

THE EFFECT OF TYPES OF ACOUSTICAL DISTORTION ON LEXICAL ACCESS

Marianne Pelletier, Marco Coletta, Renée Giroux, Huiwen Goy and Kathy Pichora-Fuller

Department of Psychology, University of Toronto, 3359 Mississauga Rd N., Mississauga, Ontario, L5L 1C6.

1. INTRODUCTION

Lexical access is crucial to understanding spoken language. According to the Cohort model by Marslen-Wilson & Welsh (1978), the process of lexical access is accomplished according to three steps: the *activation* of specific candidates based on the acoustic input, the *selection* of one candidate from a pool of candidates, and the *integration* of the term with others according to the semantic context of the discourse. The process of lexical access and comprehension enables accurate understanding of language. Therefore, when distortions are introduced, there may be difficulties in comprehension because it is more difficult to decipher the acoustic signal. Distortions induced in the laboratory are analogous to difficulties in understanding spoken language in everyday situations, such as when there is noise in crowded streets, or in busy workplaces, or over a noisy telephone line, or when talkers have unclear speech.

Aydelott and Bates (2004), in their study of the effects of acoustic distortion and semantic context on lexical access, argue that different types of distortions affect lexical access at different stages. In their research, these authors argue that low-pass filtering affects the early stages of lexical access (encoding and activation of lexical-semantic information), whereas time compression inhibits the later stages of selection and integration. In their study, these authors appeared to have arbitrarily selected the amount of low-pass filtering (1Hz cutoff) and time compression (50 %). The goal of the present work was to replicate the findings of Aydelott and Bates (2004) using the same type and amount of distortion, while also extending their work by including a third type of distortion that is encountered in everyday life, namely multi-talker babble noise.

1.1 Preliminary Investigation

A preliminary investigation was conducted to guide the selection of the amounts of distortion used in the present study. Specifically, psychometric functions were determined using the Northwestern University Auditory Test No. 6 (NU6), which consists of four lists of 50 monosyllabic words. There are no differences in word recognition performance among the four lists if they are administered in quiet (Stuart, Green, Phillips, & Stanstrom, 1994). These word lists were distorted to varying degrees by low-pass filtering, time compressing, and adding background babble to create different signal-to-noise ratio (SNR) conditions. Three groups of 16 (young) adults with normal hearing were tested using the NU6 lists distorted by each of the three methods (each group heard only one type of distortion). The psychometric functions enabled us to estimate speech intelligibility in the two conditions used in the study of Aydelott and Bates (2004): 1000Hz low-pass filtering

corresponded to 50% correct on NU6 lists, whereas 50% time compression corresponded to 76% correct on NU6 lists. In the present study of lexical access, we replicated the two original conditions tested by Aydelott and Bates (2004). The initial SNR level to be tested was chosen to correspond to 50% correct on NU6 lists so that the effect on intelligibility of the degree of distortion was the same for SNR (-15 dB) condition and the original filtering condition, but the degree of distortion chosen for SNR was greater than the degree of distortion resulting from the original 50% time-compression (see companion paper for comparisons between different degrees of distortion due to filtering). Table 1 summarizes the levels of distortion selected for each distortion type reported here, as well as those reported in our companion study and those being tested in ongoing studies.

Table 1. Performance for degrees and types of distortion

Type of Distortion	% Correct	Degree of Distortion
Low-Pass Filtering	50%	1000 Hz
	76%	1750 Hz ^c
Time Compression	50%*	72%*
	76%	50%
Signal-to-Noise Ratio	50%	-15dB
	76%*	-9dB*

^c See companion paper in this issue.

* These levels of distortion are being tested in ongoing experiments.

2. METHOD

2.1 Participants and General Set-Up

Participants were tested individually in a single experimental session lasting 45-60 minutes. They completed a hearing and language history, a vocabulary test and an audiogram. They were randomly assigned to conditions so that the stimulus list and the hand used to press the response button were counterbalanced across participants.

2.2 Stimuli, Task, and Equipment

The stimuli were sentences consisting of an initial context, a 50-ms pause, and a sentence-final target utterance. The target utterance spoken by a male was always presented intact. The task of the listeners was to decide if the target utterance was a word or non-word. The initial portion of each sentence was spoken by a female and was presented either intact or distorted, and it provided a semantically congruent, incongruent, or neutral context for the following intact target (when it was word). All stimuli were presented binaurally at 70dB SPL using Sennheiser HD 250 headphones. A light signal on the response box at the beginning of the target word indicated to the participant that a response could be entered by pressing the correct button as

quickly and accurately as possible. Participants were allotted 3000 ms to answer, after which, regardless of whether a response was entered, the next trial was presented. The participant's response time started at the beginning of the target utterance (same time as the light signal on the response box) and ended when they pressed a button. Participants performed a block of nine practice trials prior to the test-trial sequence of 48 items, which contained 8 examples of both the altered and unaltered conditions for each of the congruent, incongruent and neutral sentence contexts, half of which were followed by word targets and the other half by non-word targets.

3. RESULTS

Inclusion of participants into the analysis was based on the criterion that participants correctly answered 90% of the test trials. RT's were eliminated from analysis if an incorrect or no response was entered. Only the reaction times for word targets were analysed. Priming effects in the unaltered and altered conditions were calculated for both facilitation (congruent minus neutral contexts) and inhibition (incongruent minus neutral contexts) effects. A repeated measures analysis of variance (ANOVA) with distortion (altered vs. unaltered) and priming (facilitation vs. inhibition) as within-subject variables was conducted; distortion type (low-pass filtering, time compression, or signal-to-noise ratio) was included as a between-subject variable. Figure 1 depicts the priming effects for each distortion type, where values above zero reflect slower reaction times than in the neutral baseline conditions and values below zero reflect faster reaction times.

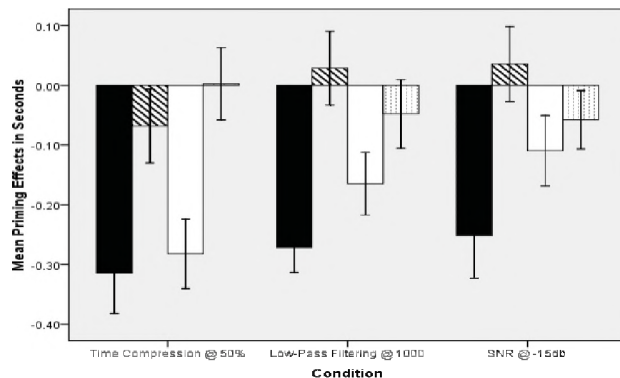


Fig. 1. Mean priming effects (Facilitation and Inhibition) for both unaltered and altered contexts for each type of distortion. Black bars show facilitation for the unaltered context; striped bars show inhibition for unaltered context; white bars show facilitation for altered contexts; dotted bars show inhibition for altered context. Error bars represent 95% confidence intervals.

There was a significant main effect of type of distortion, ($F(2, 105) = 3.945, p < 0.05$). A significant priming effect also emerged, $F(1, 105) = 214.508, p < 0.01$. The priming effects varied from -0.232 sec ($SE = 0.013$) for the

facilitation effect to -0.018 sec ($SE = 0.012$) for the inhibition effect. No main effect of distortion (unaltered vs. altered) was found. A significant distortion type X priming effect interaction emerged, $F(2, 105) = 3.629, p = 0.03$, as well as a significant distortion X priming effect interaction, $F(1, 105) = 30.819, p < 0.001$. Finally, a significant distortion X priming effect X type of distortion interaction emerged, $F(2, 105) = 13.521, p = 0.00$.

4. DISCUSSION

The goal of the present study was to replicate and extend the claims of Aydelott and Bates (2004) regarding the effects of acoustic distortions on lexical access. For intact sentence contexts, it was expected that reaction times to targets in congruent contexts would be faster compared to reaction times to targets in a neutral context, whereas those in an incongruent context would be slower. Furthermore, if reaction times differ depending on the type of distortion then the patterns suggest how priming (facilitation or inhibition) may differ in lexical access for different types of distortion.

The analysis revealed that different types of distortion did affect lexical access to different degrees. Low-pass filtering at 1000Hz and at -15 dB SNR both appear to affect the earlier stages of lexical access, which replicated the findings of Aydelott & Bates (2004). However, in the time compression condition, an inhibition effect was expected based on previous findings, but instead, the results of the replication revealed a facilitation priming effect. Importantly, the distortions due to low-pass filtering and SNR produced a release from inhibition and significant facilitation decrease, whereas time compression significantly reduced facilitation and increased inhibition.

4.1 Future Research

These results indicate that different types of distortion have similar effects on lexical access when the degree of distortion is matched (filtering and SNR). The differences observed between time-compression and the other two types of distortion are confounded with differences in degree of distortion referenced to percent correct scores on NU6 words. Extensions of the current study will investigate the effects of different degrees of distortions (e.g., comparing low-pass filtering at 1000Hz and 1750Hz as shown in Table 1 and as described in our companion study in this issue).

REFERENCES

- Aydelott, J., & Bates, E. (2004). Effects of acoustic distortion and semantic context on lexical access. *Language and cognitive processes*, 19, 29-56.
- Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology*, 10, 29-63.
- Stuart, A., Green, W. B., Phillips, D. P., & Stenstrom, R. (1994). List equivalency of the Northwestern University Auditory Test No. 6 in quiet and in continuous broad band noise. *Journal of Speech-Language Pathology and Audiology*, 18, 121-125.