The Lombard Effect as a Communicative Phenomenon

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1. Introduction

First described by Etienne Lombard in 1911, the Lombard effect is a phenomenon in which speakers alter their vocal production in noisy environments, such as loud parties or restaurants. Previous research examining the acoustic differences between Lombard speech and normal speech has found measurable differences in vowel duration and intensity (Summers et al. 1988, Junqua 1996). In addition to measuring vowel duration and amplitude, Summers et al. (1988) also measured formant frequencies, finding that F1 and F2 frequencies tend to show an increase in noise, thus causing a shift in the vowel space when the Lombard effect is produced. The results of a study examining the Lombard effect in Spanish (Castellanos et al. 1996) support the results of Summers et al. (1988) regarding the effects of noise on formant frequencies; Castellanos et al. similarly found a small increase in F1 and F2 frequencies in noise.

In their paper "The Lombard Sign and the Role of Hearing in Speech," Lane and Tranel (1971) stress the importance of intelligible communication as a factor to the Lombard effect. Specifically, they argue that "the speaker does not change his voice level to communicate better with himself, but rather with others" (Lane and Tranel 1971, p.692). In stating that the speaker produces the Lombard effect out of a desire to be more intelligible for a listener, there is an implication that the speaker may not be completely unconscious to his or her production of the Lombard effect. Much of the research done on the Lombard effect, however, has neglected this communicative aspect and has instead used experimental designs in which a subject is asked to read a list to no one in particular while hearing noise over headphones. This type of experimental design not only shows that the Lombard effect can be reproduced artificially, but also encourages the assumption that the Lombard effect is a "physiological effect" (Junqua 1996), implicitly suggesting that the speaker may not be aware of his or her production of the Lombard effect. Experiments such as these have also given rise to the interpretation that the Lombard effect is more of a reflex, arising automatically when speaking in noise.

Although most research on the Lombard effect has neglected the communicative aspect of the phenomenon that was emphasized by Lane and Tranel (1971), it is important to study the Lombard effect as a communicative phenomenon, as most productions of the Lombard effect in the real world tend to be in communicative environments rather than isolated instances where a person is talking to him or herself. This paper examines the Lombard effect with a focus on its communicative aspect, presenting the results of an experiment designed with the hypothesis of intelligible communication in mind. Measurements of amplitude, duration, and formant frequencies will be examined to see if they correspond with the results of previous research. Additionally, a possible Lombard effect on voice onset time will be tested.

The experiment designed for this study involves two subjects at once, with one functioning in the role of a speaker and the other as a listener. The experiment tests whether speakers will exhibit the Lombard effect even when not hearing noise themselves but knowing that the listener is hearing noise. At the beginning of this study, I hypothesized that speakers would display some indication of producing the Lombard effect even when not hearing noise themselves, as long as they knew that the listener was, indicating the existence of a communicative basis for the Lombard effect.

2. Method

A. Subjects. Thirty-two undergraduate students, six of which were male, participated in this experiment as subjects. All subjects were native English speakers, who were unaware of the purpose of the study and none reported a speech or hearing problem at the time of the experiment.

B. Stimuli. The stimuli consisted of a set of eight word lists composed of common English words, with the words being one to two syllables long (see the appendix for the word lists). A diverse phonetic inventory was sought, and the American English voiced and voiceless stops, [b], [d], [g], [p], [t], and [k], and the four corner vowels of American English, [i], [u], [æ], and [a] were richly represented in the resulting words. Each word list consisted of twenty-four words, totaling 192 words.

C. Procedure. Subjects were paired up randomly in the experiment, with each person taking turns reading lists to the other. There were four noise conditions in the experiment: (1) neither person hearing noise, (2) both hearing noise, (3) only the speaker hearing noise, and (4) only the listener hearing noise. Four word lists were read by each person, one list per condition. Speaker and listener were separated, with the speaker being located inside a sound booth and the listener sitting outside of it, communicating through an intercom-like system where the listener had to push a button to speak to the speaker.

Subjects wore AKG headphones (K240 and K271) which were calibrated. White noise was played through these headphones using a Sony CFD-V17 CD radio cassette-corder as the noise source, with the noise set at 70dB. The listener used a table top condenser microphone while the speaker used a head-mounted one microphone to keep a consistent distance from the speaker's lips to the microphone. Subjects' speech was recorded using a PMD670 Marantz solid-state recorder with a sampling rate of 44 kHz.

The speaker was instructed to read the list of words to the listener, who would be writing the words down. The listener was instructed to ask for clarification on six of the twenty-four words, but was also free to ask for clarification on any other words if needed. At the beginning of each noise condition, both subjects were notified whether they would be hearing noise or not. This was done in order to be sure that the speaker knew that the listener was hearing noise in the fourth condition. The speaker could also hear the listener's noise over the intercom when the listener asked for clarification of words.

3. Results and discussion

A. Amplitude

The mean amplitude in the "both in noise" condition was 7.4 dB louder than in the "no noise" condition. This is a replication of the classic Lombard effect. Similarly, the mean amplitude in the "speaker in noise" condition was 6.3 dB louder than in the "no noise" condition, and of particular interest, mean amplitude in the "listener in noise" condition was 2.16 dB louder than in the "no noise" condition. Various descriptions of the Lombard effect indicate an increase in amplitude or intensity in the speaker's vocal production, so it is not surprising that there would be an increase in amplitude in the "both in noise" and "speaker in noise" conditions. Under the assumption that the Lombard effect is a physiological effect, however, we would predict that there would not be a significant increase in amplitude in the "listener in noise" condition. Although a 2.16 dB increase is small, I would still consider it an increase in amplitude worth noting, given that a 6 dB increase is produced by doubling the sound amplitude.

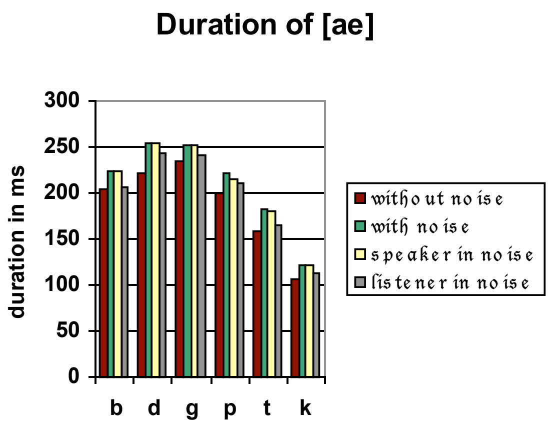

Figure 1. Mean word durations for words with [æ] produced in four noise conditions.

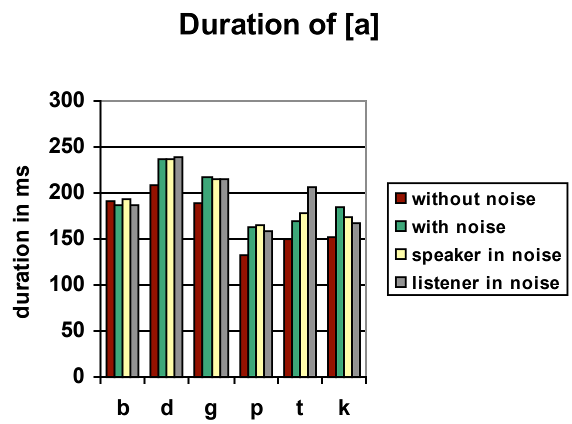

Figure 2. Mean word durations for words with [a] produced in four noise conditions.

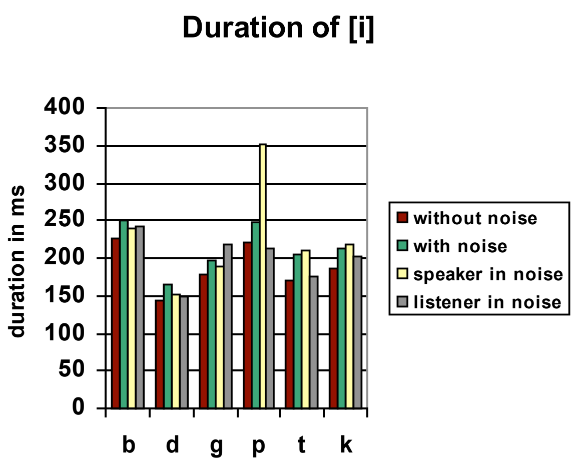

Figure 3. Mean word durations for words with [i] produced in four noise conditions.

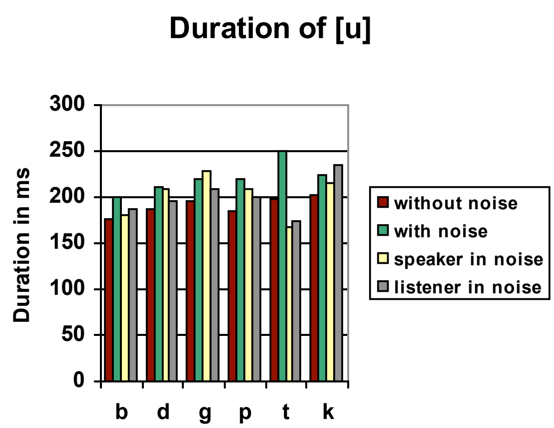

Figure 4. Mean word durations for words with [u] produced in four noise conditions.

B. Duration

Mean word durations for utterances spoken by subjects are shown in Figures 1 through 4, separately for each of the four test vowels. Consistent with the results found in other studies (Summers et al. 1988, Junqua 1996), word durations in the "no noise" condition are shorter than in the "both in noise" and "speaker in noise" conditions, with a difference of 20-30 ms. The "listener in noise" condition also shows a smaller increase in word duration for most utterances with variable differences (between 3-30 ms). Of the twenty-four mean word durations shown in the charts below, only three are shorter in the "listener in noise" condition than in the "no noise" condition; specifically, in the environments of [ba], [pi], and [tu], the durations in the "no noise" condition are longer than those in the "listener in noise" condition by roughly 10-20 ms.

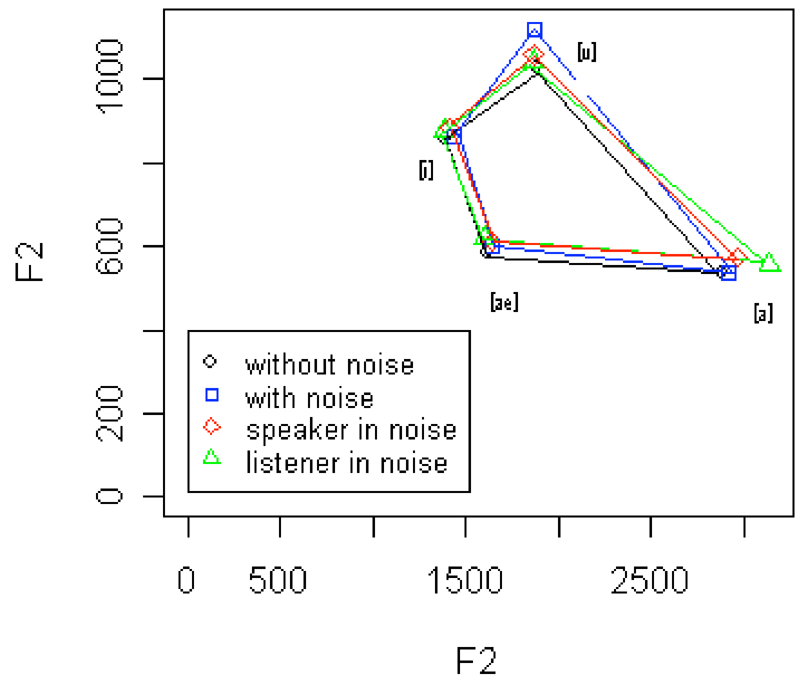

Figure 5. Average F1 and F2 frequencies for female speakers in the four speaking conditions.

C. Formant frequencies

Formant frequencies across speakers for F1 and F2 are shown in figures 5 and 6. Similar to the findings in Summers et al. (1988) and Castellanos et al. (1996), F1 and F2 frequencies show an increase in the noise conditions, resulting in a shift of the vowel space when the Lombard effect is produced.

In the word duration measurements above, the durations in the "listener in noise" condition generally exhibited characteristics of the Lombard effect by being longer than the durations in the W/O condition. There were, however, a few exceptions. Here with formant frequencies, the differences between the "listener in noise" and "no noise" conditions show a similar trend; for the most part, the formant frequencies in the "listener in noise" condition exhibit characteristics of the Lombard effect as they are greater than the formant frequencies in the "no noise" condition.

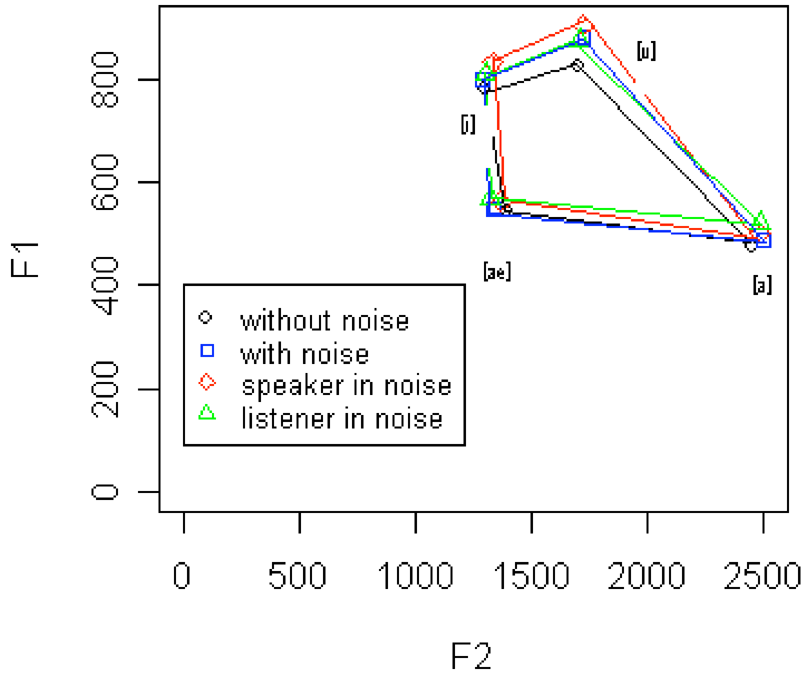

Figure 6. Average F1 and F2 frequencies for male speakers in the four speaking conditions.

D. Voice onset time

Mean voice onset times of both voiced and voiceless stops are shown in Figures 7 and 8. In Fig. 8, there is no consistent difference in voice onset times among the different noise conditions. Fig. 7, however, shows that the voice onset times of voiced stops are generally lower in the "both in noise" and "speaker in noise" conditions than in the "no noise" and "listener in noise" conditions. In the case of [b], the VOT even hits negative, indicating that some speakers began to voice before they uttered the words, an occurrence that is rare in English speakers who generally don't voice their initial voiced stops. In Fig. 7, VOT for [d] and [g] in the "listener in noise" condition are lower than in the "no noise" condition, although it is higher for [b]. Again, the data here shows a similar trend where speakers seem to produce the Lombard effect to some extent in the L condition, although there are still some exceptions.

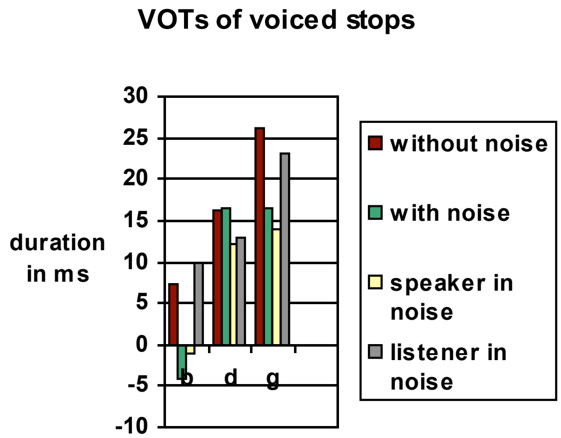

Figure 7. VOTs of voiced stops

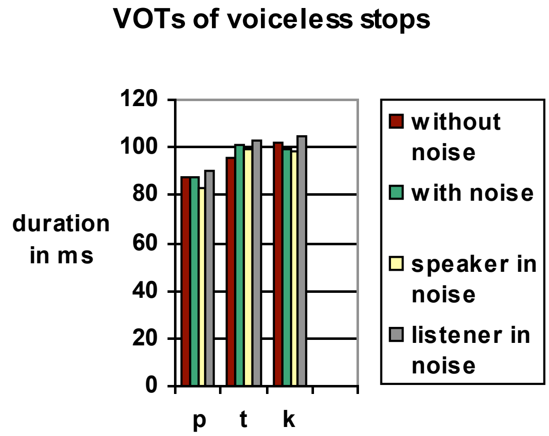

Figure 8. VOTs of voiceless stops

4. Conclusion

Although most research tends to discount the communicative aspect of the Lombard effect, I think it is important to keep in mind that when the Lombard effect is produced in non-artificial environments, it is generally produced through one person communicating to another. The results of this study have shown that although utterances in the "listener in noise" condition display less of the characteristics often attributed to the Lombard effect, these characteristics still exist in this condition. The findings of this study indicate that the Lombard effect is produced in situations where speakers, although not situated in noise themselves, know that the listener is in a noisy environment, thus supporting the Lane and Tranel's (1971) interpretation of the Lombard effect as a communicative phenomenon. This study has also shown that the communicative Lombard effect found in the "listener in noise" condition was not as large as the effect found in the "both in noise" or "speaker in noise" conditions. Whether this indicates the operation of an additional Lombard reflex or simply a failure of empathy on the part of speakers in the "listener in noise" condition is an open question.

One interesting finding from this study is the VOT differences found in the American English voiced stops, especially the negative VOT. Although I hypothesized that VOT might decrease in the case of voice stops and increase for voiceless stops, I did not expect negative VOT to show up in some of the data, considering that English speakers do not generally voice their initial voiced stops. Perhaps further research on the Lombard effect could look more into the VOT differences and determine whether VOT difference may be considered another characteristic of the Lombard effect.

References

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Appendix: Word Lists

Word List #1	**Word List #2**	**Word List #3**	**Word List #4**
1. gap	1. pooch	1. goop	1. cuckoo
2. peeved	2. daub	2. daft	2. beep
3. dappled	3. bee	3. pea	3. goof
4. cough	4. tooth	4. bobbin	4. poplar
5. tea	5. TV	5. beetle	5. pasture
6. doodle	6. captain	6. cooper	6. pooh
7. pad	7. bath	7. gas	7. teeth
8. toddler	8. coo	8. popcorn	8. dad
9. boot	9. tab	9. geese	9. tassel
10. caption	10. decent	10. toot	10. bother
11. deep	11. gasp	11. cabbage	11. deeper
12. bauble	12. boost	12. gobble	12. captive
13. beef	13. copy	13. teeter	13. tuba
14. two	14. duty	14. poof	14. dog
15. baffle	15. peep	15. tattle	15. people
16. dot	16. pass	16. copper	16. booty
17. coop	17. top	17. deed	17. taut
18. geese	18. key	18. booth	18. keeper
19. tap	19. goose	19. path	19. babble
20. ghoul	20. poppy	20. dawdle	20. dude
21. possess	21. dab	21. baptize	21. got
22. poop	22. geeky	22. dubious	22. geek
23. keep	23. gaudy	23. Keats	23. cobble
24. gossip	24. bought	24. toffee	24. gag

Word List #5	Word List #6	Word List #7	Word List #8
1. cooed	1. possum	1. Google	1. tuple
2. gadget	2. tootle	2. tavern	2. gaudy
3. body	3. beet	3. deeply	3. peach
4. t-shirt	4. capsule	4. tease	4. dash
5. due	5. tophat	5. pooch	5. topic
6. capsize	6. Keith	6. dabble	6. bees
7. bead	7. duped	7. keyed	7. coos
8. God	8. tapdance	8. dotted	8. tadpole
9. toothache	9. deepen	9. tube	9. pool
10. pot	10. bodice	10. peeve	10. batch
11. peace	11. geese	11. battle	11. dock
12. goo	12. pooed	12. toss	12. teat
13. batboy	13. doctor	13. duke	13. bootleg
14. topple	14. cooped	14. beach	14. gaps
15. geek	15. bad	15. patch	15. pod
16. dazzle	16. peas	16. gotten	16. keys
17. cobbler	17. booster	17. cool	17. duvet
18. poodle	18. pat	18. cost	18. passing
19. keepsake	19. cot	19. gather	19. geese
20. boo	20. gab	20. bottle	20. coffee
21. taffy	21. teabag	21. geeky	21. detour
22. doctrine	22. goofy	22. pauper	22. bottom
23. paddle	23. dapper	23. capture	23. goose
24. deacon	24. gosling	24. bootcamp	24. capture