Determination of cognitive workload variation in driving from ECG derived respiratory signal and heart rate

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Laboratory Ergonomics and Cognitive Sciences applied to Transport **(TS2-LESCOT)**

AutoConduct

CONTEXT

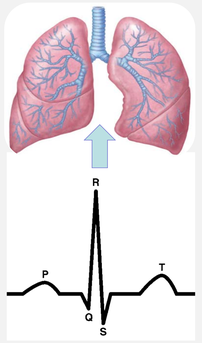
To manage takeover phases, it is desirable that automated cars decode driver's mental state to improve security

(Putze et al., 2010)

Gathering several signal modalities improves accuracy for cognitive workload (CW) diagnosis

(Grassmann et al., 2016)

Respiratory signal is usually used for ECG artifact rejection and scarcely utilized to estimate CW



OBJECTIVES

- Verifying the advantage of incorporating Breathing Rate (BR) as feature, with regard to Heart Rate (HR), to evaluate driver's CW

Inclusion of new sensors could be difficult to ensure high quality signals without hindering driver's comfort

- Checking the feasibility and accuracy to extract BR from ECG recordings in order to save on sensors by ECG derived respiration algorithm **(Moody et al., 1985)**

MATERIAL AND METHOD

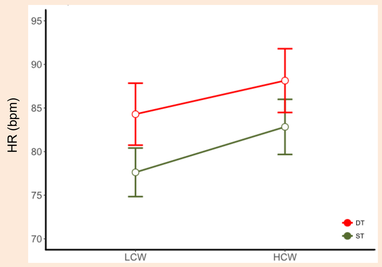
18 participants* (10 males, 22.7 ± 1.4 years). A valid driving license for at least 3 years was required.
Two different **cognitive tasks**, 5-minutes length per condition:

- Low Cognitive Workload (**LCW**): beep counting
- High Cognitive Workload (**HCW**): mental displacement within a memorized 5×5 grid and addition

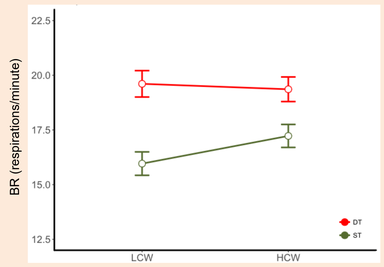
1	2	3	4	5
11	12	13	14	15
21	22	23	24	25
31	32	33	34	35
41	42	43	44	45

Conditions
- Single Task (**ST**) : cognitive task while seated in the car but without driving
- Dual Task (**DT**): cognitive task while driving in a simulator (urban zone)

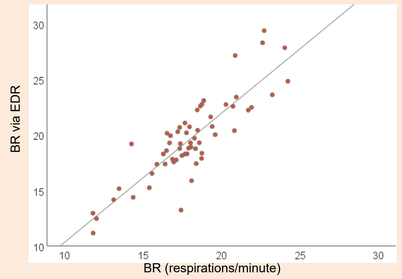
RESULTS



- **HR** increases in driving
  $F(1,11) = 21.2$, $p < .001$, $\eta^2 = .658$
- **HR** increases when CW is higher, for both ST and DT
  $F(1,11) = 32.68$, $p < .001$, $\eta^2 = .748$



- **BR** increases in driving
  $F(1,14) = 48.19$, $p < .001$, $\eta^2 = .775$
- **BR** is suitable to evidence a variation of CW in ST
  $t(16) = -3,72$, $p = .002$, $d = -0,902$



- **ECG-derived BR** is a cost-effective way to get BR
- Overestimation of 1,63 respirations/min **r = .86** ($p < .01$)

*some subjects were excluded in different analyses due to low quality signals

CONCLUSIONS

- **Cardiac and respiratory signals are impacted differently by CW in driving. This fact hints the use of both measures to monitor driver mental state.**
- **BR is particularly suitable in autonomous vehicles to estimate CW, where continuous driving is not required.**

References
- Putze et al., (2010). Multimodal recognition of cognitive workload for multitasking in the car. *20th International Conference on Pattern Recognition (ICPR)* (pp. 3748-3751).
- Grassmann et al., (2016). Respiratory changes in response to cognitive load: A systematic review. *Neural plasticity, 2016.*
- Moody et al., (1985). Derivation of respiratory signals from multi-lead ECGs. *Computers in cardiology*, *12*, 113-116.

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