Does sentence complexity interfere with intelligibility in noise? Evaluation of the *OLACS* Sentence Test

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MOTIVATION

Linguistic complexity seems to be an important factor in speech recognition and seemingly interacts with other factors, such as age or hearing impairment [1,2], possibly because of their relation to cognitive factors such as working memory or attention, which seem to play a vital role in understanding speech [3]. The material used in German speech intelligibility tests does not have the controlled and graded linguistic complexity needed for studying the effect of linguistic complexity on speech recognition. Thus, we developed a speech intelligibility test containing seven test lists with graded linguistic complexity, the *Oldenburg Linguistically and Audiologically Controlled Sentence Test* (OLACS).

AIM:
Establishing test lists for each sentence type, while making sure that all differences in intelligibility across the different sentence types originated from the different sentence structures and not from differences in sensory/acoustic factors.

HYPOTHESES:
1.There should be differences between sentence types regarding their intelligibility.
2.There should be differences between listeners based on their individual cognitive capabilities

METHODS

Sentences or sentence fragments were presented in a random order via headphones. After the presentation of each sentence, the participant was asked to repeat what she/he had just heard. Participants were explicitly allowed to guess.

PHASE 1
- fragments
- -7dB SNR (noise 65 dB SPL)
- **720** sentences
- 12 subjects (NH)

→ **PHASE 2**
- whole sentences
- -7dB SNR
- **560** sentences
- 12 subjects (NH)

→ **PHASE 3**
- whole sentences
- two sentence specific SNRs
- **360** sentences
- 12 subjects (NH)

→ calculation of sentences discrimination functions for the remaining sentences

RESULTS

Fragments (PHASE 1)

	W1	W2	W3	W4	W5	W6	W7	overall
SVO	81	69	62	26	44	35	47	**57**
OVS	40	49	56	32	84	63	58	**55**
amb OVS	77	64	57	35	90	70	67	**66**
SR	78	71	76	65	50	44	72	**65**
OR	76	70	44	63	48	25	79	**58**
amb SR	60	44	23	82	67	22	72	**53**
amb OR	62	48	18	81	67	48	73	**57**

Whole Sentences (PHASE 2)

SVO	82	72	70	60	62	30	30	**58**
OVS	63	58	68	52	48	26	24	**49**
amb OVS	82	72	72	55	40	22	32	**53**
SR	90	86	80	79	59	48	69	**73**
OR	87	86	53	79	59	35	67	**67**
amb SR	82	65	73	76	63	33	52	**63**
amb OR	84	65	74	77	66	41	54	**66**

Tab.2: *mean recognition rates [%] in evaluation phase I (upper panel) and evaluation phase II (lower panel) averaged across listeners for each fragment (W1 to W7) and for all sentences of each type (over all).*

Differences between fragment and sentence presentation (see Tab. 2)

Recognition rates for the subject fragments and the ambiguous object fragment are comparable in all three sentences types (light gray cells in the upper panel).

Non-ambiguous object fragments are less well recognised (compare light gray and medium gray cells of the upper panel).

There is a preference for the singular/male form (e.g. compare W2 of SR with amb SR and OR with amb OR, dark gray cells in the upper panel).

Whole sentences show strong primacy and recency effects [4].

The recognition increases for whole sentences.

In OVS and ambiguous OVS the recognition of the subject part of the sentences (W5 to W7) decreases to about half the value of the recognition rate when the fragment is presented alone (light gray cells of upper and lower panel).

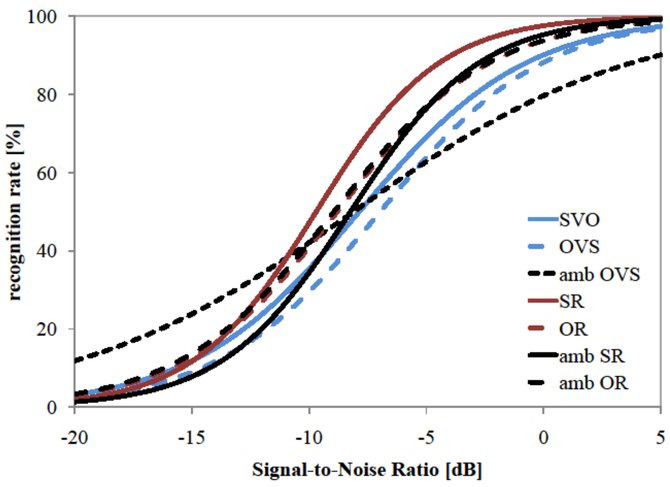


Fig.1: *mean sentence discrimination functions (recognition rate [%] over signal-to-noise ratio [dB]) for each of the seven sentence types*

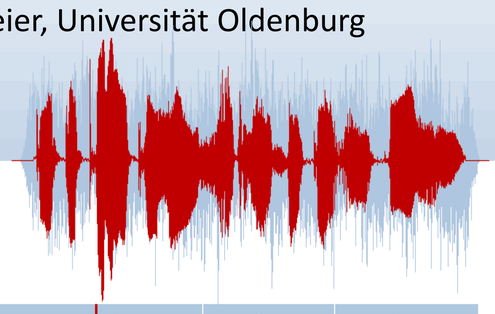
Differences between sentences (see Fig. 1)

Differences in the SRT of up to 2.6dB.

The SR type shows the lowest SRT and the OVS type yields the highest SRT

The ambiguous OVS sentences show a shallower slope than all other sentence types.

OLACS-MATERIAL



Category ONE: Verb2 sentences

SVO	**Der**	liebe	Drache	fesselt	den	großen	Panda.
	the$_{NOM}$	nice$_{NOM}$	dragon$_{MAS}$	ties up	the$_{ACC}$	big$_{ACC}$	panda$_{MAS}$
OVS	**Den**	großen	Panda	fesselt	der	liebe	Drache.
	the$_{ACC}$	big$_{ACC}$	panda$_{MAS}$	ties up	the$_{NOM}$	nice$_{NOM}$	dragon$_{MAS}$
amb OVS	**Die**	liebe	Prinzessin	fängt	**der**	schnelle	Dieb.
	the$_{AMB}$	nice$_{AMB}$	princess$_{AMB, FEM}$	catches	the$_{NOM}$	fast$_{NOM}$	thief$_{MAS}$

Category TWO: Sentences with relative clauses

SR	Der	Taucher,	**der**	die	Zauberer	malt,	zittert.
	the$_{NOM}$	diver$_{MAS}$	who$_{NOM}$	the$_{AMB}$	wizards$_{PL, MAS}$	draws	shivers
OR	Der	Taucher,	**den**	die	Zauberer	malen,	zittert.
	the$_{NOM}$	diver$_{MAS}$	who$_{ACC}$	the$_{AMB}$	wizards$_{PL, MAS}$	draw$_{PL}$	shivers
amb SR	Die	Taucher,	**die**	die	Lehrerin	**malen**,	lachen.
	the$_{AMB}$	divers$_{PL, MAS}$	who$_{AMB}$	the$_{AMB}$	teacher$_{FEM}$	draw$_{PL}$	smile$_{PL}$
amb OR	Die	Taucher,	**die**	die	Lehrerin	**malt**,	lachen.
	the$_{AMB}$	divers$_{PL, MAS}$	who$_{AMB}$	the$_{AMB}$	teacher$_{FEM}$	draws	smile$_{PL}$

Tab.1: *Examples for each of the seven sentence types used in the OLACS test. Highlighted words: BEGINNING and END of (potential) ambiguity. All words are in their singular form if not stated otherwise. Vertical red lines indicate the cutting points for the fragments used in evaluation phase I*

Differences across listeners (see Fig. 2)

Each listener performed either good or bad in any condition.

Differences in over all performance of up to 30%; BL88 (blue bars) recognized over 70% of all words correct over all conditions and PL85 (red bars) only recognized 46%.

The variability across listeners depends on the condition; about 15% between the best and the worst listener in the SVO type and about 35% in the OVS type.

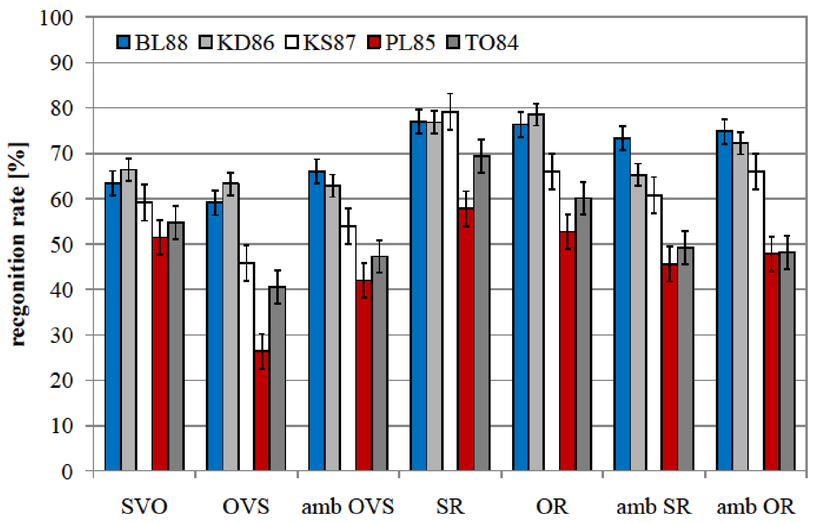


Fig.2: *mean recognition rate [%] for each sentence type for five out of 12 listeners in evaluation phase II*

CONCLUSIONS

- **For each of the seven sentence types a list of 40 sentences is established**.
- Through the **presentation of sentence fragments** in the first evaluation step, its possible to distinguish between the effect of the respective acoustical representation and the effect of the syntactical structure, which in turn enabled us, to **reliably discard sentences based on their acoustical divergence**.
- **Differences of up to 3 dB in SRT occurred for the different sentence types**, confirming our first hypothesis, that the sentence structure indeed has an influence on speech recognition in noise. This effect should be further studied with different groups of listeners.
- **Interindividual differences of up to 30% in overall recognition rate** support our second hypothesis that individual cognitive capability may play an important role in the processing of speech in noise. This effect allows the test to be used for diagnostic purposes, e.g. to differentiate between individual listeners.

[1] Weik, V. N. et al., Einfluss von Satzkomplexität auf das Sprachverstehen am Beispiel des Göttinger Satztests. 12. annual meeting of the german association for audiology (DGA), Innsbruck, 2009.

[2] Wingfield, A. et al., Effects of adult aging and hearing loss on comprehension of rapid speech varying in syntactic complexity. JAAA, 17: 487-497, 2006.

[3] George, E.L.J., Festen, J.M., \& Houtgast, T., Factors affecting masking release for speech in modulated noise for normal-hearing and hearing-impaired listeners. JASA, 120(4): 2295-2311, 2006.

[4] Murdock Jr., B. B., The serial position effect of free recall. J Exp Psy, 64(5): 482-488, 1962.

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