Impact of Office Noise, Irrelevant Speech and Music on Short-Term Memory Performance

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Theoretical Background

Verbal short-term memory performance is impaired by irrelevant speech and non-speech sounds as far as these sounds are characterized by distinct temporal-spectral variations (e.g. narration, instrumental music with prominent staccato passages). This empirically robust finding is well-known as the Irrelevant Sound Effect (ISE) and occurs even though the background sounds are irrelevant for task performance itself and subjects are told to ignore them.

The ISE is explained in terms of short-term memory models. First use was made of the Phonological Loop Model proposed by Alan Baddeley [1], [2]. In this model, visually presented verbal material is encoded in an acoustic-phonological code for storage in the Phonological Loop. Heard speech as well as periodic non-speech sounds are supposed to gain obligatory access to it [3]. The ISE is attributed to information loss due to simultaneous existence of the representations of the heard or read verbal items and those of the irrelevant sound. An alternative model for explaining the ISE is the Object-Oriented Episodic Record Model (O-OER Model) by Dylan Jones and colleagues [4], [5]. In this model, all sensory input is deposited directly in one unitary store. The ISE for visual items is considered to be the consequence of loss of order information given rise by irrelevant background sound with distinct temporal-spectral variations (changing-state features). Sounds without these characteristics (steady-state sounds) do not cause an ISE. Detrimental effects of irrelevant sounds on short-term retention of auditory items are not elaborated in this model.

For read items, detrimental effects of changing-state speech and non-speech sounds have been repeatedly shown [e.g., 6]. However, the influence of irrelevant sounds on heard items has hardly been investigated although the intake of heard verbal information is of special importance in working and learning environments (e.g., face-to-face conversation, phone calls). It is still an open question whether irrelevant sounds have the same impact on auditory as on visual items. Our experiments compare the effects of different irrelevant sounds on short-term retention of heard and read items and test the possibility of reducing detrimental effects of office noise by superimposing it with other irrelevant sounds.

Empirical Studies

In all experiments to be reported subjects had to perform the immediate serial recall of unrelated digits, the standard task for investigating verbal short-term memory capacity. Digits from 1 to 9 were presented in randomized order (1 item/s). Visual items appeared one after the other in the middle of the screen and auditory digits were spoken by a female voice and presented with 64 dB(A) via one loudspeaker located in front of the subjects respectively. After a 10 s retention interval all digits appeared simultaneously in random order on the computer screen and had to be clicked with a computer mouse in exactly the same order as previously presented. Each digit not recalled on the correct serial position was classified as an error. Presentation of irrelevant sounds started 2 s before list presentation and stopped after the subject completed his response. During each sound condition 20 trials had to be performed. Sequence of sound conditions varied from trial to trial and was randomized for each subject. All irrelevant sounds were played with 60 dB(A) via one loudspeaker placed behind the subjects. Perfect intelligibility of auditory digits was attained and checked for each subject under each sound condition.

Experiment 1: Serial Recall of Auditory and Visual Items under Irrelevant Music

In experiment 1 serial recall performance was tested during instrumental staccato music (baroque music; distinct temporal-spectral dynamics), instrumental legato music (meditation music; low temporal-spectral dynamics) and silence. One experimental group learned auditory items (n_1=30) and another visual items (n_2=30). Means and standard errors of error rates are depicted in Fig. 1.

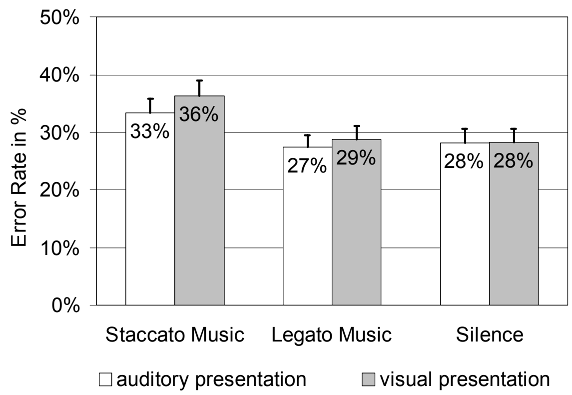

Figure 1: Serial recall of auditory (n_1=30) and visual items (n_2=30) during irrelevant background music.

Solely staccato music causes an ISE for auditory items ($F(2,58)=10.77$, $p<.001$) as well as for visual items ($F(2,58)=20.37$, $p<.001$). Performance during legato music was not significantly different from performance during silence for any of the groups according to paired t-tests.

Experiment 2: Serial Recall of Auditory and Visual Items under Irrelevant Speech

In experiment 2 serial recall performance was tested during silence, pink noise, steady-state speech (vowel A spoken by a male voice and looped) and changing-state speech (consonants G M K P F L Q spoken by a male voice and looped). Mean error rates and standard errors are depicted in Fig. 2 for an auditory (n_1=20) and a visual group (n_2=20).

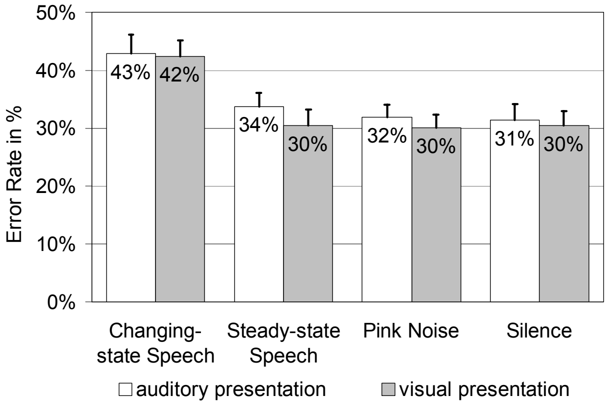

Figure 2: Serial recall of auditory (n_1=20) and visual items (n_2=20) during irrelevant background speech.

Serial recall performance is in both groups just reduced during changing-state speech (auditory items: $F(3,57)$= 20.37, p<.001, visual items: $F(3,57)$=23.19, p<.001).

Although perfect intelligibility of the auditory items was ensured and checked, a further auditory group (n_3=20) was tested which heard irrelevant sounds just during retention and recall but not during item presentation. However, once more just changing-state speech ($F(3,57)$=22.89, p<.001) gives rise to an ISE (Table 1).

	Changing-state Speech	Steady-State Speech	Pink Noise	Silence
M	45.4 %	36.1 %	34.5 %	33.6 %
(*SE*)	(2.0 %)	(1.9 %)	(2.0 %)	(1.7 %)

Table 1: Serial recall of auditory items during irrelevant sounds which were just presented during retention and recall (n_3=20); *M* = Mean of error rates, *SE* = Standard error.

Experiment 3: Serial Recall of Visual Items during Office Noise

In this experiment 30 subjects learned visual items during recordings of real office noise in comparison to superimposed versions of it with pink noise, staccato and legato music of equal sound pressure level. 20 successive trials had to be performed under each sound condition in one experimental block (balanced sequence of blocks). All irrelevant sounds were presented with 55 dB(A) and lasted all throughout the corresponding experimental block. Table 2 shows means and standard errors of error rates.

	Office Noise	ON & St. Music	ON & L. Music	ON & PN	Silence
M	29.8 %	28.3 %	27.1 %	23.9 %	23.2 %
(*SE*)	(3.1 %)	(2.8 %)	(2.4 %)	(2.5 %)	(2.8 %)

Table 2: Serial recall during office noise (ON) and different sound mixes (St.= Staccato, L. = Legato, PN = Pink Noise; n=30); *M* = Mean, *SE* = Standard error.

Once again, an ISE is observed ($F(4,116)$=3.04, p=.020). Post-hoc tests indicate that serial recall performance is significantly reduced by untreated office noise recordings in comparison to office noise superimposed with pink noise.

Summary and Conclusions

Experiments 1 and 2 replicated findings which show that the serial recall of visual items is only disturbed by changing-state speech and staccato music, but not by steady-state sounds [e.g., 6]. Furthermore, our experiments demonstrated that the same is true for auditory items. Further testing ensured that the observed effects for auditory items are not due to partial masking or increased listening effort potentially caused by the irrelevant background sounds.

Most aspects of our experimental results are covered by the described verbal short-term memory models though none covers all aspects. The O-OER Model does not elaborate effects of irrelevant sound on auditory items but accounts for the detrimental effects of changing-state sounds in contrast to ineffective steady-state sounds. This can not be explained in such detail within the Phonological Loop Model which predicts an ISE for visual and auditory material as well. Despite these theoretical loopholes our results have practical implications for workplaces such as open-plan offices, call-centers and classrooms. There people must conduct mental work during ambient speech and non-speech noise which often shows distinct temporal-spectral variations. Our experiments show that short-term retention of read and heard verbal material is affected by such irrelevant sounds, in particular by irrelevant speech, staccato music and office noise. However, detrimental effects of the latter on short-term memory performance can be reduced significantly by superimposing the office noise with pink noise of equal sound pressure level, as our third experiment ensured.

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