CHANGING STATE AND THE IRRELEVANT SOUND EFFECT

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1. INTRODUCTION

When a stream of irrelevant sound is present during an immediate memory task, serial recall is typically impaired even when the to-be-remembered items are visual. This "irrelevant sound effect" (ISE) is very robust and the magnitude of the typical effect can be large (Beaman & Jones 1997; LeCompte & Shaibe, 1997; Surprenant, LeCompte, & Neath, 2000). The semantic content of the irrelevant speech (Salamé & Baddeley, 1982) and the phonological similarity between the irrelevant speech and memory items (LeCompte & Shaibe, 1997) seem to have little effect on the amount of disruption.

Not all irrelevant auditory stimuli will cause an ISE, however. There is much less disruption when the irrelevant sound consists of a single, repeated item compared to the case in which the irrelevant sound is changing. A steady-state stimulus of any kind, such as a repeating vowel or a continuous pitch glide, does not cause a decrease in performance (Beaman & Jones, 1997; Jones, Macken, & Murray, 1993). This "changing state effect" has been identified as a critical feature in producing an ISE.

Unfortunately, despite numerous attempts, there is still no clear definition of what 'changing' is, other than in intuitive terms; for example, white noise 'changes' less than tones which 'change' less than speech. The current experiments were designed to explore the definition of 'changing' relating to the dynamic spectral and temporal properties of the irrelevant stimuli.

Fluent speech varies over time on a number of different dimensions, the most salient of which are frequency and amplitude. The approach we have taken in this research is to begin by taking a stimulus that we know results in an ISE and constructing a new stimulus that varies by the same amount on one of those dimensions while keeping the other dimension constant.

We started by looking at amplitude variation and created an irrelevant stimulus that was equated for amplitude modulation with the base sound but that had no changes in frequency. This "envelope stimulus" was constructed by outlining the amplitude envelope of the base passage and then replacing the time-varying frequency information with a pure tone or white noise. Essentially we kept the amplitude-modulated segment of the signal but replaced the frequency-modulated elements with a static stimulus. Thus, the only difference between the base passage and the envelope stimulus are the changes in frequency. If 'changing' means changes in amplitude over time, an equally amplitude-modulated irrelevant sound should result in an equal decrement in recall.

In subsequent experiments we tested the effect of backward speech and sinewave speech modeled after the base stimulus. Backward speech has segmental and suprasegmental properties that are very different from those of forward speech; however, it retains similar phonetic and temporal information. A sinewave speech stimulus is constructed by replacing the noise in speech formants with sinewaves at the center frequency of the formant. The stimulus changes in frequency at the same rate as the base stimulus and has similar suprasegmental (prosodic) features but contains little or no phonetic information and is seldom even identified as a speech sound (Remez & Rubin, 1990).

2. METHOD

Subjects. Thirty different Purdue University undergraduates participated in each experiment.

Materials. The to-be-remembered stimuli were random permutations of the letters F K L M R X Q (the dissimilar letters from Colle & Welsh, 1976).

The irrelevant sounds were all modifications of the base sound consisting of a passage (in German) from *Die Wilden* by Franz Kafka recorded by a female talker. This passage was modified by: Experiment 1) outlining the amplitude envelope of the German passage and replacing the time-varying frequency information with a 400 Hz pure tone; Experiment 2) using the same technique except filling the envelope with white noise; Experiment 3) playing the base stimulus backward; Experiment 4) replacing the base stimulus with forward and backward sinewave speech constructed from the base stimulus. The sinewave speech was constructed by performing an LPC re-synthesis on the base stimulus in order to extract the formant values for the first three formants. These were then converted to sinewave speech using sinewave speech source code obtained from Ellis (2005).

Design. The design was within-subjects with each participant receiving twenty-five trials of each of three conditions; no noise and two types of irrelevant sound (depending on the experiment). The order of presentation of the three conditions was random.

Procedure. Each letter was shown in the middle of a computer monitor for 1 s. On irrelevant sound trials the sound was played through headphones at a comfortable level and subjects were instructed to ignore the sounds. After the final letter was shown, seven response buttons became active and were labeled with the seven letters in alphabetical order. The subjects were asked to indicate the presentation order by clicking on appropriately labeled buttons on the screen using the mouse.

3. RESULTS

Figure 1 shows the results from Experiments 1-2. There was a small ISE in the tone condition but, upon examination of the spectrogram, it appeared that there was some spurious frequency modulation in the stimulus. This was not the case for the white noise envelope stimuli and did not give rise to an ISE. It is clear, therefore, that amplitude changes, by themselves, do not play a large part in the 'changing state' effect.

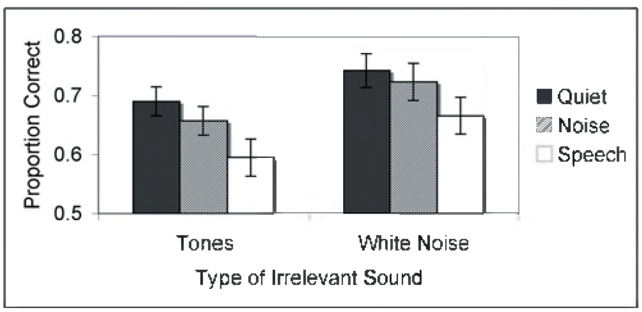

Fig. 1. Mean proportion correct as a function of type of irrelevant speech for Experiments 1-2.

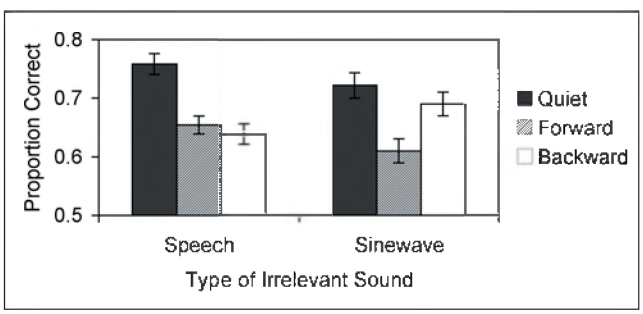

Fig. 2. Mean proportion correct as a function of type of irrelevant speech for Experiments 3-4.

Figure 2 shows the results of Experiments 3-4 in which the irrelevant stimuli included backward speech and forward and backward sinewave speech. The natural speech (both forward and backward) significantly disrupted performance on the memory task but the sinewave speech had an effect only when it was played forward.

4. DISCUSSION

The data from Experiments 1 and 2 are consistent with a great deal of speech perception research that shows that in perceiving speech, the perceiver uses the coherent pattern of frequency variation and gross signal energy, but probably gets rather little information from tracking the precise details of the energy envelope (Remez and Rubin, 1990). Change in amplitude by itself gives little or no information about the content of the stimulus and, therefore, does not attract much in the way of attentional resources.

The backward speech used in Experiment 3 has segmental and suprasegmental properties that are very different from those of forward speech; however, it contains similar phonetic and temporal information. In contrast, the sinewave speech from Experiment 4 has similar segmental properties and similar temporal information as natural speech but very different phonetic information. Backward sinewave speech has little in common with speech with very little recognizable phonetic information, a very different prosodic form, and no apparent segmental properties. It is perhaps perceived rather like a continuous pitch glide which does not result in an ISE (Jones, et al., 1993).

Thus, it seems that in order to produce an ISE the stimulus must hold some informational value for the listener.

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