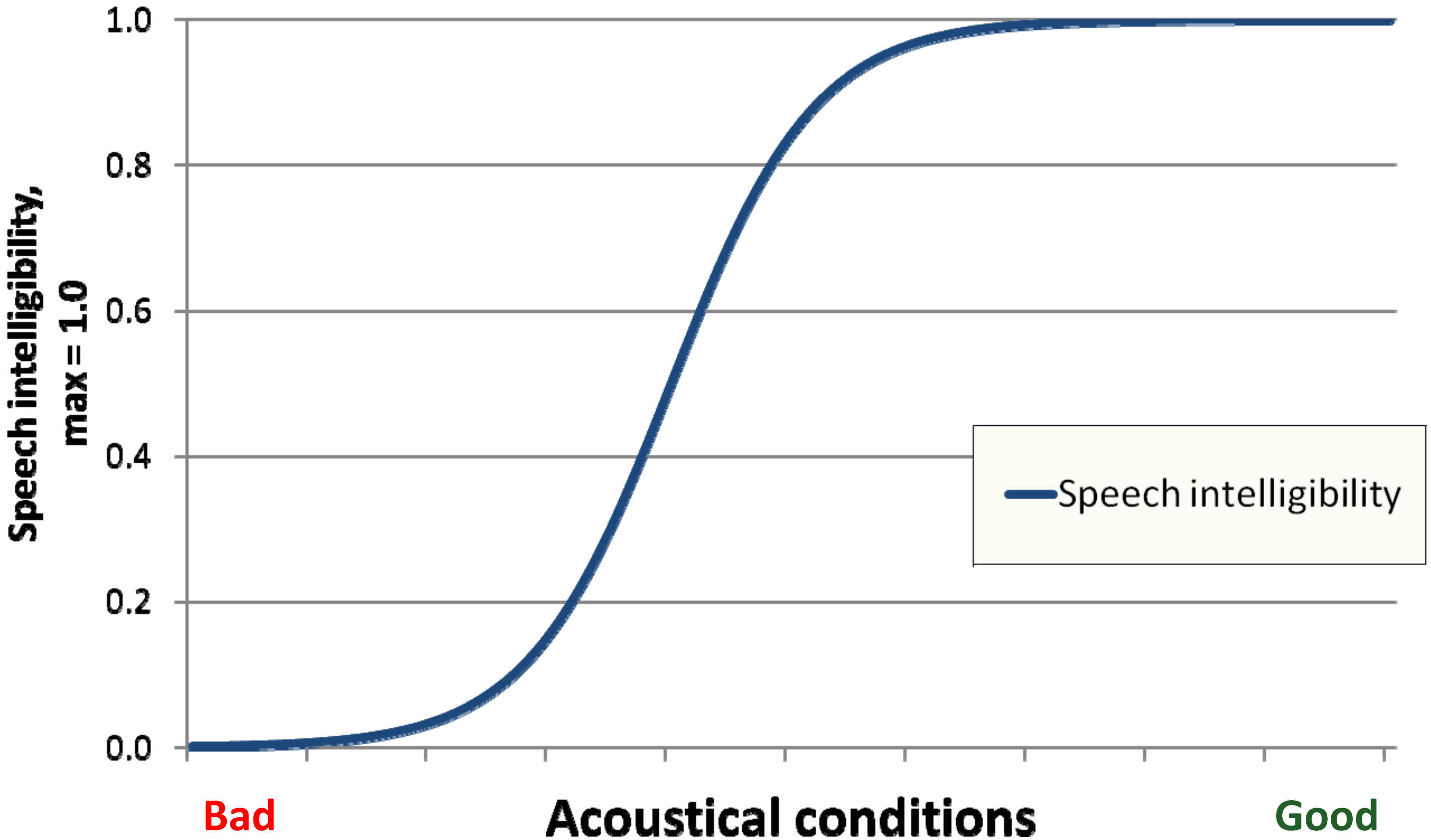
Further away it does not drop much more thanks to reflections. See the Figure!

52 dB(A) is only 7 dB(A) higher than an very quiet (≈45 dB(A)) classroom with a very low activity noise level. A +7 dB SNR-level is not good enough for speech intelligibility.

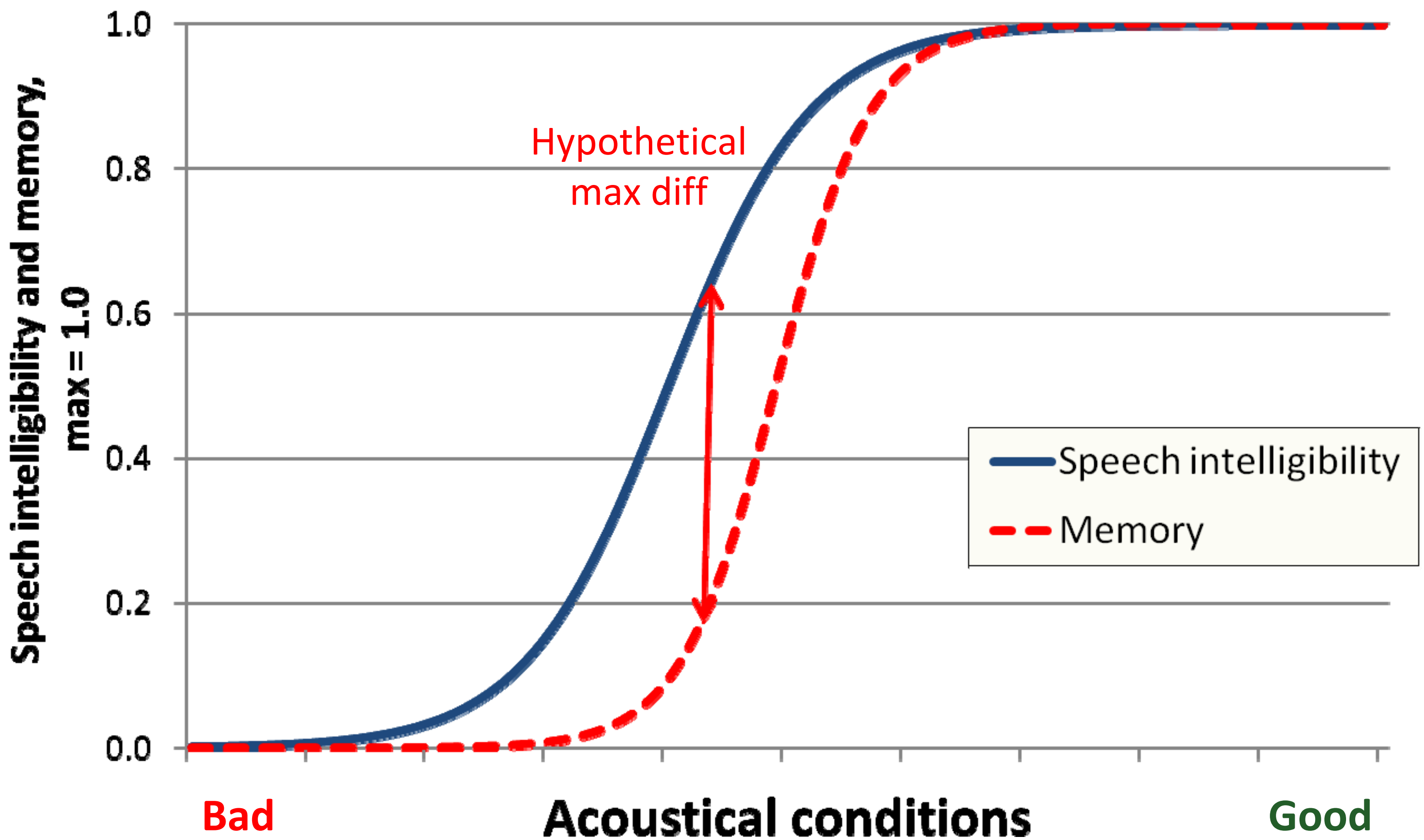
Often it is said that a SNR = +12 is a preferred minimum, but if there is a long RT or the receiver has a hearing impairment, an even better SNR is needed.

A MODEL OF SPEECH INTELLIGIBILITY AND MEMORY

An attempt to speculate in an orderly way about how speech intelligibility and memory are affected by acoustical conditions, such as SNR and RT.



Examples Acoustical conditions:
Signal-to-Noise ratio, (S/N, SNR dB)
Reverberation time (RT, s)
Speech transmission index (STI, 0-1)



Examples Acoustical conditions:
Signal-to-Noise ratio, (S/N, SNR dB)
Reverberation time (RT, s)
Speech transmission index (STI, 0-1)

From this model a set of expectations follow:

1. Memory performance depends upon speech intelligibility but there is a difference in the slopes for two functions.
2. The *slope for speech intelligibility* in the mid region of the x-axis should be steeper and drop off earlier and faster when the form or content of the spoken message renders speech intelligibility more difficult, e.g. at a low SNR, a long RT, low redundancy, unfamiliar words or sentences, complex content, subject area unknown to the listener, or the speech is spoken in a foreign language. Poor articulation should also have this effect.
3. The *difference in slope* between the functions for speech intelligibility and memory should increase when the speech is more difficult to identify, e.g. when heard by children and the elderly, when poorly articulated or in a foreign language. Thus, the difference between the slopes is not expected to be a constant.

From this model, a set of expectations follow:

4. Effects on memory are mediated by speech intelligibility, at least when the curves are in the mid-region and not close to 0.0 or 1.0.
5. A low working memory capacity should also increase the difference between the slopes, as a low working memory capacity implies that the available resources are more easily depleted during the listening process, leaving little resources left for further elaboration, processing and storage of the information.

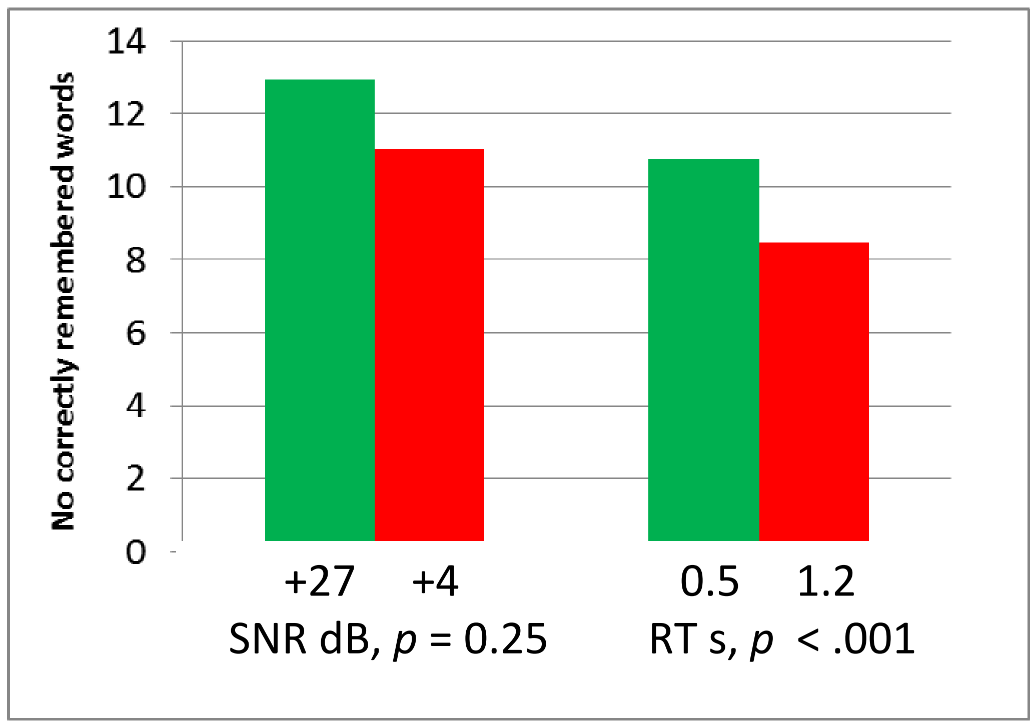
OVERVIEW OF THE RESEARCH

Cornerstone: Establishing equal speech intelligibility but different degrees of memory

In Kjellberg, Ljung & Hallman (2008), participants heard word lists with SNR +27 dB or +4dB. Ljung and Kjellberg (2009) presented word lists with RT = 0.5 or 1.2 s.

The participants repeated the words immediately to verify that they have heard them correctly, and there was no difference between conditions.

At the of the list they wrote down the words they could remember (free recall).



SNR

Surveys

A Swedish survey of the background noise levels from installations (mainly ventilation) in ≈200 classrooms in southern Sweden (Sjöström 2007) reported that 66% of the classrooms did not meet the criterion of 30 dB(A), (c.f. previous Table).

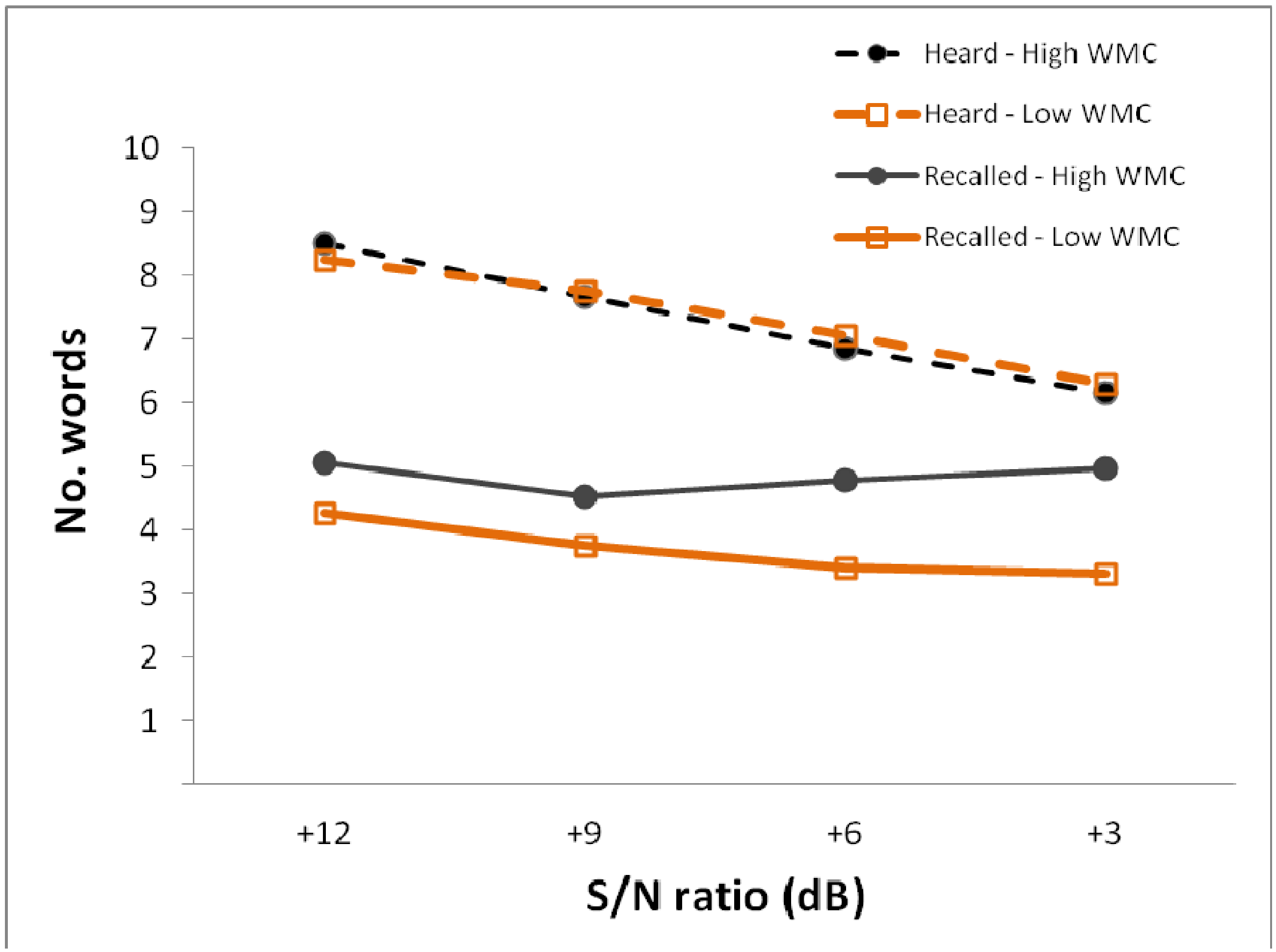
In a related study (Swedish Work Environment Authority 2006) reported that in 19 out of 39 classroom the sound level was ≥ 35dB(A). Thus, the background noise levels in Swedish classrooms do not, on the average, meet criteria for low background levels

SNR (cont)

Experimental studies

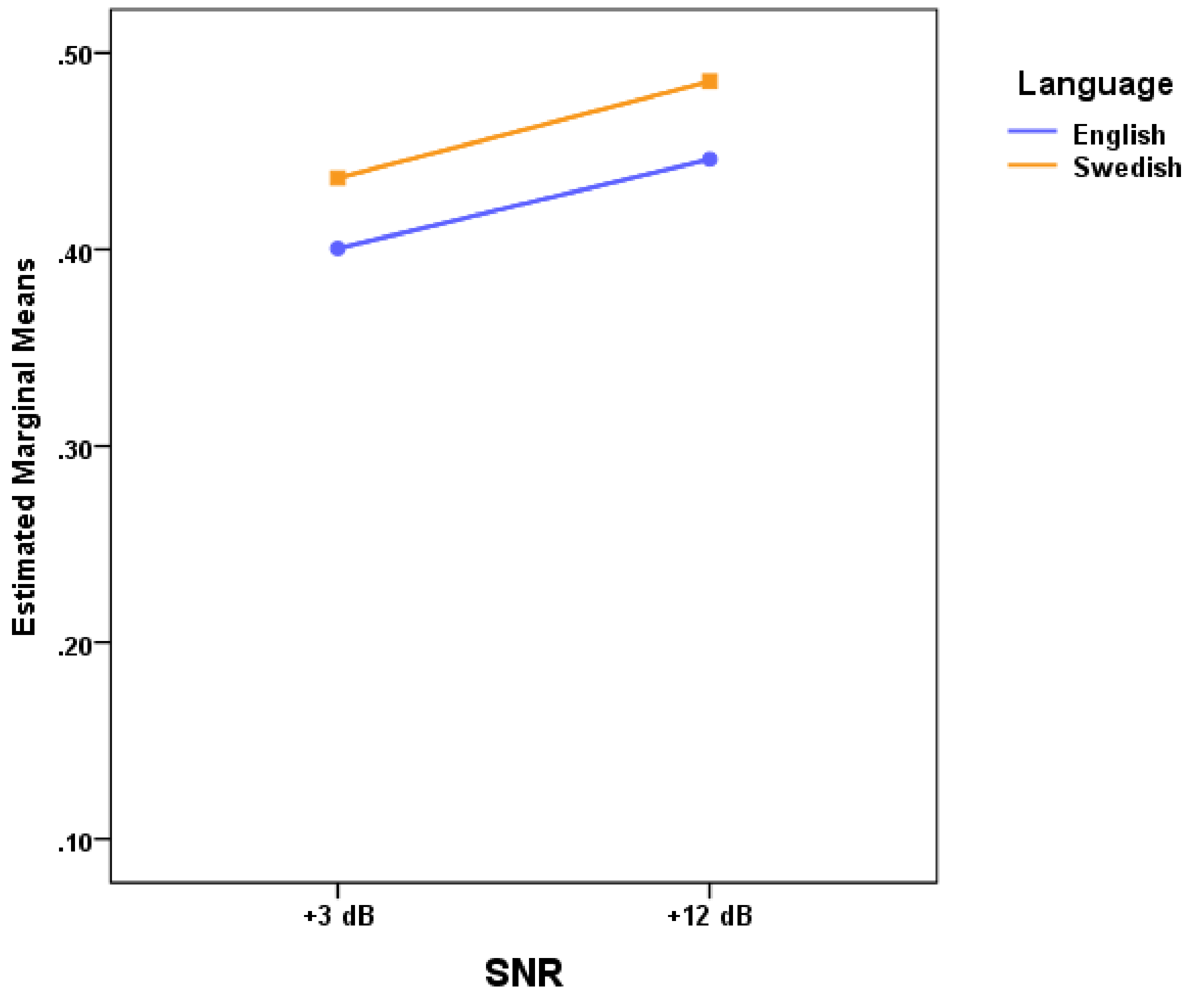
Ljung, Israelsson & Hygge (2013).

Note that speech intelligibility (Heard) did not mediate Recall in the High WMC group.



SNR (cont)

Hurtig, Hygge, Kjellberg et al. (2014), ICBEN 2014.



There are main effects of Language and SNR, but no interaction.

RT

Surveys

In the study by Sjöström (2007) 225 classrooms were measured on RT in the year of 2004 and 217 classrooms in 2005-2006. Of these, 46 % and 38 % (respective periods) did not meet a RT criterion of ≤ 0.6 s (c.f. Table).

A related study (Swedish Work Environment Authority 2006) reported that 24 % out of 50 classrooms had an RT equal to or above 0.6 s. Thus, as well as for the background noise levels, a lot would be gained if schools actually met the acoustical guidelines already in effect.

RT (cont)

Experimental studies

Studies from our lab suggest that RT manipulations have effects on memory similar to the SNR manipulations. Ljung and Kjellberg (Ljung & Kjellberg 2009). See Figure earlier in this presentation!

We have also found that memory of continuous stories is similarly impaired by unfavorable listening conditions (Ljung et al. 2009)

Interactions SNR x RT

In recommendations and building standards, SNR and RT are basically treated as independent and *additive* variables, but from a theoretical working memory perspective we would expect them to interact. However, there is a lack of studies of interactions between SRT and RT.

Klatte, Lachman and Meis (Klatte et al. 2010) is a notable exception. For two RTs at 0.47 and 1.1 s and with different background noise conditions (silence, background speech and classroom noise without speech) they reported that children (1st and 3rd grade) were more impaired than adults by background sounds both in speech perception and listening comprehension. RT had no effect on speech perception in silence but strong impairing effects against background noise. For listening comprehension, the younger the children, the more the impairment, while adults were unaffected.

Interactions SNR x RT (cont)

In the present ICBEN 2014 conference, Hygge et al. (2014) report on a comparison between children in Grade 4 (10-11 years old) and College students. Both groups listened to words lists in English and in Swedish, where two levels of SNR (+3 and +12 dB) and two levels of RT (0.3 and 1.2 s) were employed.

The main results in that study are shown in the following Figures.

Interactions SNR x RT (cont)

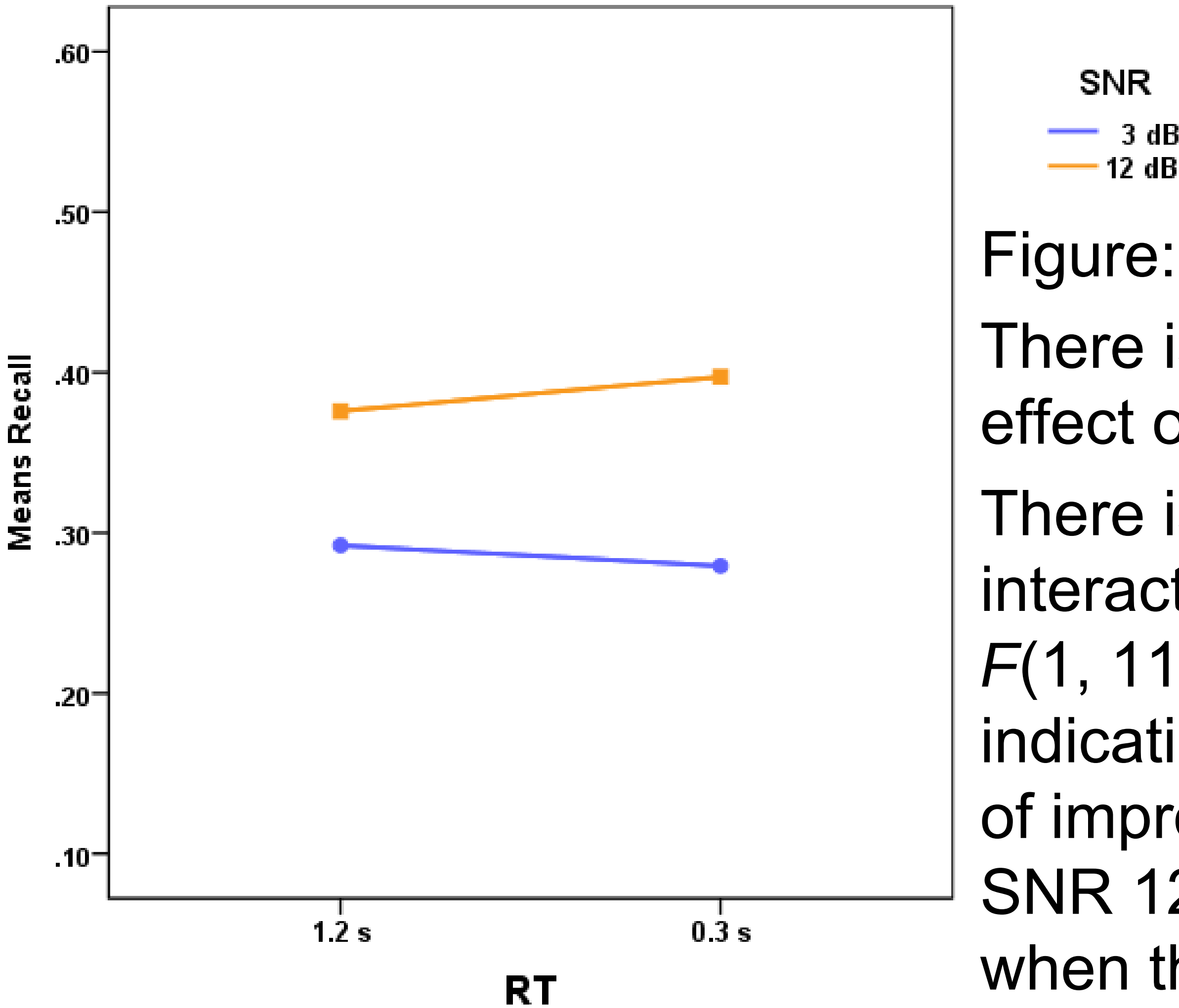


Figure: Means recall RT*SNR

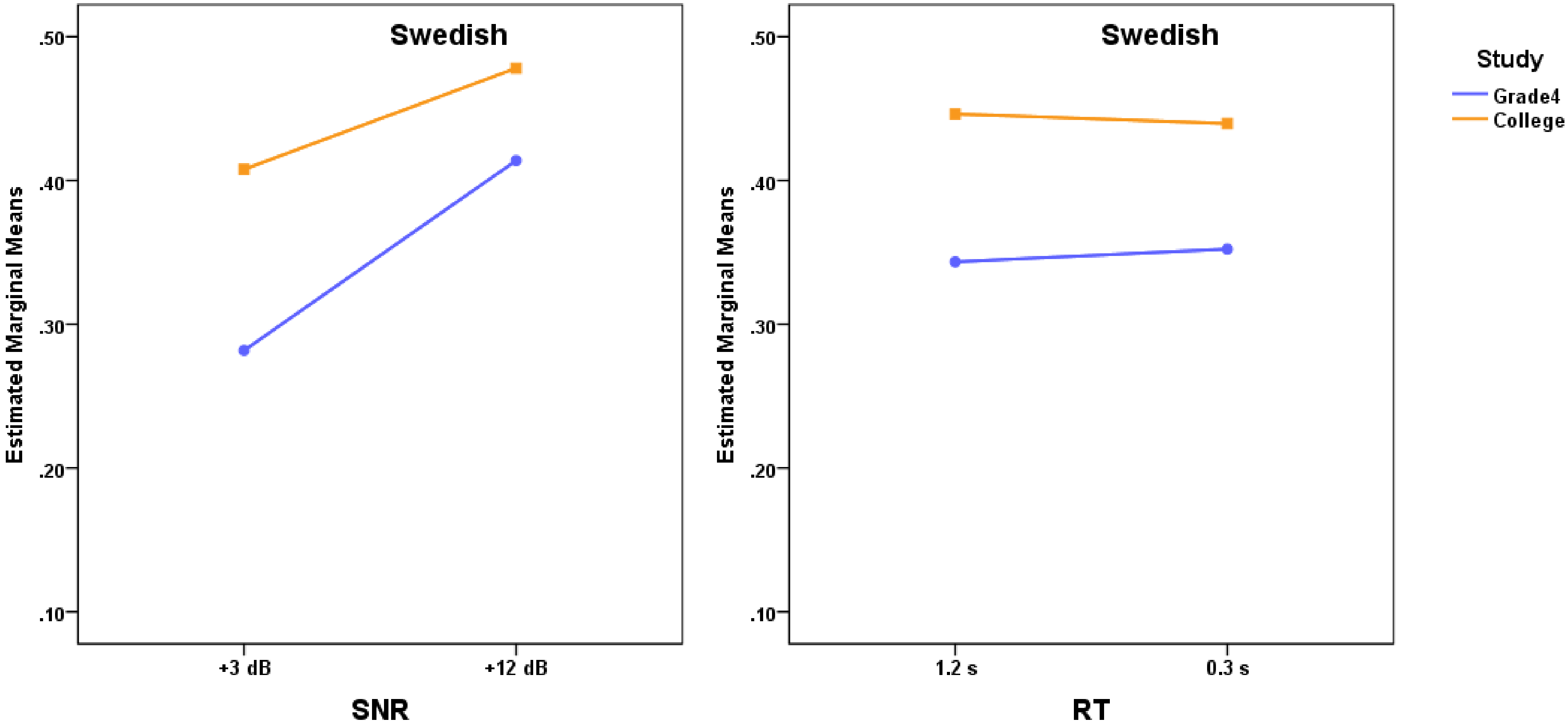
There is a significant main effect of SNR, but not of RT.

There is a significant interaction between SNR*RT, $F(1, 118) = 8.74$, $p < .01$, indicating that the net effect of improvement between SNR 12 and 3 dB is larger when the RT = 0.3 s.

Interactions SNR x RT (cont)

Grade 4 and College Students

Native Swedish

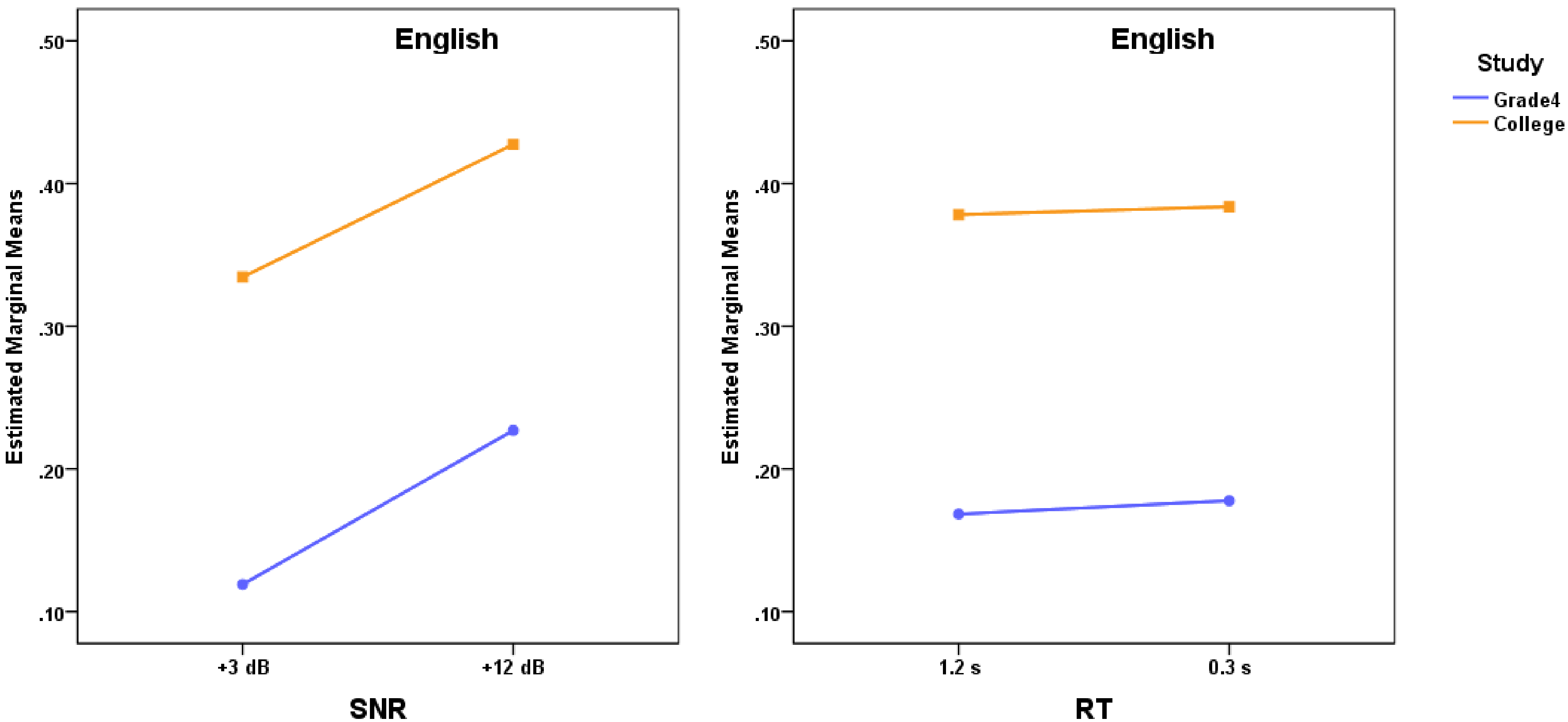


Significant main effect SNR and interaction SNR*Study.
No main effect RT, no interaction RT*Study.

Interactions SNR x RT (cont)

Grade 4 and College Students

English



Main effect SNR, no interaction SNR*Study.
No main effect RT, no interaction RT*Study.

Summary of the studies with varying SNR

Authors		Recall - Improvement per SNR 5 dB, %
Kjellberg, Ljung & Hallman (2008)		4.4
Hurtig, Hygge, Kjellberg et al. (2014)		
English		6.4
Swedish		6.3
Hygge, Nöstl, Hurtig et al. (2014)		
Grade 4	English	50.4
	Swedish	26.0
College English		15.4
Swedish		9.5

CONCLUDING REMARKS

Several studies indicate reliable and strong effects of SNR on recall and memory, but the effects of RT are not as strong and reliable.

The SRT effects of improved recall in percentage with a better SNR is very strong for children in Grade 4, particularly for the English word lists.

The effects on memory from varying RTs also seem to vary with speech material. Short stories and sentences are more vulnerable to long RT than single words are, the reason being that with single word presentations there is no forward masking from one word to the next.

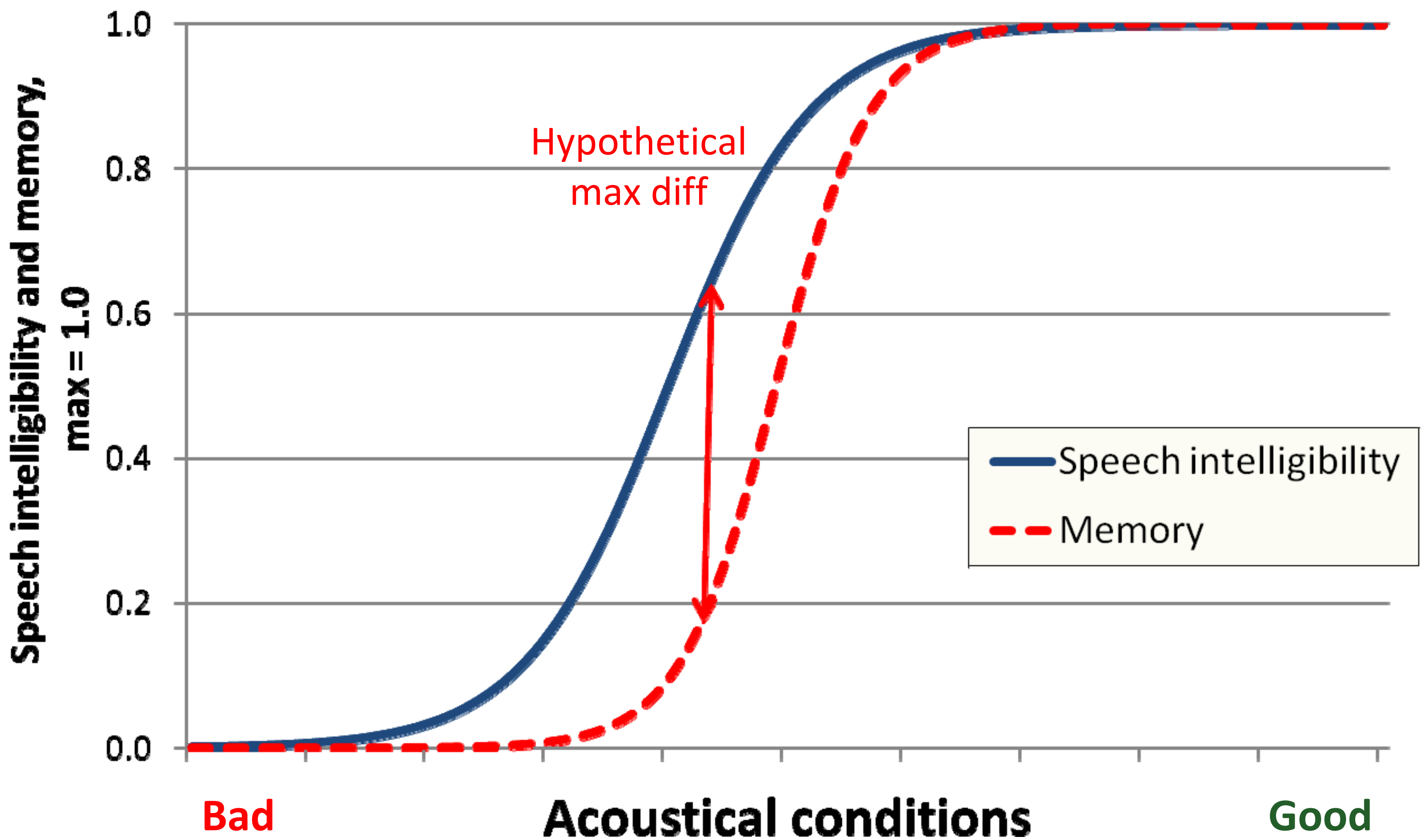
It is unclear to which extent recall and memory are mediated by speech intelligibility.

CONCLUDING REMARKS (cont)

As yet we do not really have a sufficient amount of relevant research to plot the exchange rates of differences between, e.g., SNR +12 and +3 dB and RT = 0.3 and 1.2 s on the same x-axis.

Also, our approach to RT is not particularly sophisticated. There is more to be said about early and late reflections, which are not handled by the standard procedures to measure RT. Early reflections that reach the listener within the first 50 ms after the direct sound will enhance the speech signal, thereby contributing to speech clarity and speech intelligibility.

Thus, we are only in the starting process of elaborating the model of speech intelligibility and memory by filling in results from different studies.



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Thanks for your attention!