Voice Analysis as a Significant Parameter of Car Driver’s Fatigue

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Abstract. One can hear a change in the quality of voice when somebody is tired. This feeling has to be studied in order to quantify these changes. As a matter of fact, fatigue could have great consequences on the behaviour of the speaker, such as aircraft pilots, truck drivers, or train drivers. Analyses have been made with a car driver during a day trip of about 800 kilometers without stops (except for a short lunch!). Speech material was 5 sentences and French vowels. Recordings were made all along the trip both during short stops and during driving. Analyses were performed with a laboratory made software with Matlab® and Audacity®. Five parameters were studied: duration of the words uttered, duration between the words while reading the sentences, duration of the pauses between sentences, fundamental frequency, and jitter. In parallel the driver was asked for his feeling about his state of fatigue. Very interesting results were found showing possible correlations of speech durations and fundamental frequency with fatigue.

1 Introduction

Some people have specific responsibilities when driving public transportation vehicles. It is the case for train, aircraft, or bus drivers. As a matter of fact, it is a question of security for all passengers. Therefore studies are carried out in order to prevent possible accidents. Theses ones are often medical investigations: electrocardiogram, brain analyses, or perspiration. They are quite easy to perform in the laboratory but much more difficult to organize for an airline pilot or a bus driver. Acoustics gives assistance.
A study is actually going on with airline pilots. Here a car driver is chosen because its workload can be similar to the one of airplane pilots for daily short-haul rotations. They perform 4 to 5 flights per day, without significant stops.

2 Experiment

The travel was about 800 km, with only one stop for a short lunch. The driver was regularly asked to read 5 sentences and 5 oral vowels alone. Ten records have been made: departure (record 1), then one each two hours (records 2 and 3), short lunch between record 5 and record 6, then each hour (records 7 and 8), arrival (record 9). The sound recording was made with a headset proximity microphone to maintain constant distance between the lips and the transducer for all the head movements (AKG C555L). The recorder was a Sony Pro D.A.T. Vowels were segmented with an audio editing software (Audacity®) so as to only keep quasi – stationary part of the signal. 34 vowels are obtained from the rest period at the departure and 58 at the arrival. The material was composed of 92 monophtongs and 10 sets of the same five sentences followed by 5 vowels uttered alone, all along the travel.

3 Speech Analysis

A first set of speech parameters were examined here to test their possible modifications with driver’s fatigue. Further research will be done: shimmer, L.P.C spectrum, Lyapunov exponents. The listening of recordings has shown that delivery seemed to decrease at the arrival at the end of the afternoon. Therefore, speech duration measurements were done. The time parameters were the total duration of the five sentences, the mean duration of vowels (including pauses) outside sentences and the mean duration of the pauses between sentences. Studies on time parameters are not numerous in such situations [1] but a lot of previous researches have shown that fundamental frequency and derived parameters like jitter can be modified by many factors [2,3]. A peak detection of glottal pulses gives each period duration. The averaging of the corresponding frequencies leads to the vowel mean fundamental frequency $<F_0>$. A cepstral analysis of the signal was also made to check the $<F_0>/\ F_{0cepstrum}$ ratio was close to one. Short term instability of F_0 was measured by mean jitter. If there are N periods in the vowel signal and if $F_0(i)$ is the frequency of the i period, mean jitter $<J>$ is defined as : $< J > (Hz) = \frac{1}{N-1}\sum_{i=1}^{N-1}\left|F_0(i) - F_0(i+1)\right|$.

4 Results

From Figures 1 to 3 general observations should be made:

- after lunch (record 6) all the durations have an important grow with a value greater than the rest ones and just before lunch (record 5) all the durations decrease.

- before lunch (records 1 to 4) durations increase (except for pauses (Fig. 2) which are relatively constant)

- after lunch (records 7 to 10) only the mean duration of pauses between sentences (Fig. 3) have a general decreasing; the others are stable (Fig. 1 and 3).

- Comparing rest state (record 1) and arrival (record 10), there is no significant modification of the durations.

From these remarks no general effect of fatigue on time measurements appears because the senses of variations are different before and after lunch. The experiment seems to show that a break in a workload can change driver’s behaviour. If speech variations are linked to fatigue the main observed effect is the decreasing pause duration (Fig. 2) leading to a slower delivery like the listenings suggest it.

Except for vowel n°4 for which the laboratory software has failed to detect a correct Fo value, the rest period in the morning is clearly lower than the “fatigue” one at the end of the car day trip (Fig. 4). Mean values are 112.21 Hz (σ = 42.22 Hz) for the first one and 141.13 Hz (σ = 21.45 Hz) for the second one. Even if the t-test does not indicate a significant variation, the increase is important and about 34%.

For mean jitter (Fig. 5), such a jump does not appear but an increase exists showing that an instability of Fo goes with the increase.

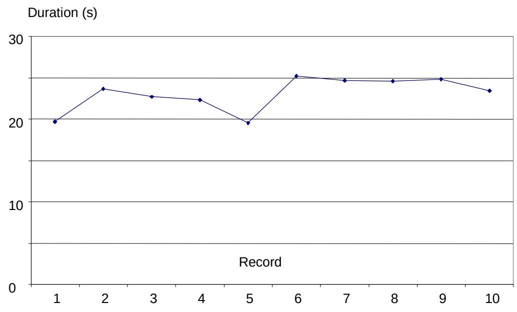

Figure 1: Total duration of the 5 sentences

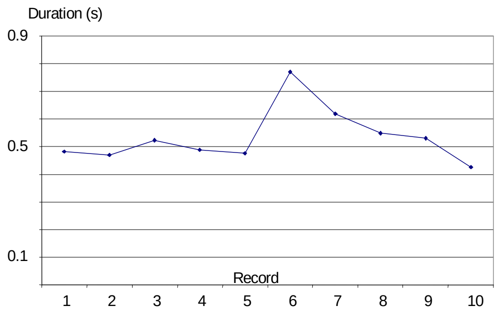

Figure 2: Mean duration of pauses between sentences

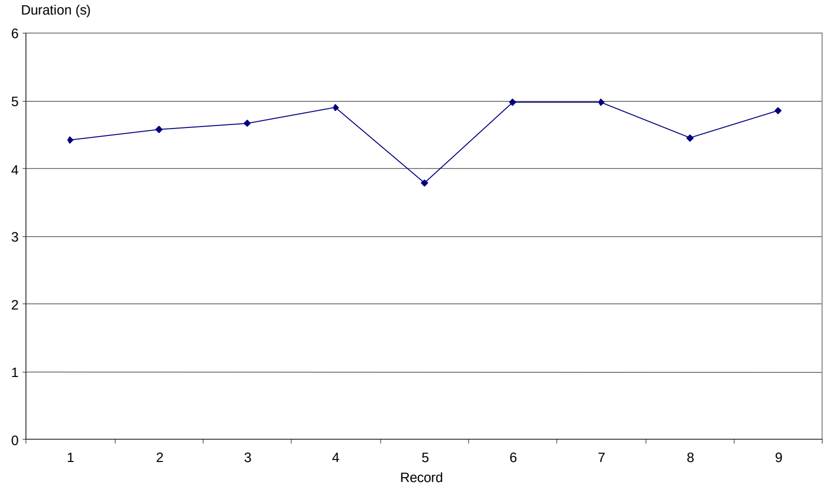

Figure 3: Mean duration of vowels (including pauses) outside sentences

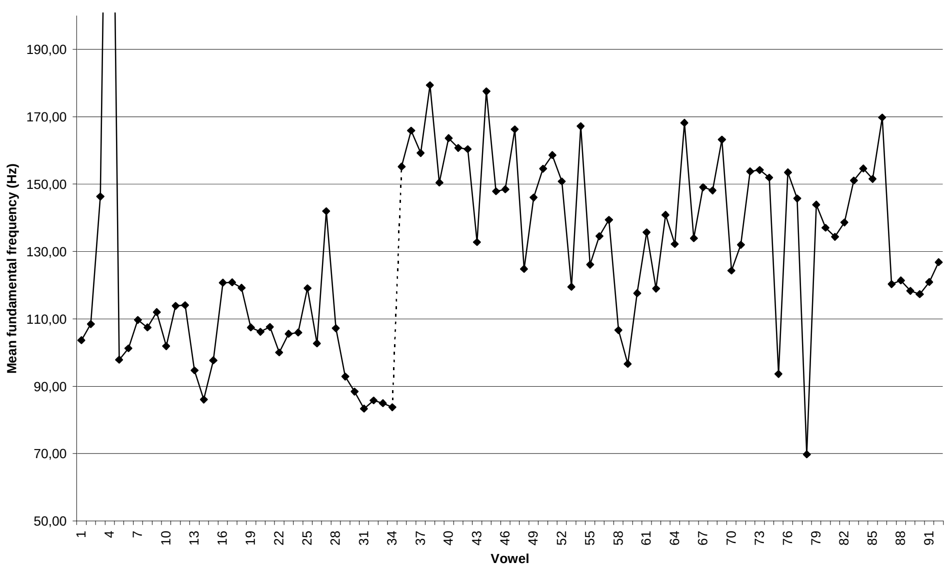

Figure 4: Mean fundamental frequency (Hz): vowels belong to the rest period (before departure) from 1 to 34 and to the "fatigue" one from 35 to 92 (record 9).

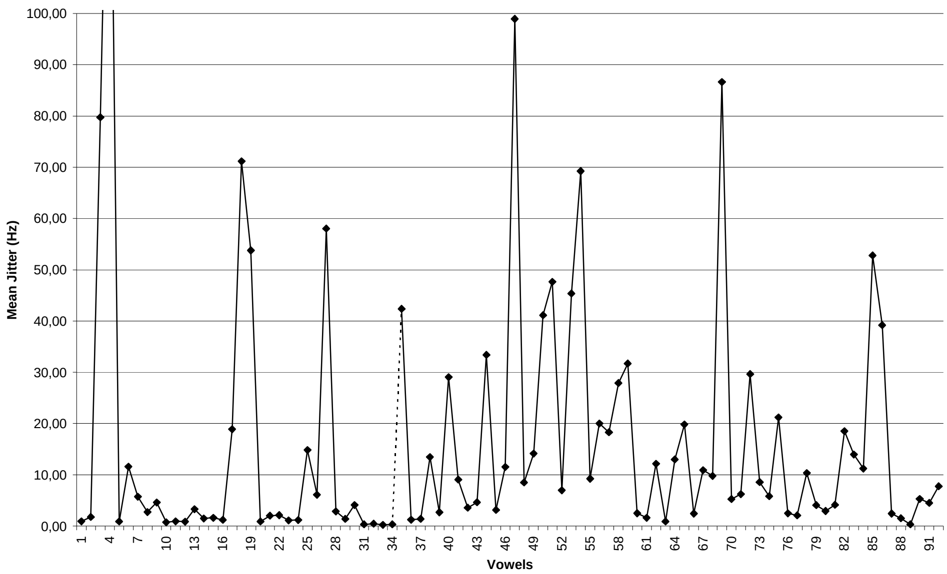

Figure 5: Mean jitter (Hz): vowels belong to the rest period (before departure) from 1 to 34 and to the “fatigue” one from 35 to 92 (record 9).

5. Conclusion

In this fatigue experiment the frequency parameters vary differently than in a sleep inertia experiment [2]. Perhaps it means that Fo measurements are able to distinguish the two situations for pilots. The delivery time parameters are promising for future research: they show variations probably related to fatigue and to driver’s behaviour before and after a break.

Signs of a link between fatigue and voice acoustic parameters exist. Voice analysis can be a significant parameter of car driver’s fatigue. The method and the measurements have now to be extended to a greater number of speakers and applied to pilots.

References

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Acknowledgments

The authors gratefully acknowledge the BEA to provide the support for the study and the car for the trip.