Relative fundamental frequency under increased cognitive load in healthy speakers

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Objective: The purpose of this study was to determine the effect of increased cognitive load on relative fundamental frequency (RFF) in individuals with healthy voices.

Introduction: Cognitively demanding tasks instigate arousal of the autonomic nervous system.[1] This autonomic arousal effects the voices of healthy speakers, as demonstrated by observed changes in mean fundamental frequency (f_o),[2,3] f_o variation,[2,4] sound pressure level (SPL),[3,4] and frequency and amplitude perturbation.[2] However, the effect of cognitive load on these measures has been variable, with some studies showing increases, others decreases, and others no change at all. It may be that measures of voice quality are more sensitive to cognitive loading than these measures of frequency and amplitude.

MacPherson and colleagues[3] have shown that cepstral peak prominence (CPP) and low-to-high spectral energy ratio (LHR) are in fact significant predictors of cognitive load. They found that CPP increased and LHR decreased in speakers with healthy voices when cognitive load was increased. The authors interpreted the increased CPP and reduced LHR as indicative of the use of a more pressed voice. This is consistent with the finding that autonomic arousal is associated with increased activation of intrinsic laryngeal muscles.[5] Further research is needed, however, to determine if increased laryngeal muscle tension is indeed driving these changes in voice quality.

This relationship could be demonstrated by a decrease in RFF under increased cognitive load. RFF has shown promise as an acoustic correlate of laryngeal tension.[6] Individuals with vocal hyperfunction, a disorder characterized by excessive laryngeal tension,[7] typically have lower RFF values than do speakers with healthy voices.[6] Lower RFF in comparison to speakers with healthy voices has also been found in individuals with other disorders associated with laryngeal tension or rigidity, namely, spasmodic dysphonia[8] and Parkinson's disease.[9] We therefore expect RFF to decrease during voice production under increased cognitive load, when the autonomic nervous system is aroused and there is greater tension in the laryngeal muscles.

Methods: Twenty young adults with healthy voices (10 female, 10 male; *M*=20.2 years, *SD*=1.4 years) were recorded as they read sentences under different cognitive load conditions. Each sentence contained four color terms printed in colored ink, thus creating an embedded Stroop task. This allowed for manipulation of cognitive load during the reading task. Speakers were instructed to say the color of the ink in which a word was printed, rather than the color term itself. Six sentences with matching ink color and printed word (e.g., "blue" printed in blue ink) constituted a standard cognitive load. Six sentences with mismatched ink color and printed word (e.g., "blue" printed in red ink) constituted an increased cognitive load. Each sentence also contained sound sequences necessary for measuring RFF. These sequences included two voiced sonorants with an intervening voiceless consonant (e.g., /upo͡ʊ/ in the phrase "new posters"). RFF was manually measured for the ten voicing cycles of the sonorant preceding the voiceless consonant (i.e., offset cycles) and the ten cycles of the sonorant following the voiceless consonant (i.e., the onset cycles). Average RFF values for each offset and onset cycle were calculated for each speaker. Repeated measures two-way analyses of variance (ANOVAs) were constructed to measure the main effects of RFF cycle and cognitive load condition on mean RFF offset and mean RFF onset and to measure the interaction between cycle and condition. Effect sizes for significant effects and interactions were calculated as partial eta squared (η_p^2).

Results: There was a significant effect of cognitive load condition (p=0.023, F=5.21, η_p^2=0.01) on mean RFF offset. Mean RFF offset values were reduced under increased cognitive load. There were also significant effects of cycle on both mean RFF offset (p<0.001, F=4.25, η_p^2=0.10) and mean RFF onset (p<0.001, F=151.38, η_p^2=0.79). There was no significant effect of condition on RFF onset nor significant interactions between cycle and condition on onset or offset RFF values.

Conclusions: The reduced mean RFF offset values seen in this sample of speakers with healthy voices indicate an increase in laryngeal muscle tension during a cognitively demanding task. This finding provides further support for RFF as a measure of laryngeal tension, with applications for diagnosis and treatment of hyperfunctional voice disorders.

Acknowledgments: This work was supported by grant DC015570 from the National Institute on Deafness and Other Communication Disorders. The authors thank Samantha Shank for her help with data analysis.

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