An Estimation Method of Intellectual Work Performance by Using Physiological Indices

Agenda

1. Background / Purpose
2. Method
3. Experiment
4. Result / Discussion
5. Future

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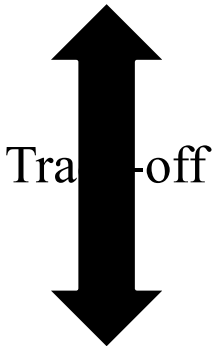
Background

Less-Energy



The improvement of Intellectual productivity

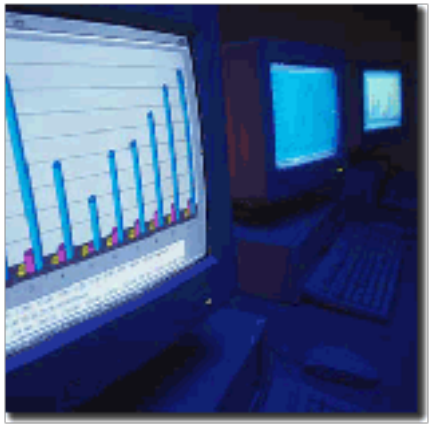
The evaluation method of Intellectual productivity is required

■Requirements
The evaluation can be performed …
- under the environment like office
- by using various cognitive tasks

■the evaluation by using contactless-measurable physiological indices is suitable
- These indices can be measured under various environments.
- They reflect cognitive load
- × There is few method which can evaluate intellectual productivity directly with these indices

Purpose

- The task performance evaluation method by using physiological indices

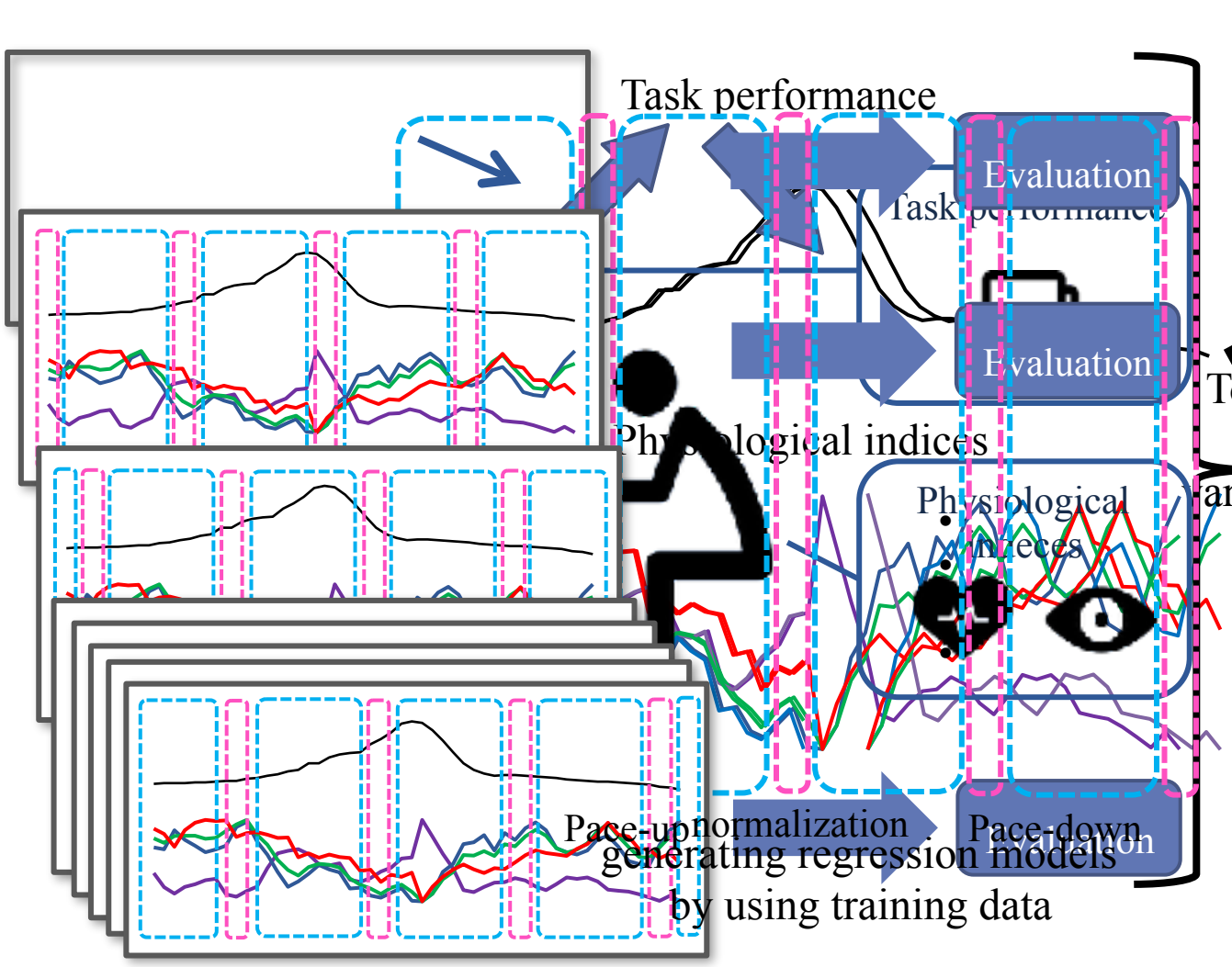


The method…

- evaluates the performance of cognitive task simulating office work
- employs machine learning : SVR, Random forest
- employs pupil diameter and heart rate variability because they are contactless-measurable

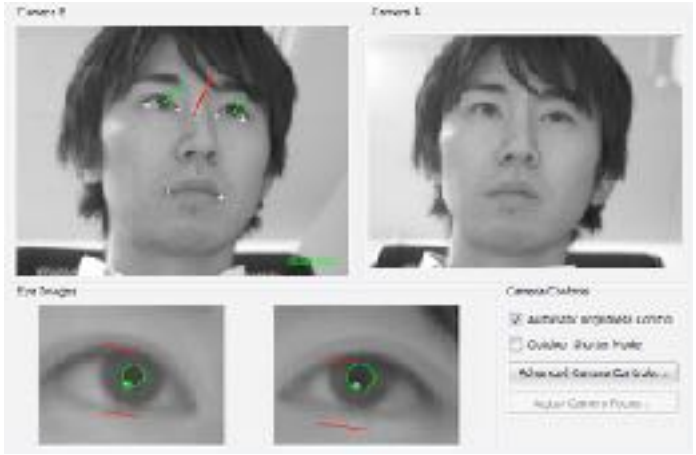
If the method can be developed,
intellectual productivity can be employed as the control variable of the control system such as
BEMS (:building energy management system)

Method：Overview



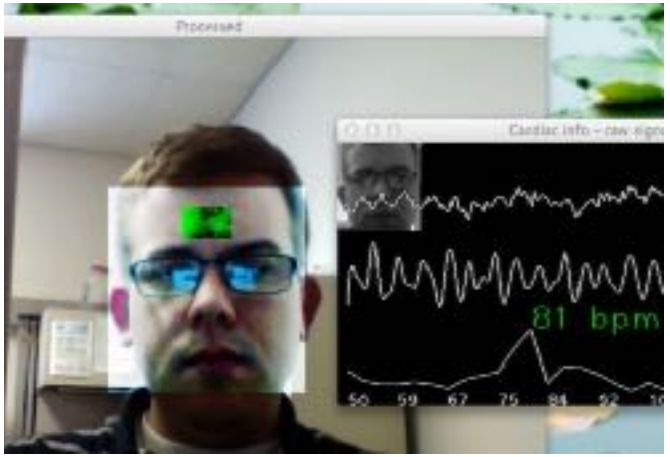
Physiological indices

- Pupil diameter



Measurement with
Infrared camera

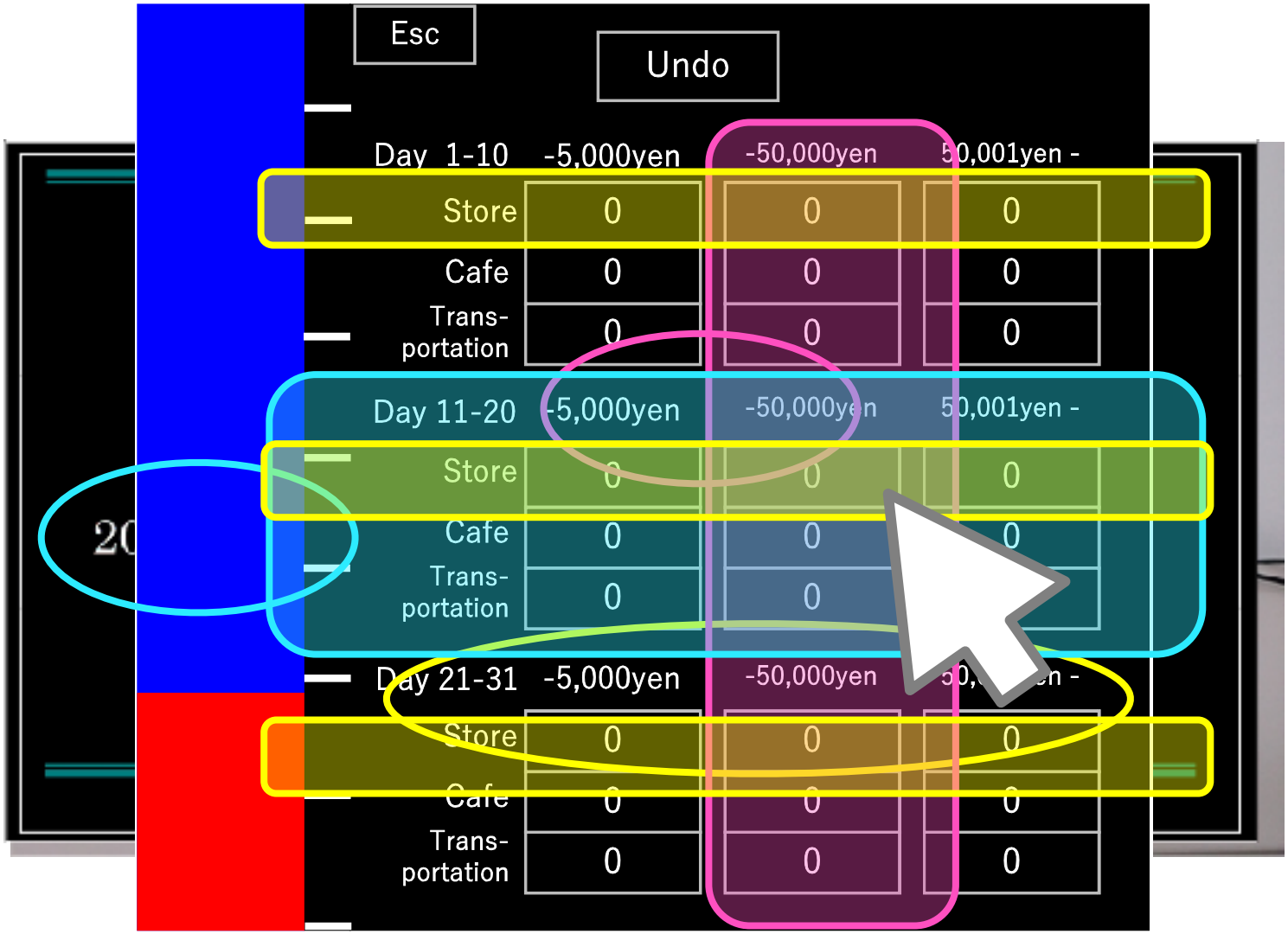
- Heart rate variability



Measurable by using camera
(future)
This study employed electrodes

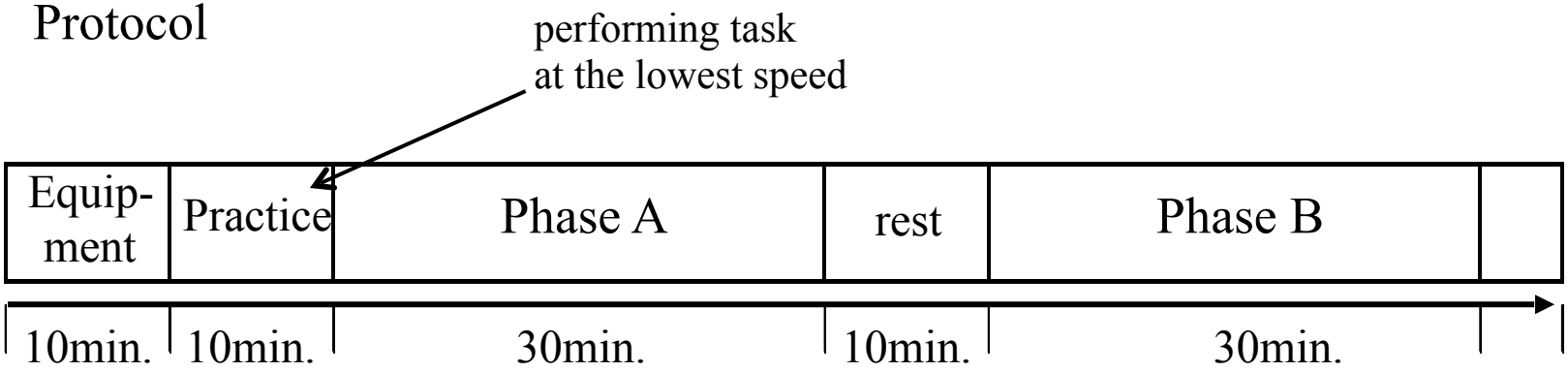
- The feature values were extracted in 5-minute timeframe with shifting it every 1 minute.

Cognitive task – Receipt Classification Task



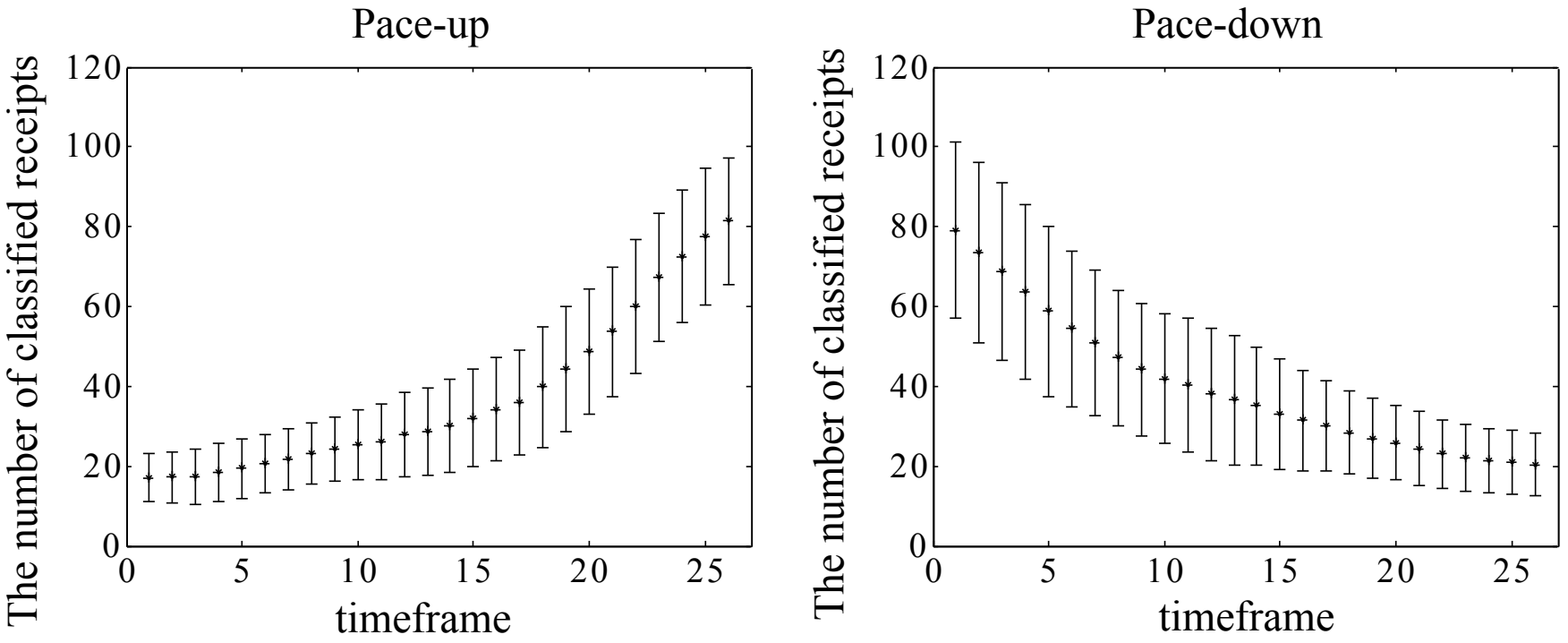
Experiment

- Protocol



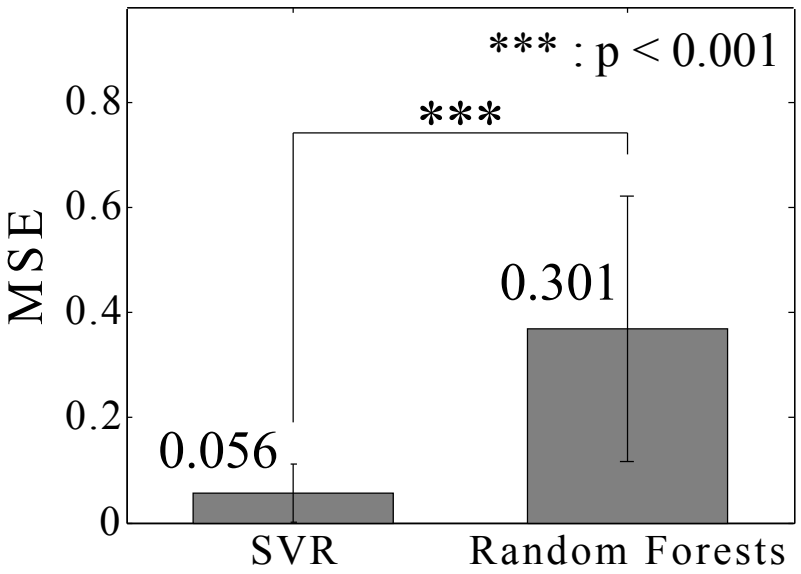
- 1st day…practice 2nd day…measurement (described above)
- 27 Japanese university students participated
- In the practice, the participants were instructed to perform the task at the slowest speed.
- Phase A : either Pace-up or Pace-down Phase at random
  Phase B : the other
  (to get counterbalance of ordering effect)

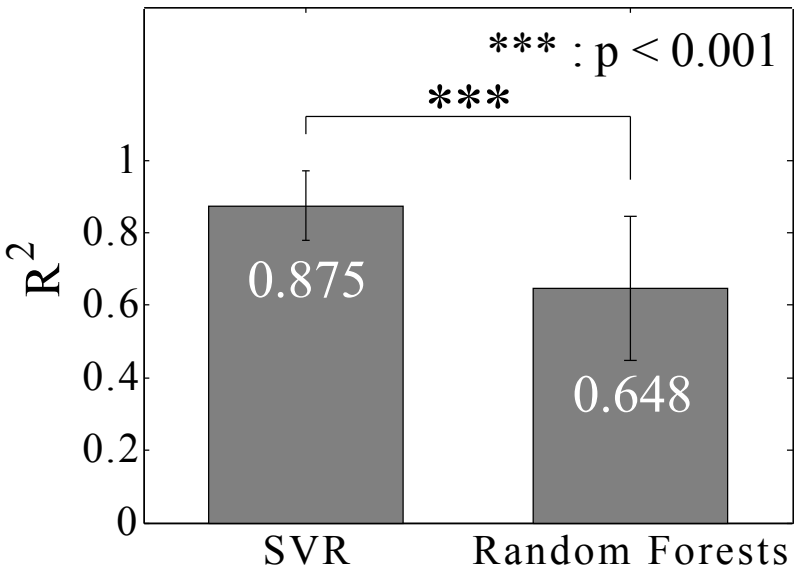
Result : task performance



- It was confirmed that both Pace-up and Pace-down were performed properly

result: accuracy of 2 machine learning models





- The accuracy of SVR was higher significantly than that of Random Forests

Result : coefficients of feature variables

- Pupil diameter had positive correlation with task performance
  - The result was supported by the study conducted by Poock [1]
- Heart rate variability had negative correlation.
  - According to Mulder [2], the higher the difficulty of a cognitive task gets, the lower the power of LF gets. The result supports this.

Average of coefficients of feature variables

Pupil diameter	LF	LF/HF	HF
2.00	**-0.98**	-0.71	-0.27

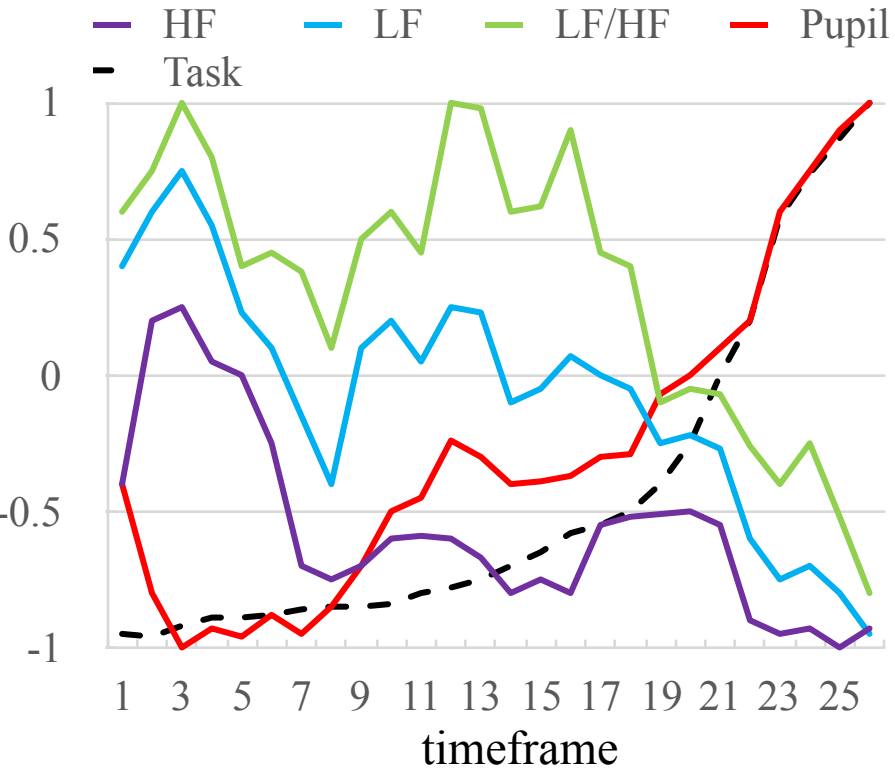
[1] Gary K. Poock: Information processing vs pupil diameter. Perceptual and Motor Skills, 37(3), pp. 1000–1002 (1973).
[2] Gijsbertus Mulder, Lambertus J. M. Mulder: Information Processing and Cardiovascular Control. Psychophysiology, 18(4), pp. 392–402 (1981).

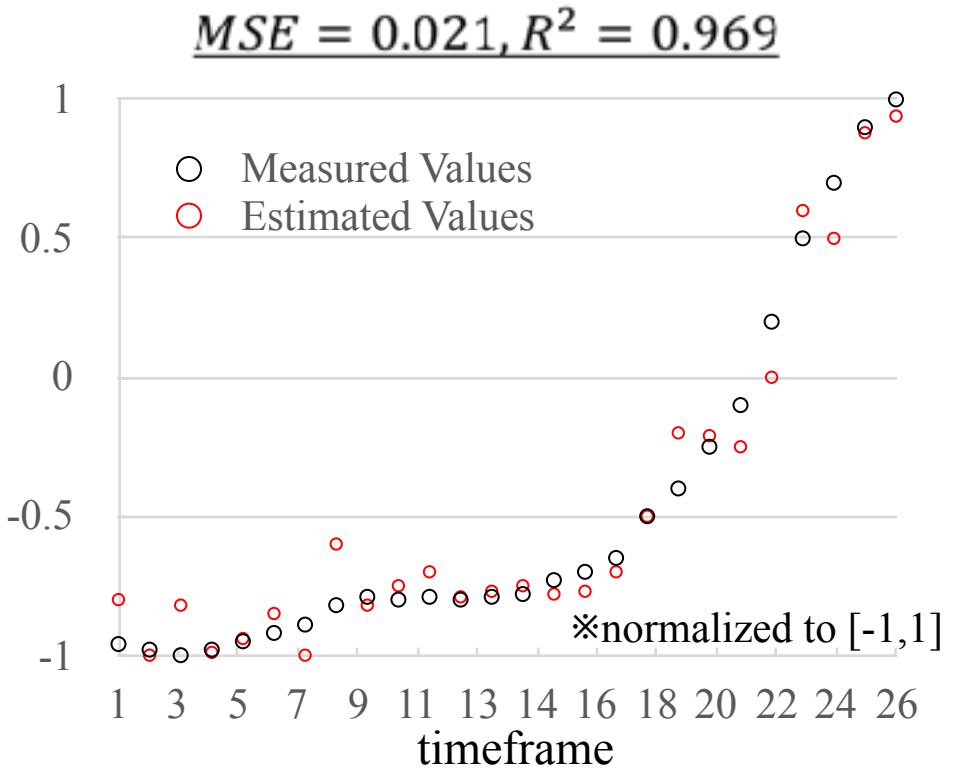
Discussion: the effect of multivariate regression model - pupil diameter

plural feature variables can deal with individual differences

Subject No.10 :
Ex. High contribution of pupil diameter

Pupil diameter	LF	LF/HF	HF
3.66	0.51	-0.66	-0.99



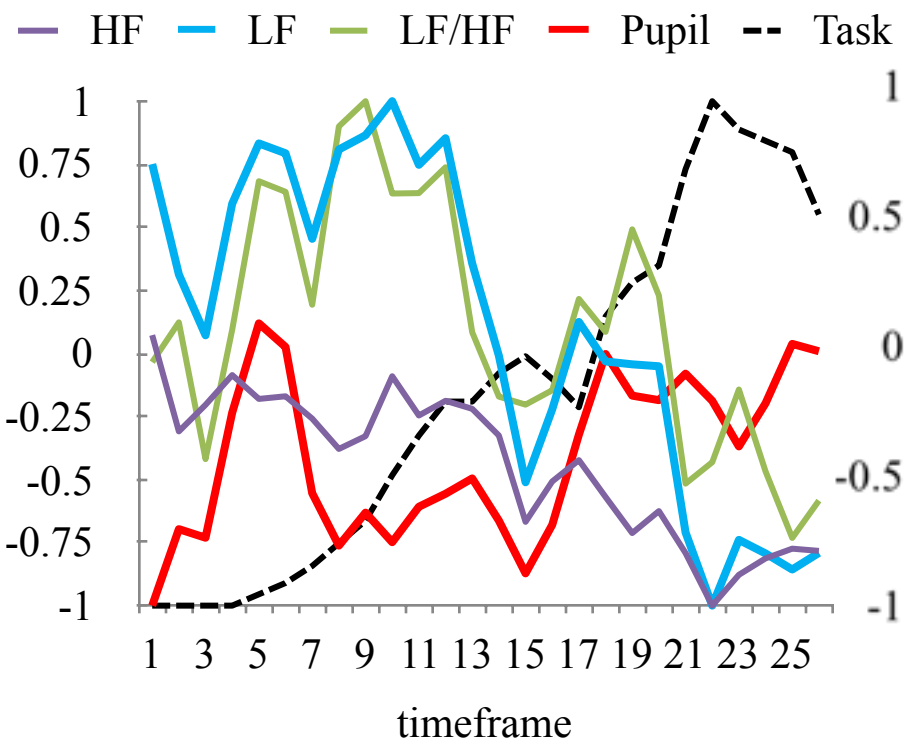


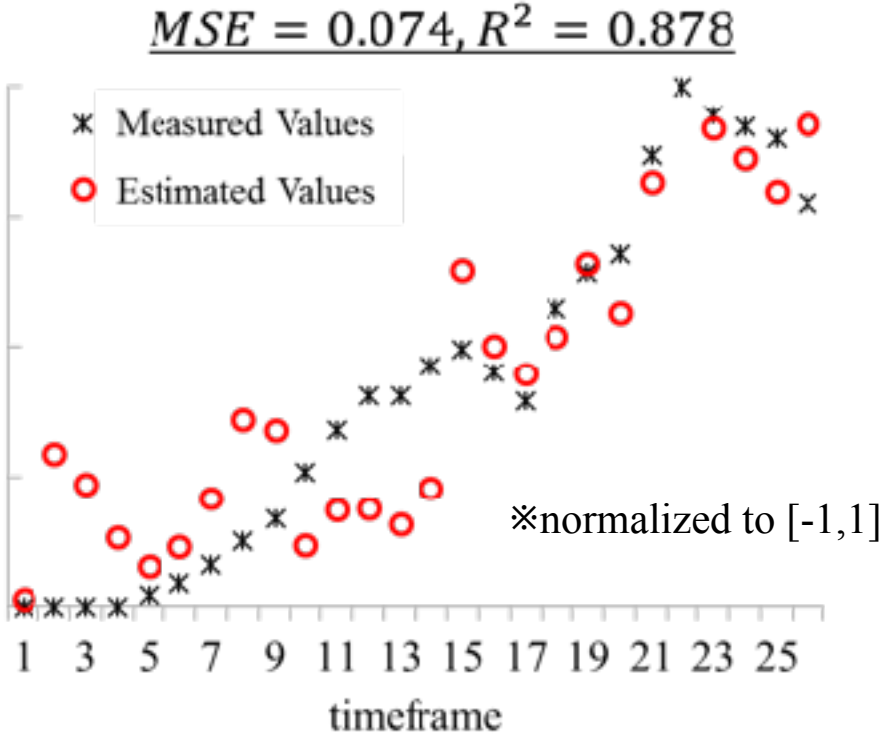
Discussion: the effect of multivariate regression model – Heart rate variability

plural feature variables can deal with individual differences

Subject No.4 :
Ex. Low contribution of pupil diameter , High contribution of heart rate variability

Pupil diameter	LF	LF/HF	HF
-0.02	-3.05	-2.06	-3.38





Conclusion

- The accuracy of SVR was significantly higher than Random forest
- Multivariate regression model
  - Pupil diameter had high contribution to the model
  - Heart rate variability had high contribution while low contribution of pupil diameter was found in some subjects.

➢ Multivariate regression model can deal with individual difference.

- In order to develop the more quantitative and objective evaluation method

Need to consider…

- the stress effect in long term measurement.
- the accuracy of this model by using various cognitive tasks

Thank you for your attention

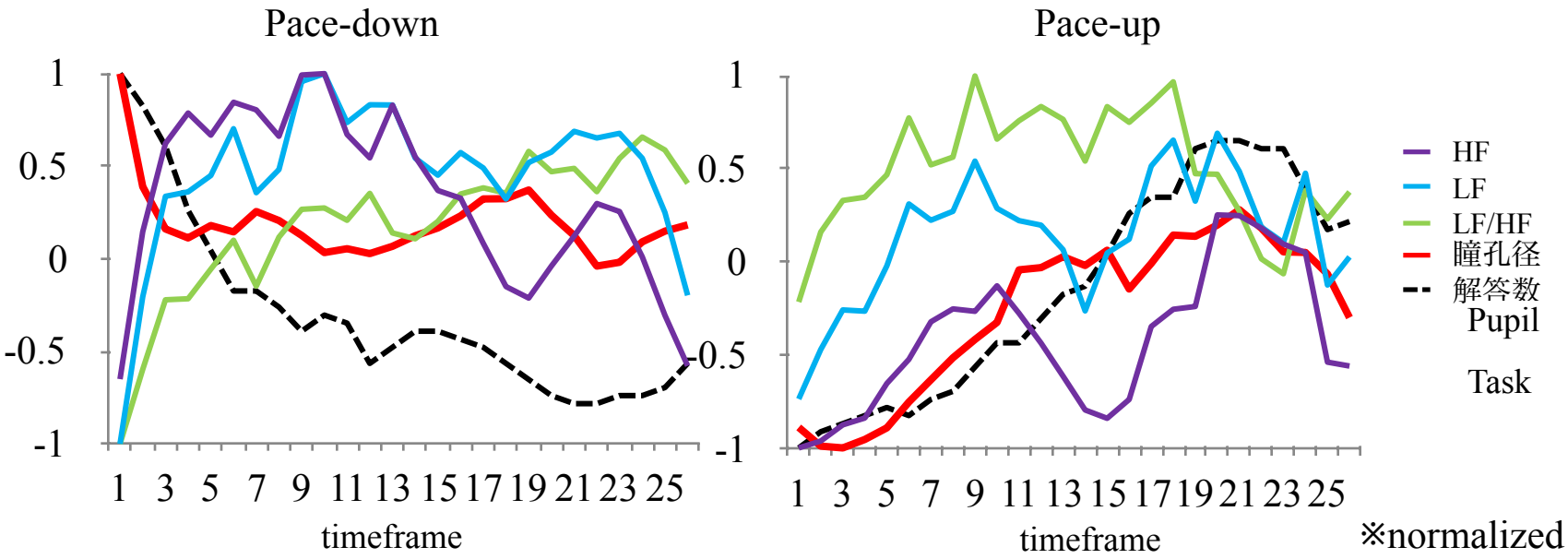
Discussion: Stress affects the accuracy of models

Stress changes the physiological responses, which affects the accuracy of models

Ex. The case of low estimation accuracy

- The proposed method (SVR)
- After adding dummy variable D
  D = 1 (Pace-up), -1 (Pace-down)

$MSE = 0.167, R^2 = 0.608$
$MSE = 0.053, R^2 = 0.917$



※normalized to [-1,1]

SVRのパラメータ

- カーネル：ガウシアンカーネル
- パラメータ探索範囲…$10^3 = 1000$パターン
  - $-3 \leq \log_2 C \leq 6$　(マージンから逸脱した場合のペナルティの大きさ)
  - $-6 \leq \log_2 \sigma \leq 3$　(ガウシアンカーネルの形状)
  - $-10 \leq \log_2 \varepsilon \leq -1$　(許容範囲の広さ)
- 探索範囲の影響
  - 探索範囲を2倍、探索幅を1/2（$40^3 = 64000$パターン）にして推定精度の低かった3名の被験者で再度推定精度をEvaluation

	拡大前	拡大後
MSE	0.188	0.186
R^2	0.652	0.660