

Pilot Workload and Speech Analysis

A Preliminary Investigation

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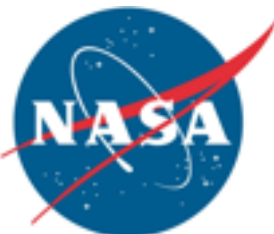
Can speech analysis be used
as a basis for detecting
changes in a pilot's workload?



Previous Work

- Heart rate is correlated with both speaking rate and fundamental frequency. Brenner and Shipp, (1987)
- The acoustical effect of stress varies greatly among individuals. Hecker et al. (1968)
- Single parameter analysis (ex. using only fundamental frequency) is insufficient for predicting workload. Ruiz et al., (1990)

Experimental Design



Objectives

- Investigate the influence of objective workload on fundamental frequency.
- Investigate the influence of objective workload on articulation rate.

Variables

- **Dependent**

- Objective Workload

- **Independent**

- Subjective Workload Rating
- Fundamental Frequency
- Articulation Rate (number of syllables per second)

Experiment



Read-Back

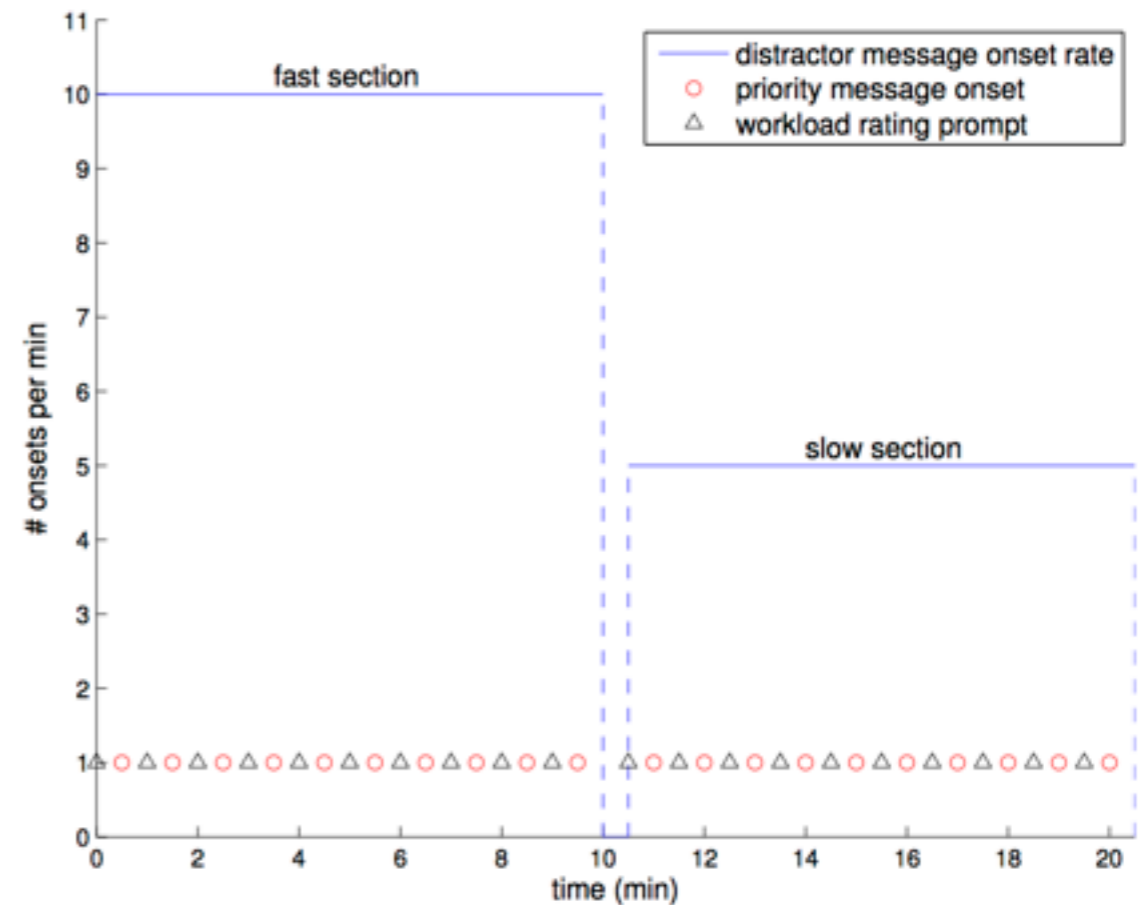
- Synthesized instructions from Air Traffic Control
 - “United 972, Saint Louis center. Climb to flight level 380.”
- Participant responded using restricted vocabulary
 - “Saint Louis center this is United 972. Climbing to flight level 380.”

Task

- Participants acted as “pilots”.
- Attended to a non-verbal task
 - clicked in response to incoming audio messages
- Responded to Air Traffic Control via a “read-back” task with a restricted vocabulary.
- Gave subjective workload ratings on a 7-point Likert scale.

Experimental Blocks

- Two 20 min experimental blocks
- Two conditions per block
 - High Workload (10 messages/min)
 - Low Workload (5 messages/min)
- 20 read-backs per block (1 per min)
- 20 subjective workload ratings per block (1 per min)



Speech Measurements

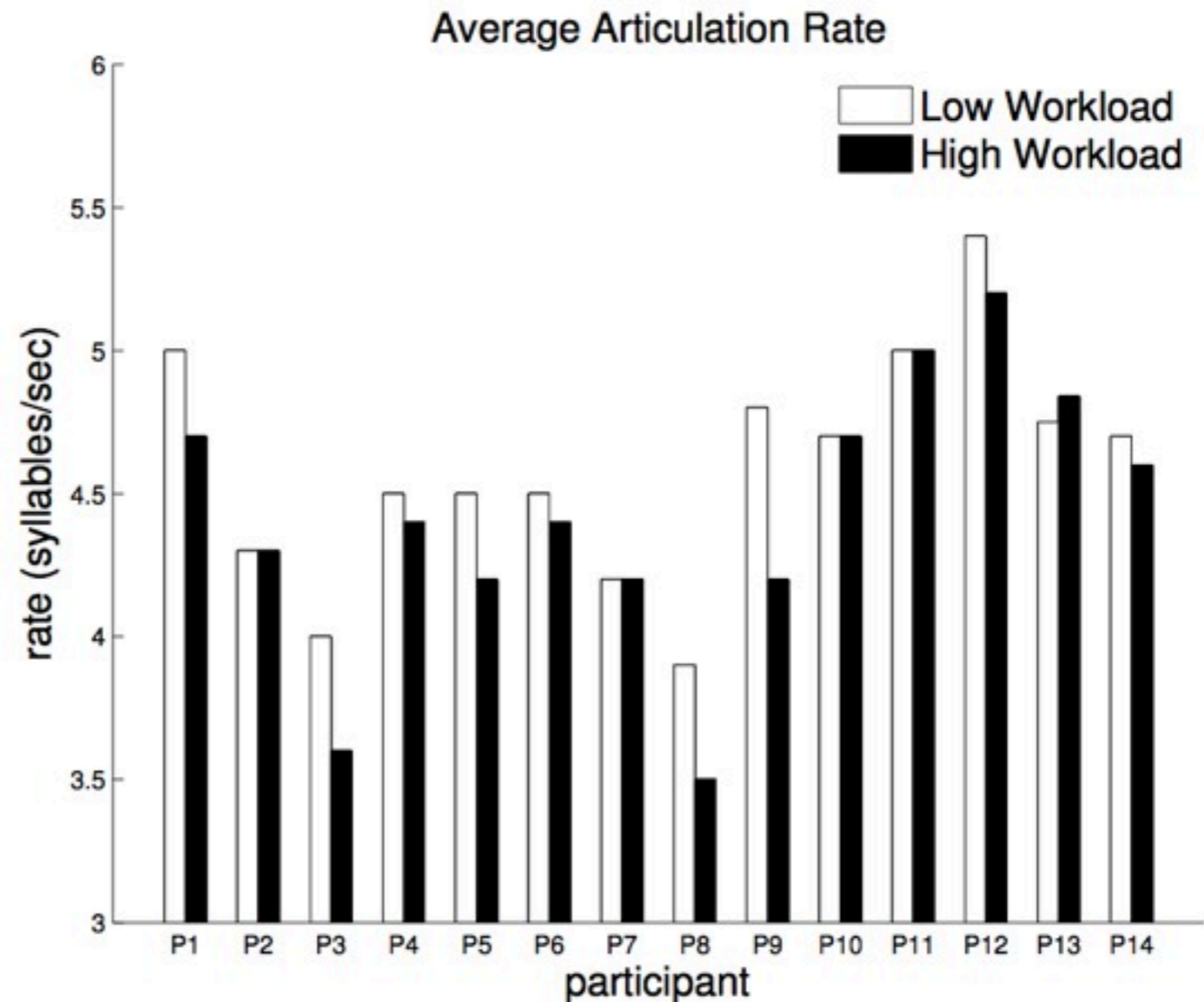
- Utterance-level measurements (one per read-back)
 - Fundamental frequency (Hz)
 - Articulation rate (syllables per phonation time)
- Analysis performed using PRAAT.
- Data for each participant averaged for each workload condition.

Results



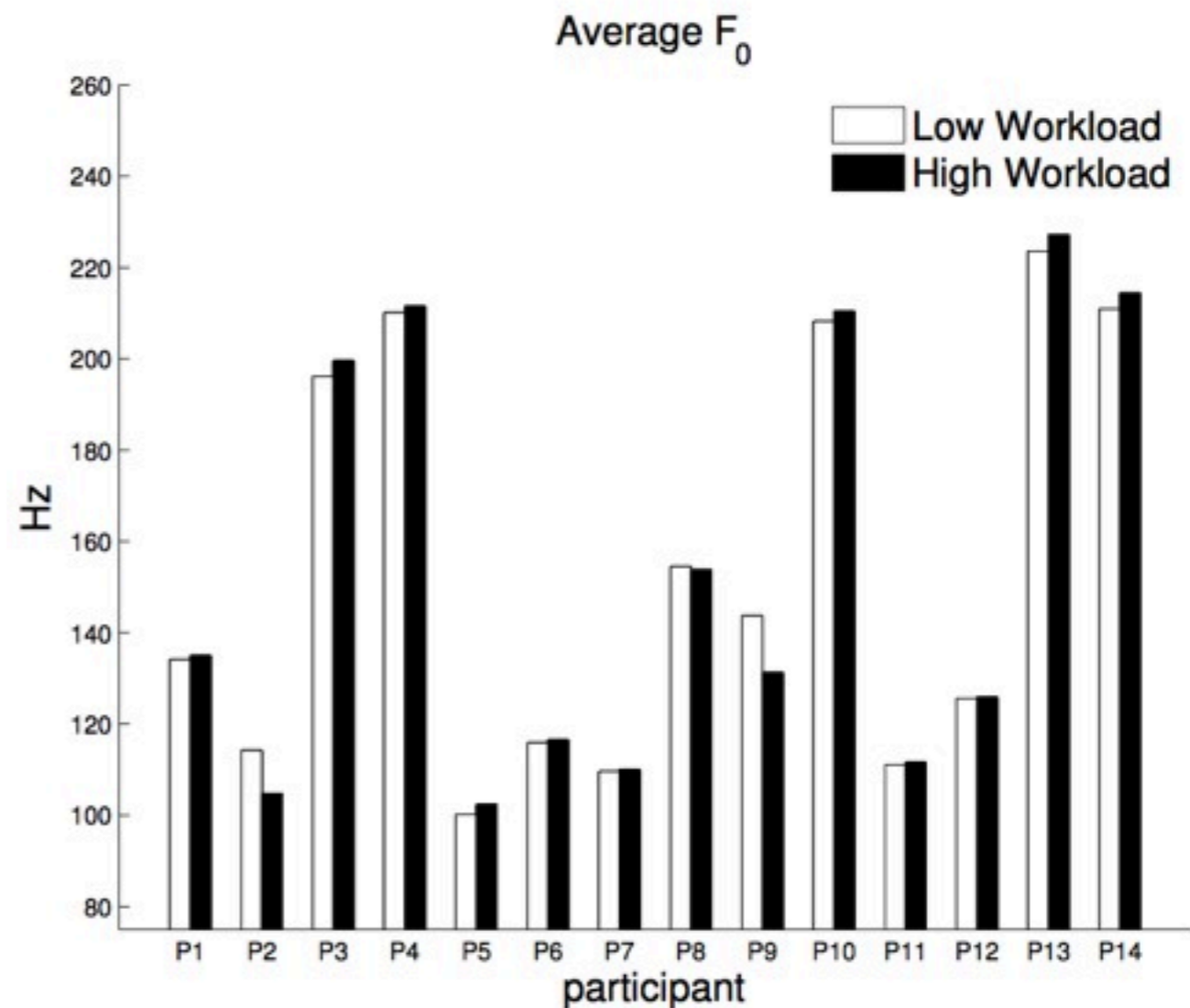
Articulation Rate

- Paired-samples t-test showed significant difference ($p < .05$)
- Average articulation Rate faster in low workload conditions compared to high workload conditions.



Fundamental Frequency

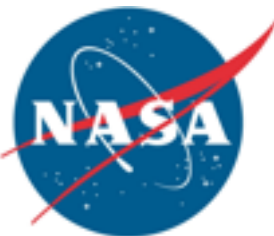
- Paired samples t-test showed significant difference ($p < .01$)
- Mean increase of 1.5 Hz during high workload conditions compared to low workload conditions.



Workload Manipulation

- Wilcoxon signed rank test on subjective workload ratings showed significant increase in perceived workload during high workload segments compared to low workload segments. ($p < .0005$)
- No statistically significant difference between subjective workload ratings and either speech measurement.

Conclusions



- Increased workload results in (slightly) increased fundamental frequency and decreased articulation rate.

References

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- Brenner, M. and Shipp, T. (1987). Voice stress analysis. In Constuck, J. R. (ed.) *Mental State Estimation*. NASA Conference Publication 2504.
- Hecker, M. H. L., Stevens, K. N., von Bismarck, G. D. and Williams, C. E. (1968). Manifestations of task-induced Stress in the Acoustic Speech Signal. *Journal of the Acoustical Society of America*, vol. 44, pp. 993-1001.
- Boersma, P. and Weenink, D. (2013). Praat: doing phonetics by computer [Computer program]. Version 5.3.41. <http://www.praat.org/>