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Production of number agreement in adverse conditions: Speech-free noise interferes with processing at the formulation stage

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Introduction

- Under adverse, noisy conditions, speaking becomes arguably more difficult, but little is known about effects of noise on the formulation process for production
- *Formulation* is often considered fairly "automatic" (Levelt, 1989), but might be subject to interference from concurrent processes engaging the same resources
- Babble noise contains linguistic material, processing of which might create dual-task load - but is linguistic content the only source of difficulty?

Current study

- Do non-linguistic aspects of different background noise types interfere with formulation process?

Irrelevant sound effect (ISE)

- Speech-free, irrelevant sound has detrimental effect on performance in verbal serial recall tasks (e. g. Jones & Macken, 1993; Klatte & Hellbrück, 1993)
- Effect is profoundly stronger with temporally structured than with constant noise (Klatte, Kilcher & Hellbrück, 1995)

Agreement attraction

- Hierarchically or linearly interpolated controller candidate can 'attract' away verb agreement, e. g. number agreement (e. g. Bock, 1991; Eberhard, 2005):
  *"The inscription on the ancient pillars was/*were hard to read."*
- Attraction effect has been shown to increase under other dual-task load conditions (Fayol, 1994; Hartsuiker & Barkhuysen, 2006)

Expectations

- Speech-free noise will create dual-task load
- Temporally structured noise will lead to stronger disruption than constant noise
- Under dual-task load, attraction effect will become stronger

Procedure

Stimulus sentences

Singular head noun, match between head/local number
Die Inschrift auf der antiken Säule ist verwittert.
[the inscription;SG]$_{HEAD}$ on [the;SG ancient pillar;SG]$_{LOCAL}$ be;SG weather;PTCP
"The inscription on the ancient pillar is weathered."

Plural head noun, match between head/local number
Die Inschrift-en auf den antiken Säule-n sind verwittert.
[the inscription-PL]$_{HEAD}$ on [the;PL ancient pillar-PL]$_{LOCAL}$ be;PL weather;PTCP
"The inscriptions on the ancient pillars are weathered."

Plural head noun, mismatch between head/local number
Die Inschrift-en auf der antiken Säule sind verwittert.
[the inscription-PL]$_{HEAD}$ on [the;SG ancient pillar;SG]$_{LOCAL}$ be;PL weather;PTCP
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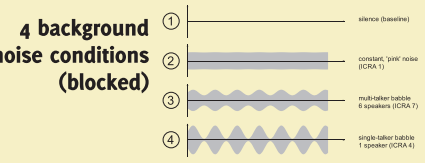
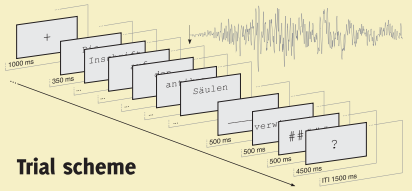
Singular head noun, mismatch between head/local number
Die Inschrift auf den antiken Säule-n ist verwittert.
[the inscription;SG]$_{HEAD}$ on [the;PL ancient pillar-PL]$_{LOCAL}$ be;SG weather;PTCP
"The inscription on the ancient pillars is weathered."

4 background noise conditions (blocked)



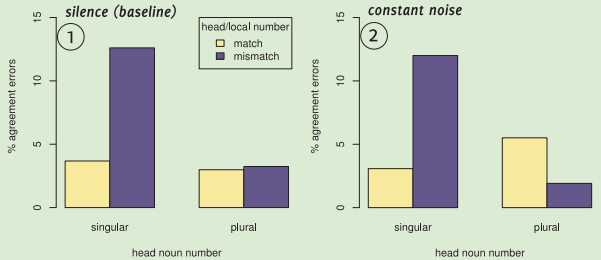
Trial scheme



Results

Error count

Condition			Responses	
Match	*Head number*	*Total*	*Agreement errors*	
mismatch	*singular*	930	94	(10.1%)
	plural	861	34	(3.9%)
match	*singular*	1046	38	(3.6%)
	plural	866	57	(6.6%)



Baseline model
MISMATCH: coef. 1.46, SE 0.42, z = 3.5, p < .001
PLURAL x MISMATCH: coef. -1.43, SE 0.75, z = -1.9, p = .055
Agreement attraction effect, plural markedness effect (Bock & Miller, 1991; Eberhard, 1997; Hartsuiker et al., 2003)

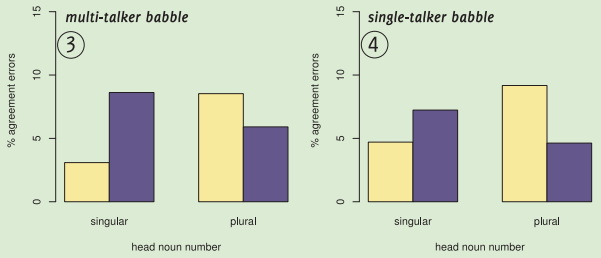
Final model
CONSTANT NOISE: n. s.
CONST. NOISE X MISMATCH: n. s.
CONST. NOISE X PLURAL: n. s.
No significant changes compared to silent baseline

Statistical analysis details

Baseline model, derived from theoretical expectations (predictors treatment-coded; N = 927, log-likelihood = -181.9)
*errorCount ~ producedHdNumber * producedMatch + (1 | subject) + (1 | sentenceID)*

Model comparison over generalised logistic mixed effects models (GLMM; Baayen, Davidson & Bates, 2008) yielded
Final model with noise as factor (predictors treatment-coded; N = 3703, log-likelihood = -761.0)
*errorCount ~ producedHdNumber * producedMatch + noiseCondition + producedHdNumber:noiseCondition + producedMatch:noiseCondition + (1 | subject) + (1 | sentenceID)*

Significantly improved model fit after inclusion of noise condition as factor ($\chi2(9) = 20.066$, $p < .05$)



Final model
MULTI-TALKER BABBLE: n. s.
MULTI-TALKER BABBLE X PLURAL:
coef. 1.19, SE 0.46, z = 2.6, p < .01
MULTI-TALKER BABBLE X MISMATCH: n. s.
Increase in erroneously produced singular verb forms after plural head noun

Final model
SINGLE-TALKER BABBLE: n. s.
SINGLE-TALKER BABBLE X PLURAL:
coef. 1.02, SE 0.46, z = 2.2, p < .05
SINGLE-TALKER BABBLE X MISMATCH:
coef. -0.89, SE 0.44, z = -2.0, p < .05
Increase in erroneously produced singular verb forms after plural head noun;
slight decrease in mismatch effect

Discussion

Number mismatch and plural markedness effect

- Results in silence replicate plural markedness effect
- Special, or *'default'* status of singular

Noise effects

- Noise has measurable effect on error patterns
- No overall increase in attraction effect, but rather resorting to default singular marking
- Stronger effect of fluctuating noise

External monitoring effect?

- Interference with external phonological representation of head noun produced earlier by speaker, otherwise used as additional cue for verb form retrieval
- No effect of constant noise?

Seriation mechanism?

- Changing state hypothesis: Competition for processing resources on *seriation mechanism* (Jones & Macken, 1993; Macken et al., 1999)
- Competition for processing time on seriation mechanism under fluctuating noise could increase likelihood of retrieval cue decay and 'defaulting' to singular verb form retrieval

Conclusion

- Speech-free, i. e. non-linguistic auditory input creates dual-task load that affects formulation process
- Acoustic characteristics of noise which yield temporally structured signal are important
- Interference between formulation and more 'low-level' auditory processing begs question for refined concept of domain-specificity

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