# Modeling of Mood States Using Multimodal Biometric Data

**HITACHI Inspire the Next**

A. Obata[a*], M. Kiguchi[a], S. Sutoko[a], H. Atsumori[a], A. Nishimura[a], T. Funane[a], H. Nakagawa[b], M. Egi[b], H. Kuriyama[c]

[a] Center for Exploratory Research, Research and Development Group, Hitachi, Ltd., Japan  [b] Center for Technology Innovation, Research and Development Group, Hitachi, Ltd., Japan
[c] Global Center for Social Innovation, Research and Development Group, Hitachi, Ltd., Japan

## Introduction

- Problem : Productivity loss due to the presentism.
- Demand : Care program for workers preventing mental disorders.
- Solution : Mental state monitoring and care using quantitative biometric measurement and AI.

## Mental Healthcare System

- Biometric measurement data and questionnaire scores are accumulated in the database.
- Mental states, care and suggestion were shown to the user, his both and his industrial doctor.
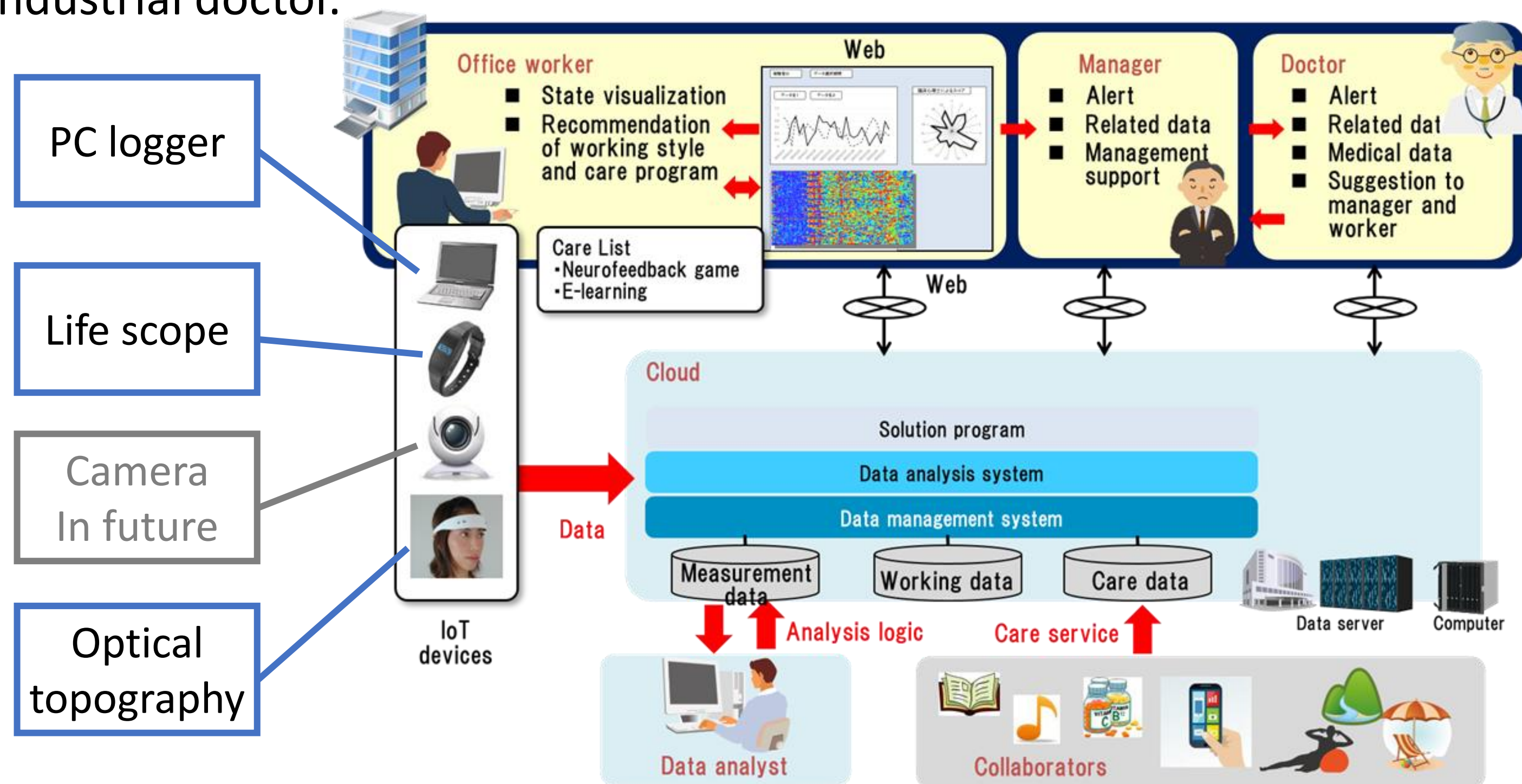


Fig.1 Structure of mental healthcare system.

## Quantitative Biometric Measurements

### 1. Optical topography (OT) : Brain indicator

- Brain index calculated from activation during working memory task correlated with depressive mood score.
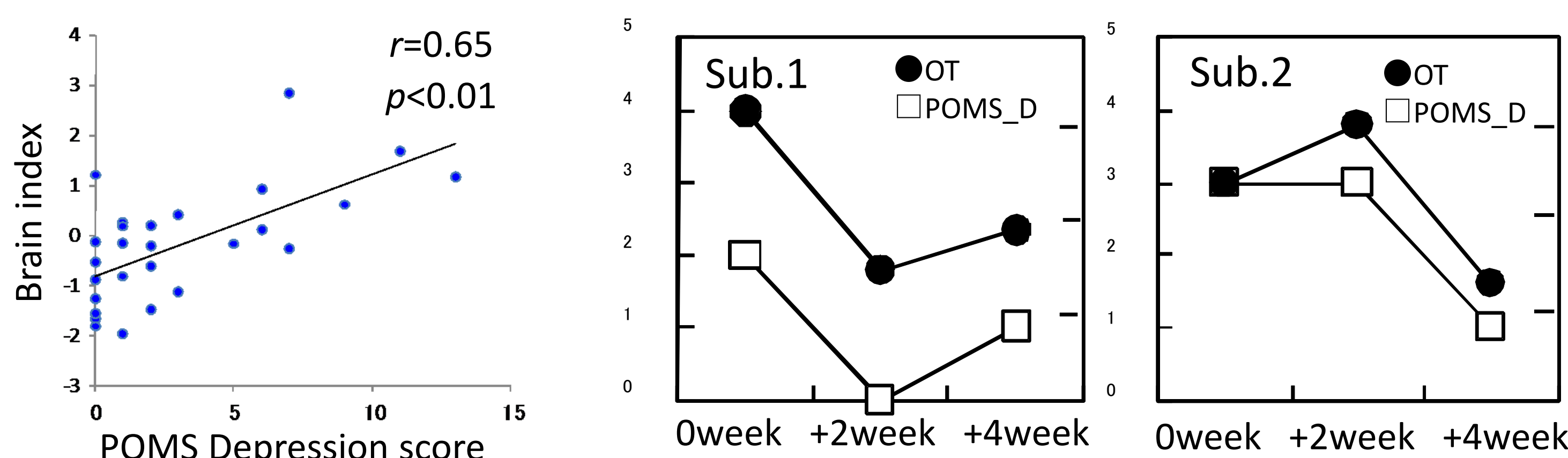


$r=0.65$
$p<0.01$

Fig.2 Brain index and depressive mood.

H Sato, et al., J Biomed Opt 16 (2011) 126007.  H Sato, et al., Front. Neurosci. 8 (2014) 37.

### 2. Life scope (LS) : Life-style

- Log visualizes the daily rhythm.
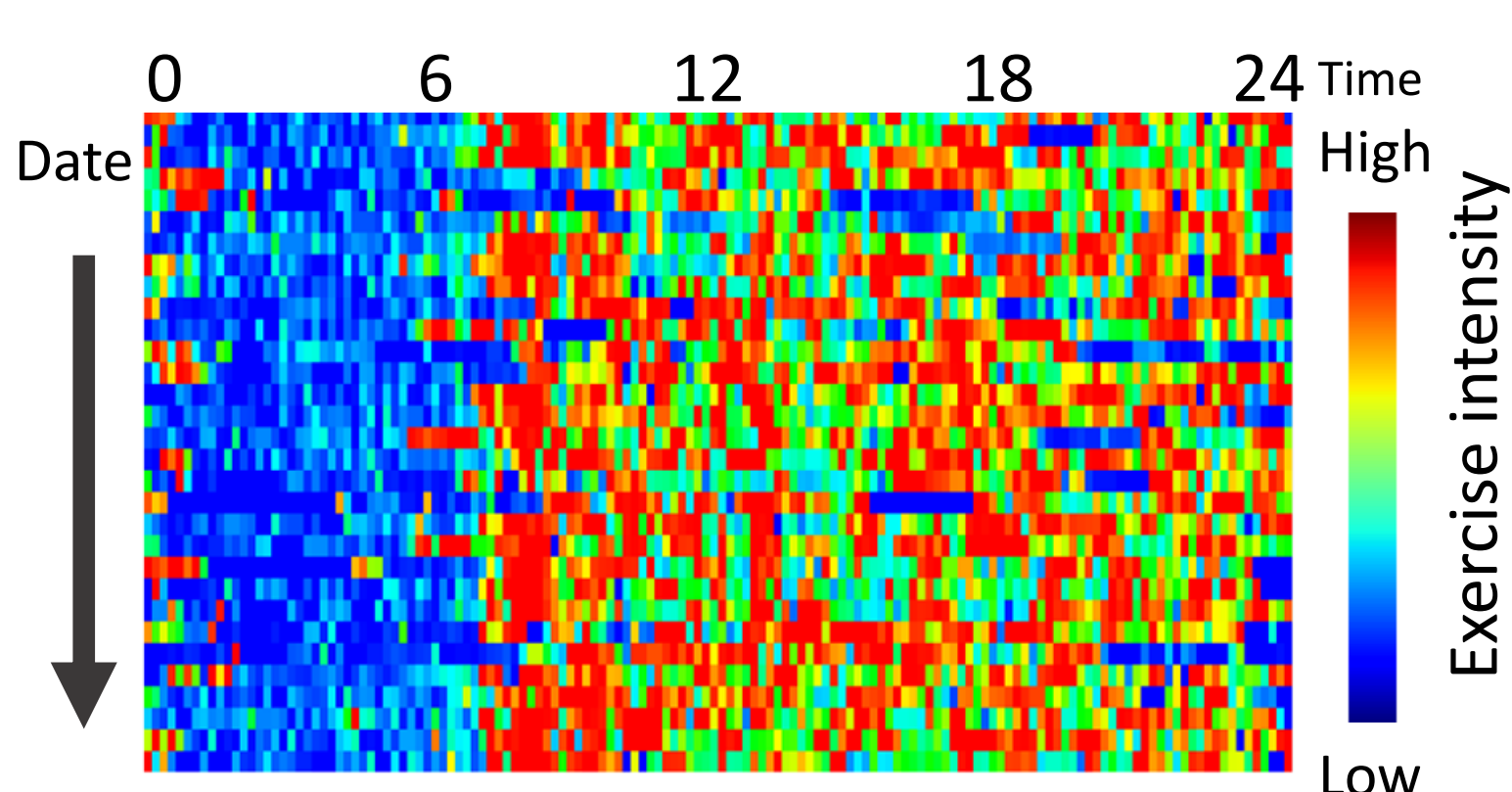- Effective tool for judgement of return to work from mental illness.



Fig.3 Life-style log.

Fig.4 Return-to-work support.

H Kuriyama, et al., 70th National Industrial Safety and Health Convention (2011).
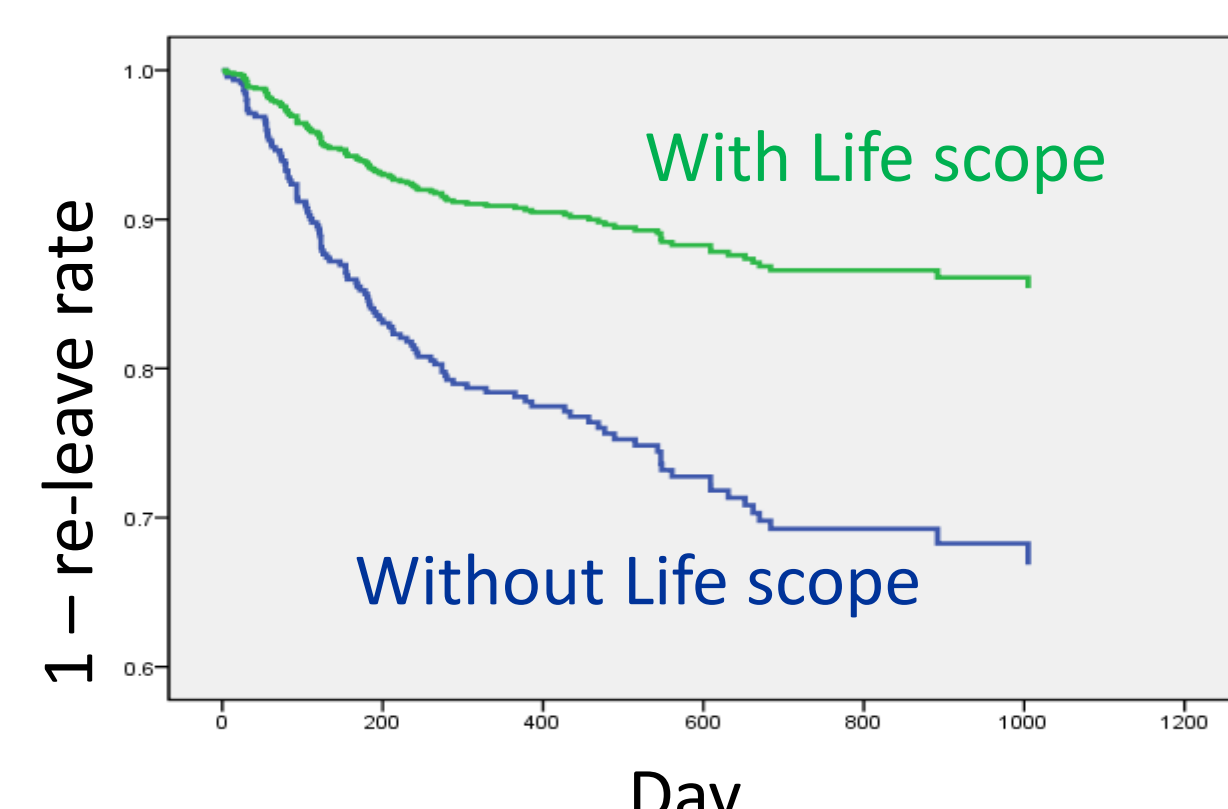
### 3. PC logger : Work-style

- Fractal dimension (keyboard and mouse) obtained using PC log depended on the mood state scores.



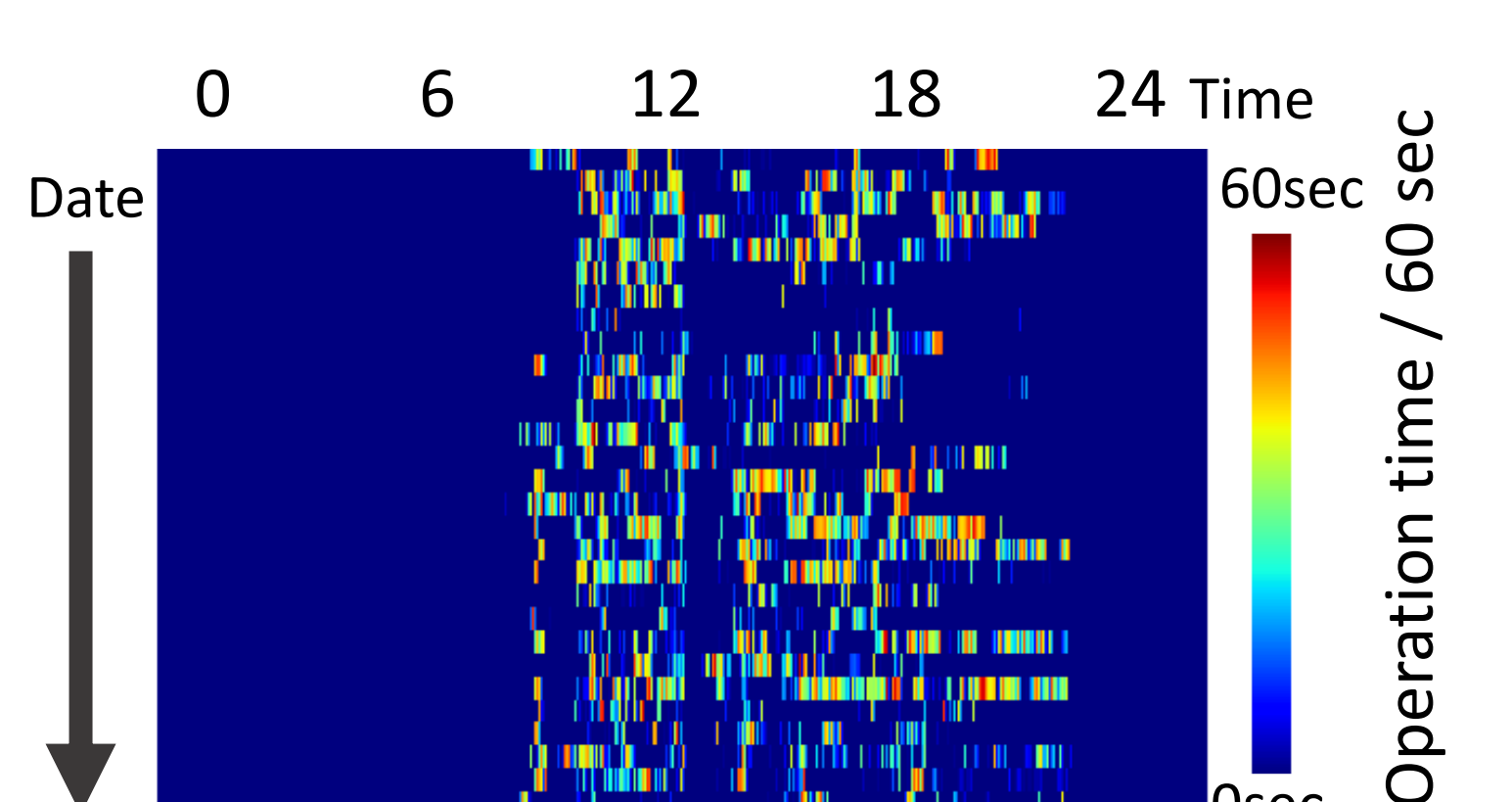Slope (fractal dimension) correlated with mood state scores

Power law

Fig.5 Work-style log.

Fig.6 Fractal dimension.

M Egi, et al., Econophysics and Its Related Topics Workshop (2015).
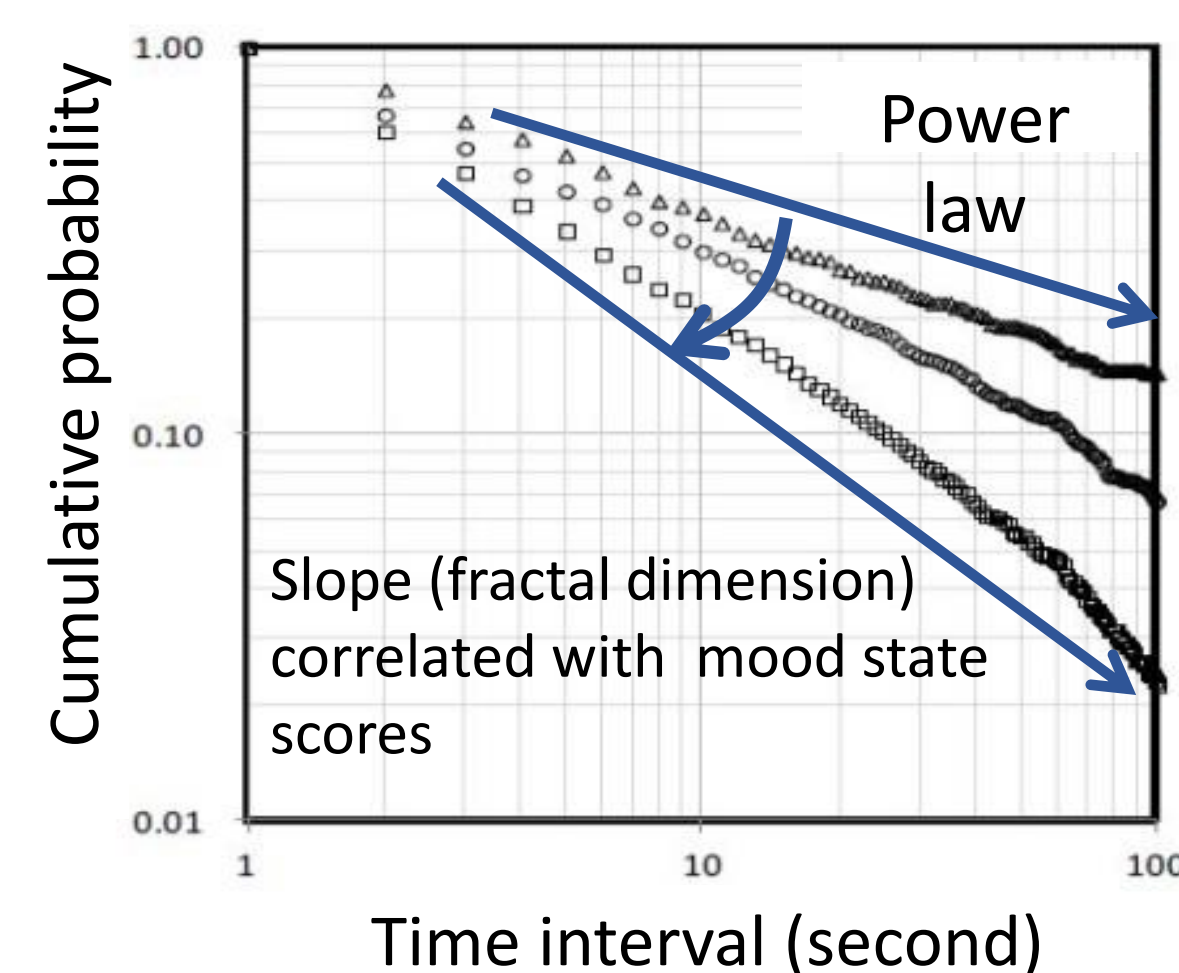
## Field Trial

- Biomedical data and questionnaire scores were collected from 39 healthy participants during 14 weeks.

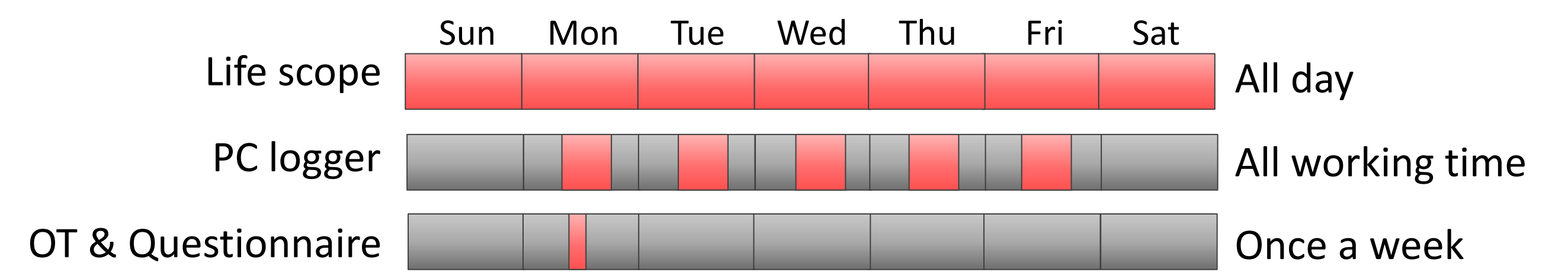

Fig.7  Example of measurement pattern.

Table1  Measurement items and the number of index.

| Measurement item | Index | Measurement item | Index |
|---|---|---|---|
| Optical topography | 12 | Brief Job Stress Questionnaire* | 6 |
| Life scope | 3 | Kessler Psychological Distress Scale* | 1 |
| PC logger | 2 | * Questionnaire | |

## Results

### 1. T-test between the upper and lower groups

- Groups were categorized by median of questionnaire's scores.
- Significant relationship between each measurement index and each score of questionnaire was obtained.

Table 2  Each biometric index with the largest effect size for each questionnaire score.

| Questionnaires | Biometric measurement | P-values of t-test and Effect sizes (Cohen's d) | |
|---|---|---|---|
| Depression | Fractal dimension (keyboard) | $p<0.0001$ | $d=-0.656$ |
| K6 | | $p=0.017$ | $d=-0.416$ |
| Lassitude | Spatial reaction time | $p=0.001$ | $d=0.559$ |
| Physical stress response | Sleeping time | $p=0.003$ | $d=-0.603$ |
| Irritation | Difference of spatial vs. verbal at ch2 | $p=0.005$ | $d=0.484$ |
| Fatigue | Bilateral difference of verbal brain activity | $p=0.008$ | $d=-0.447$ |
| Anxiety | Verbal reaction time | $p=0.007$ | $d=-0.449$ |



$p<0.0001$
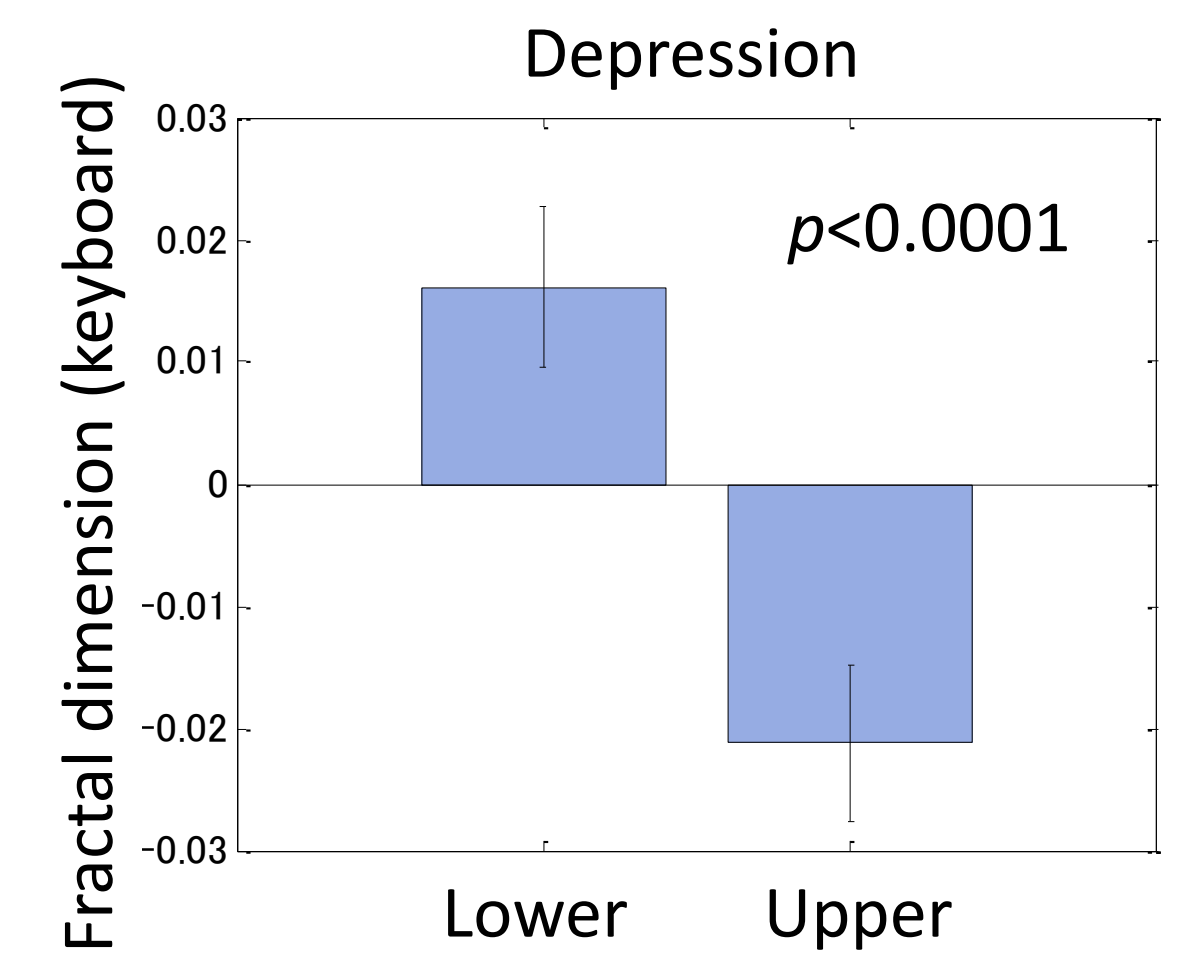
Fig.8 T-test of Fractal dimension (keyboard) and Depression.

### 2. Mental state classification

- Data-driven analysis using a cluster analysis ($k$-means method).
- Easy to monitor mental state changes due to the reduced amount of information.
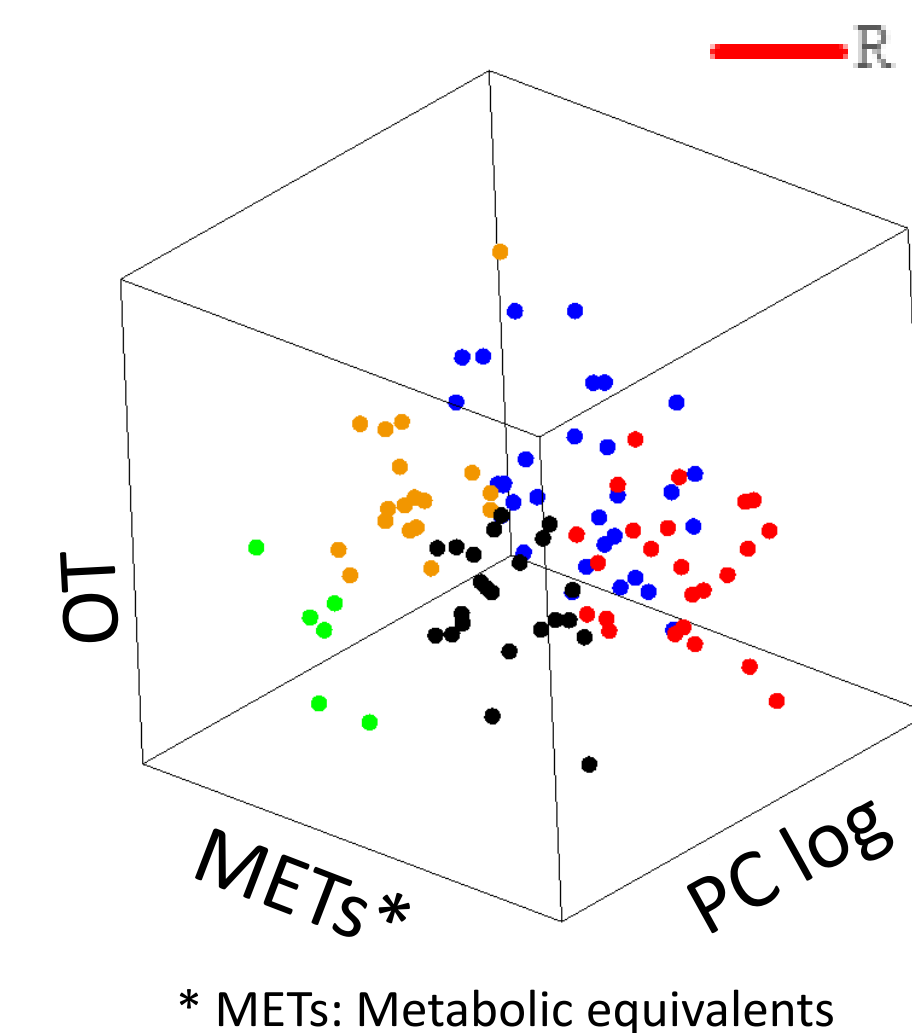


* METs: Metabolic equivalents

Fig.9  Five clusters classified by OT, METs and PC log data.
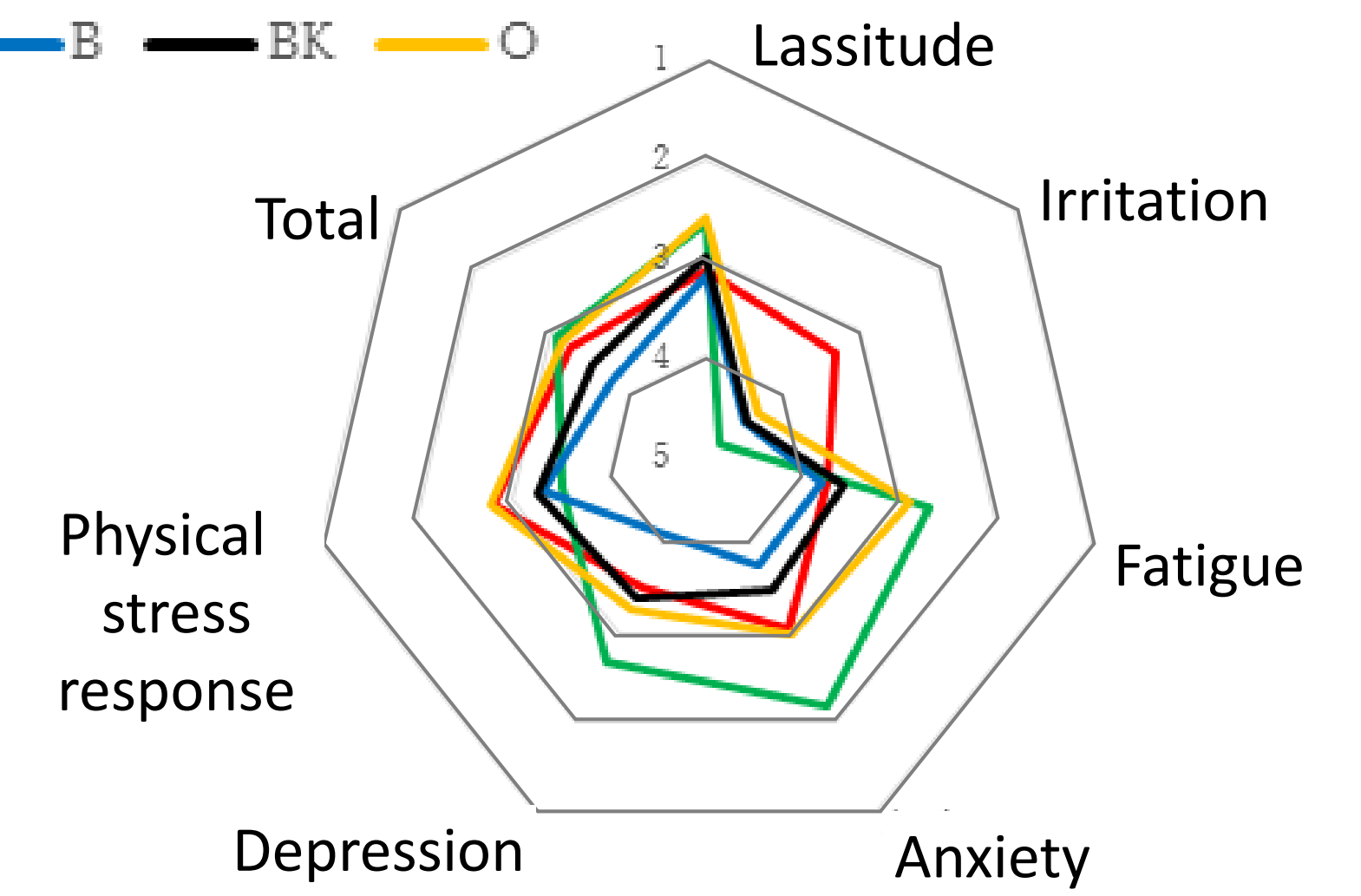
Fig.10  Comparison of psychological and physical response in five clusters.

### 3. Estimation of mental scores

- Linear multiple regression model obtained by the subject-wise three-fold cross validation.
- K6 was estimated by using biometric data obtained 1-2 weeks before.



$r = 0.76$
error = 5.2

$r = 0.77$
error = 2.9

$BJS = -4.79 + 0.135\ LS\_sleep\_0w + 1.28\ OT\_v\_R\_0w + 0.252\ OT\_s\_L\_2w + 14.3\ OT\_s\_cr\_1w + 0.0116\ OT\_v\_rt\_1w$

$K6 = 8.14 + 0.334\ LS\_sleep\_2w + 0.00702\ OT\_v\_rt\_1w + 27.5\ keylog\_2w + 49.6\ mouselog\_2w$
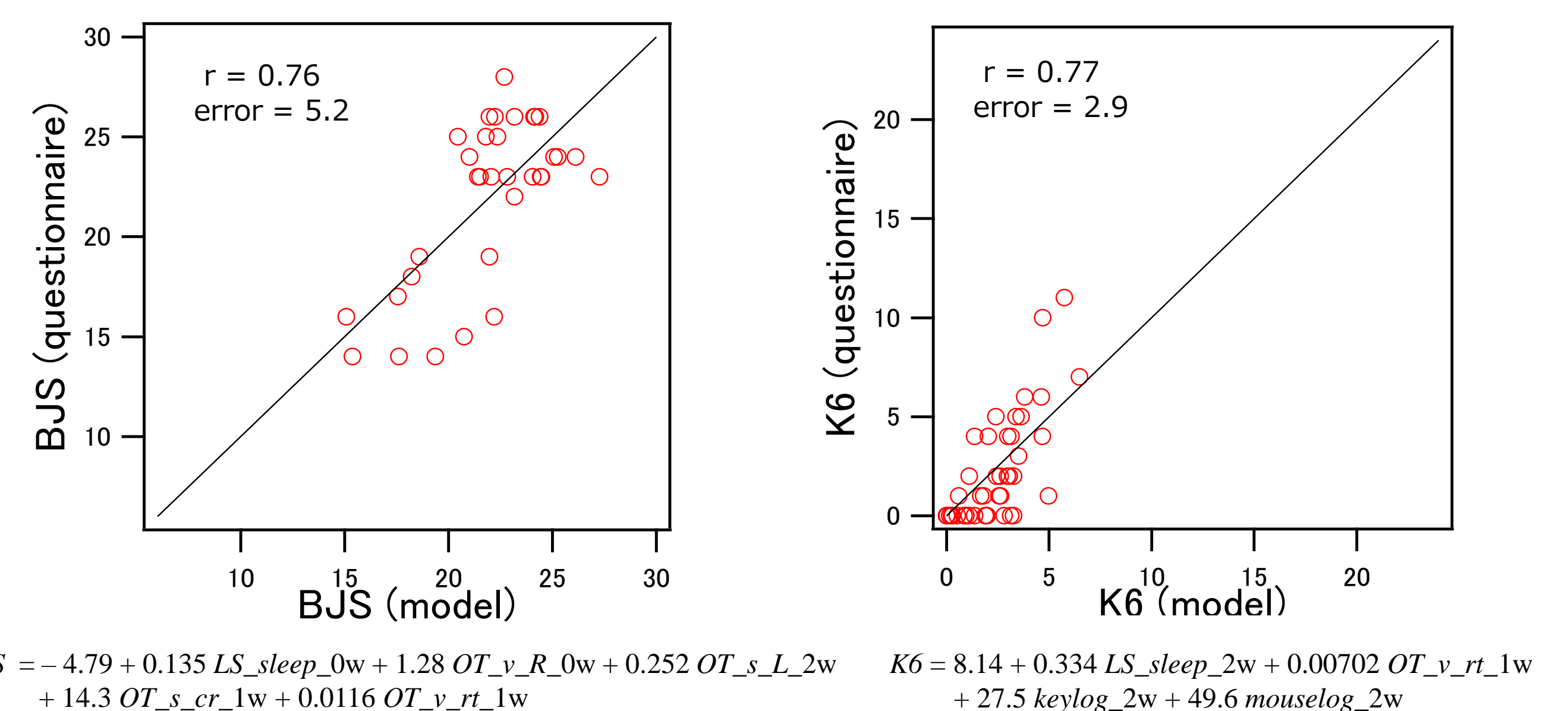
Fig.11  Relationship between BJS/K6 total scores obtained using questionnaire and BJS/K6 total scores estimated using the biometric data.

## Conclusion

- We developed a prototype of a mental health monitoring system with multiple devices, namely, a PC logger, Life scope, and Optical Topography device, which require the small workload.
- Results of field trial showed that the system is potentially compatible with typical care services based on JBS and K6.