

INTRODUCTION

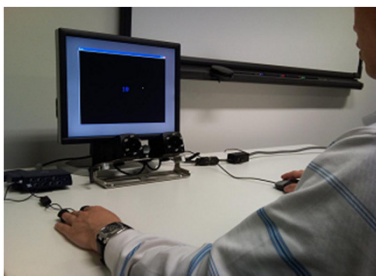
- A system capable of monitoring its user's mental workload can evaluate the suitability of its interface and interactions for user's current cognitive status and properly change them when necessary.
- In this way, the optimum performance will be obtained and many human errors will be avoided.
- Example application domains: learning, brain-computer interactions, driving, air traffic control, piloting.

Cognitive Load Measurement Methods

- Subjective methods (self-report)
- Performance based methods
- Behaviours (speech, gestures, movements)
- Physiological methods (signals from heart, eye, brain, muscles and skin): they are real-time, accurate and quick and do not interfere with the main task.
- Galvanic skin response (GSR) and eye blinks are cognitive load measures which can be captured at low cost, with short preparation time and minor restriction of users' movements.

EXPERIMENT

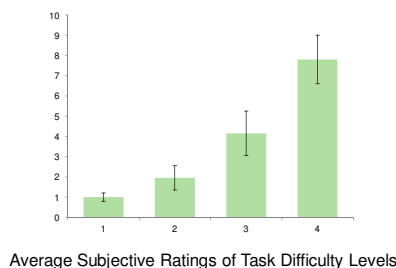
- 8 Arithmetic tasks; Adding-up 4 sequentially presented numbers (each for 3 seconds)
- 4 Task difficulty levels (in randomised order): binary, one-digit, two-digit and three-digit numbers



- GSR device: ProComp Infiniti of Thought Technology Ltd (sampling rate: 10 Hz)
- Remote eye tracker: faceLAB 4.5 of Seeing Machines Ltd (sampling rate: 50Hz)
- 13 Subjects (24 to 35-year-old)

COGNITIVE LOAD MEASUREMENT

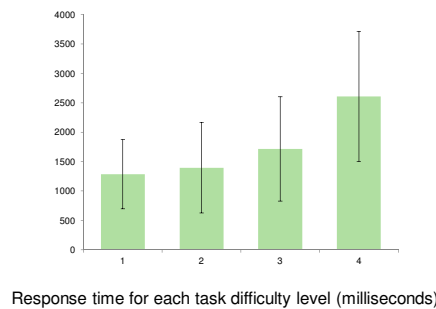
Subjective Rating



- One-way analysis of variance (ANOVA) on the self-reporting scores showed a highly significant difference between task levels ($F_{3,48}=108.63, p<0.05$).

Response Time

- Time between *disappearing the last (fourth) number* of the task and *selecting the answer*
- Response time has a direct relation with the task difficulty level.

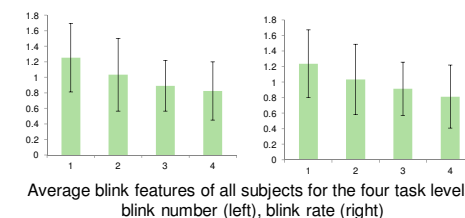
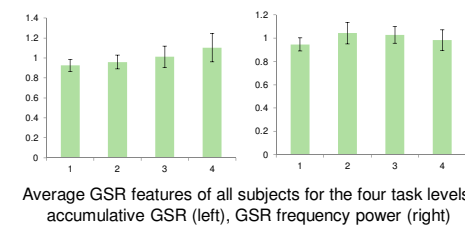


- Results of ANOVA test on response time of different task levels are significant ($F_{3,48}=62.59, p<0.05$).

- These observations about subjective rating and response time show that the designed tasks have effectively manipulated the cognitive load.

GSR and Blink Features

- Two GSR and two blink features were calculated for each task:
 - accumulative GSR (summation of GSR values over task time)
 - GSR power spectrum (frequency power)
 - blink number (number of blinks in the task)
 - blink rate (number of blinks in the task divided by task time)
- Values of each feature averaged between tasks with same difficulty levels for each subject
- Feature normalisation to omit subject-dependency



- Statistically significant results for all the features:

Feature	Results
Accumulative GSR	$F_{3,48} = 7.22, p < 0.05$
GSR Frequency Power	$F_{3,48} = 4.07, p < 0.05$
Blink Number	$F_{3,48} = 3.37, p < 0.05$
Blink Rate	$F_{3,48} = 3.22, p < 0.05$

ANOVA results of features for four task difficulty levels

COGNITIVE LOAD CLASSIFICATION

Methods

- Classification algorithms:
 - Support vector machines (SVM)
 - Naïve Bayes classifiers
- Cross validation method:
 - Leave-one-subject-out
- Four-class classification and binary classification (considering levels 1 and 2 as low load and levels 3 and 4 as high load)
- Combining GSR and blink features

Results

Classification Algorithm	2-Class Classification	4-Class Classification
SVM	66.4%	34.6%
Naïve Bayes	71.2%	40.4%

Classification accuracies of accumulative GSR

Classification Algorithm	2-Class Classification	4-Class Classification
SVM	66.4%	37.5%
Naïve Bayes	65.4%	35.6%

Classification accuracies of GSR frequency power

Classification Algorithm	2-Class Classification	4-Class Classification
SVM	62.5%	40.0%
Naïve Bayes	62.5%	40.0%

Classification accuracies of blink number

Classification Algorithm	2-Class Classification	4-Class Classification
SVM	57.5%	31.3%
Naïve Bayes	55.0%	32.5%

Classification accuracies of blink rate

- Feature combination improved accuracy:

Classification Algorithm	2-Class Classification	4-Class Classification
SVM	71.5%	53.6%
Naïve Bayes	75.0%	50.0%

Classification accuracies of blink number + GSR frequency power

Publications:

N. Nourbakhsh, Y. Wang, F. Chen, R. A. Calvo. *Using Galvanic Skin Response for Cognitive Load Measurement in Arithmetic and Reading Tasks*, In Proc. OzCHI 2012, 26-30th November 2012, Melbourne, Australia, pp. 420-423, ACM Press (2012).

N. Nourbakhsh, Y. Wang, F. Chen. *GSR and Blink features for Cognitive Load Classification*, INTERACT 2013, Part I, LNCS 8117, pp. 159-166, Springer (2013).

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