Detection of Temporary Rest State when Performing Intelligent Works by Measuring Physiological Indices

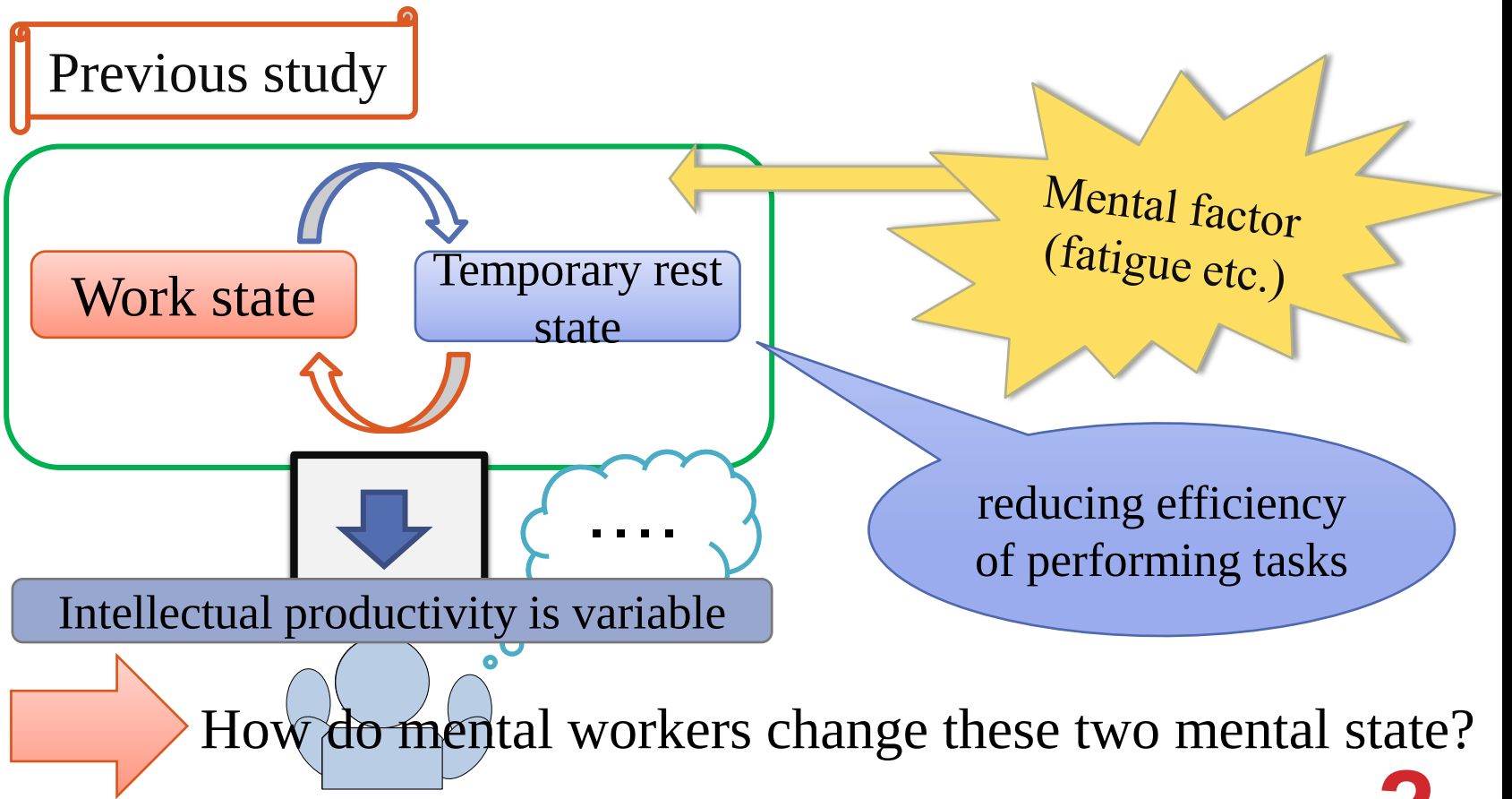
○Shutaro Kunimasa,
Hiroshi Shimoda,
Hirotake Ishii,
Kazune Miyagi,
Graduate School of Energy Science, Kyoto University

Introduce

Many offices are aiming at improving intellectual productivity

However

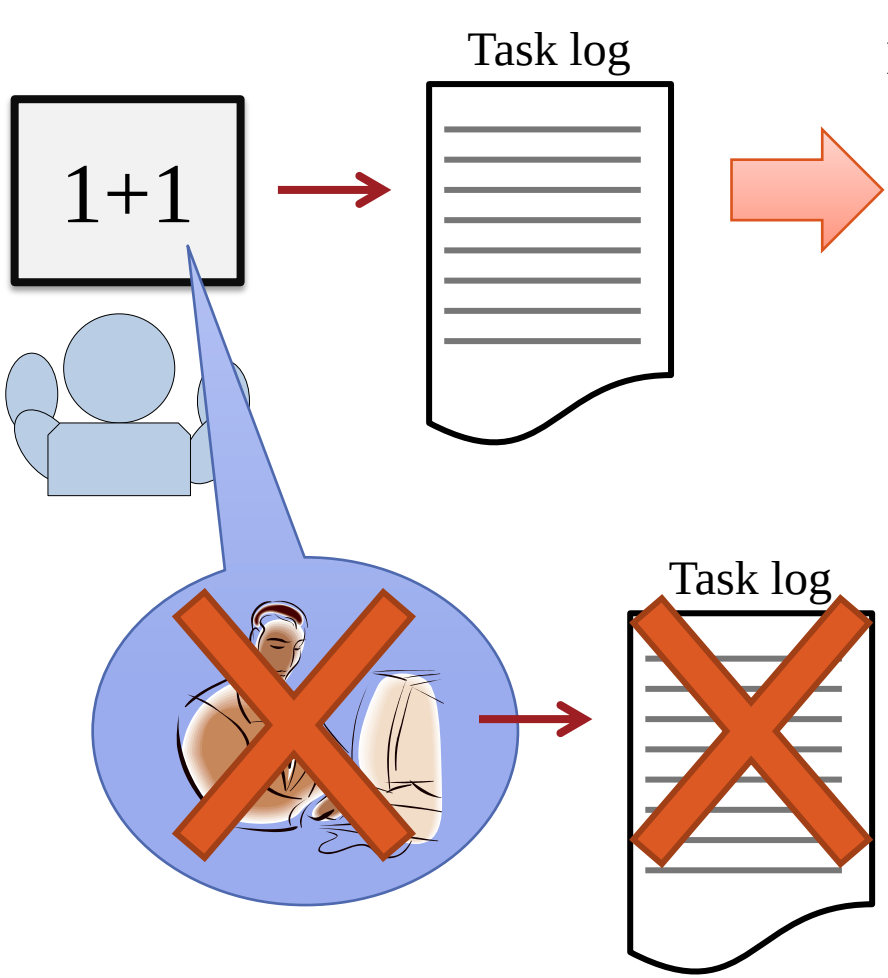
The quantitative evaluation method of intellectual productivity is required

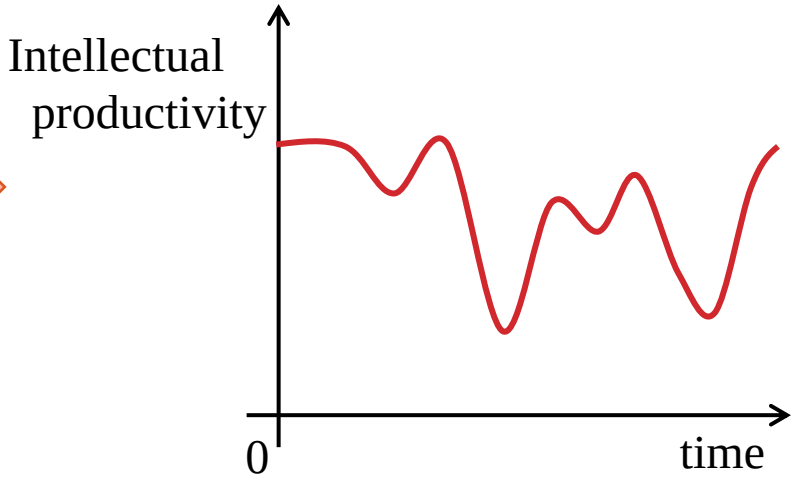


How do mental workers change these two mental state?

Introduce

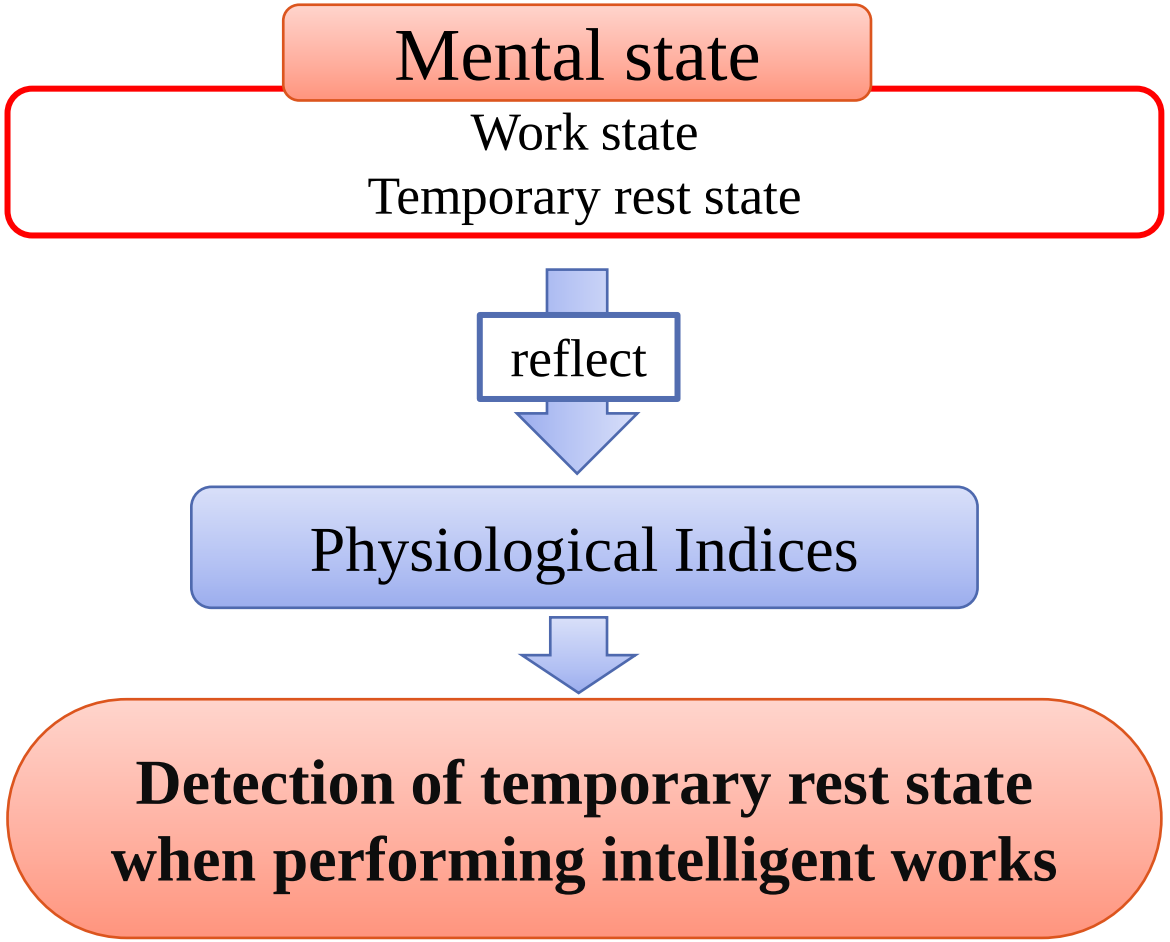
Previous study





- It is desired that mental states of the actual office workers can be detected somehow.

Propose



Evaluation of intellectual productivity in actual office works can be performed.

Physiological indices

ECG — The autonomic nervous system

- Sympathetic nerve
- Parasympathetic nerve

The low (0.05-0.20Hz) and high (0.20-0.35Hz) frequency wave of heart rate

EEG — Brain activity

- α wave
- β wave

Calculated by the power spectrum of EEG (α:8-13Hz β:13-30Hz)

EMG around left eye — Mental state or arousal level

- eye blink
- saccade movement

The frequency of eye blink and saccade movement

- These features change according to mental state
- High temporal resolution (these features is calculated every 2 seconds)
- The load on subjects is light during measurement of these indices

Physiological indices

Physiological indices depend on

subjects or tasks

- The standards of detection is calculated for each subject and task.
- Temporary rest state is detected statistically by using linear discrimination analysis (LDA)

Method of detection

- Explanatory variable vector is calculated every 2 seconds.
- Each variable is physiological feature.

$$\boldsymbol{x}_t = \begin{bmatrix} x_{t1} \\ x_{t2} \\ \vdots \\ x_{tp} \end{bmatrix}$$

- TWO measurements are required.

First measurement: Measuring training data to calculate LDA classifier.

$$\boldsymbol{\mu}^{(k)} = \begin{bmatrix} \mu_1^{(k)} \\ \mu_2^{(k)} \\ \vdots \\ \mu_p^{(k)} \end{bmatrix}$$

Average of explanatory variable in each mental state

$$\Sigma_{(k)} = \begin{bmatrix} \sigma^2_{1(k)} & \sigma_{12(k)} & \cdots & \sigma_{1p(k)} \\ \sigma_{21(k)} & \sigma^2_{2(k)} & \cdots & \sigma_{2p(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{p1(k)} & \sigma_{p2(k)} & \cdots & \sigma^2_{p(k)} \end{bmatrix}$$

Covariance of explanatory variable in each mental state

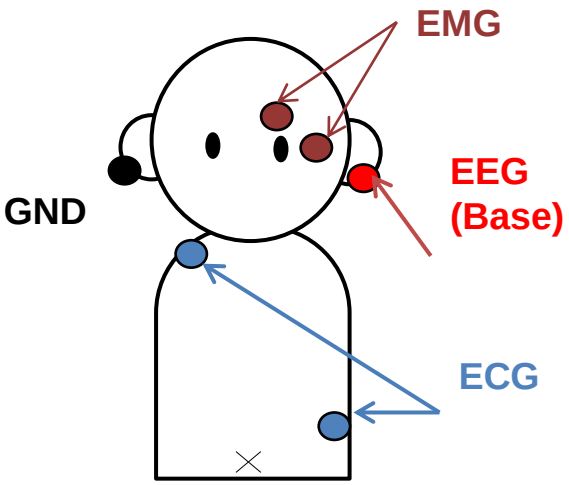
Second measurement: Measuring test data and applying them to classifier

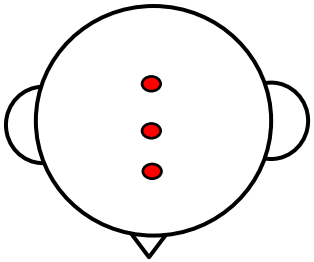
$$D_k^2 = (\boldsymbol{x}_t - \boldsymbol{\mu}^{(k)})' \Sigma_{(k)}^{-1} (\boldsymbol{x}_t - \boldsymbol{\mu}^{(k)})$$

Measurement of physiological indices

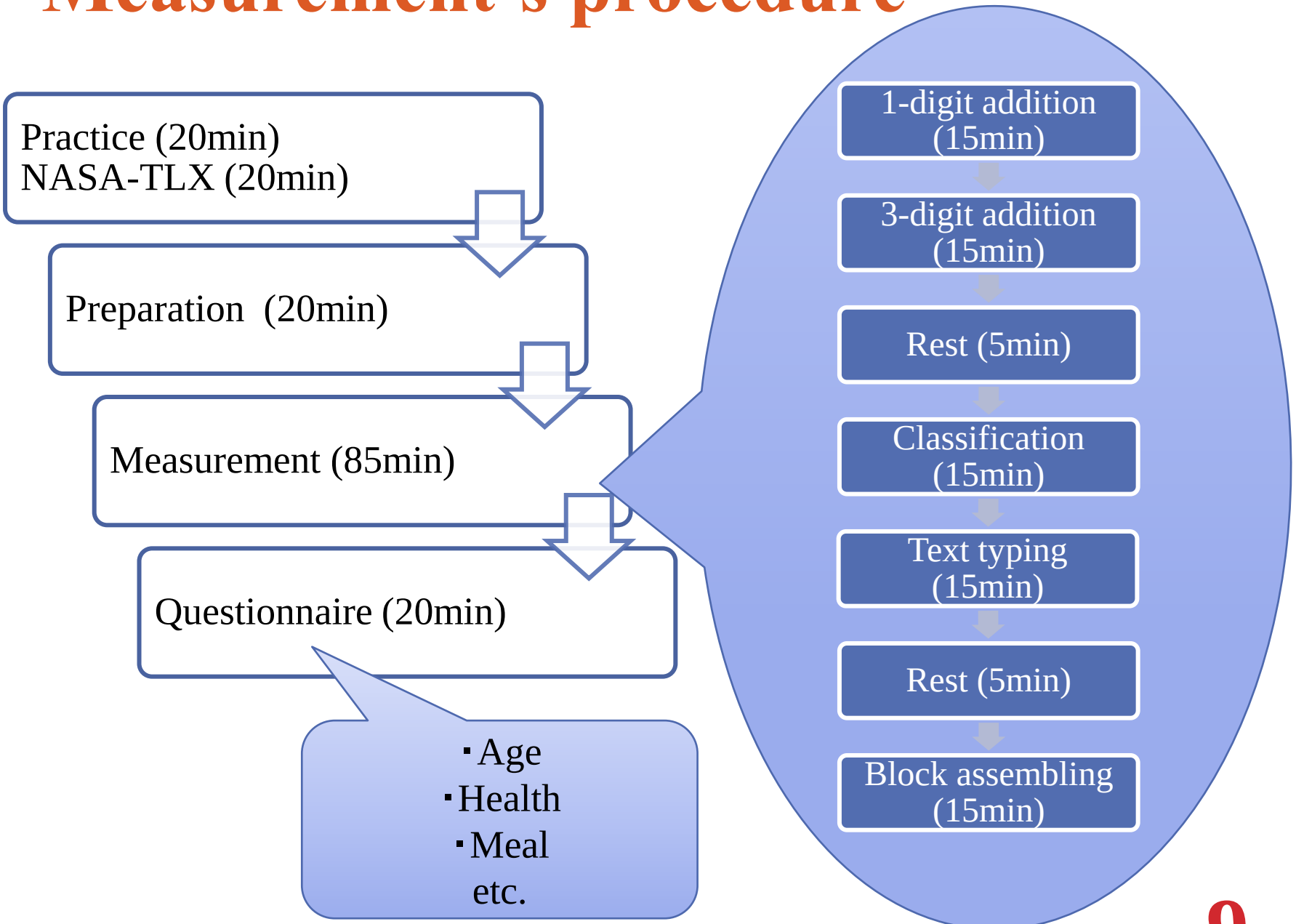
26 subjects (male/university student)
age: 19-25 (average:21)

5 tasks (7.5min/task × 2 measurement=15min)
(1-digit addition, 3-digit addition, classification, block assembling, text typing)





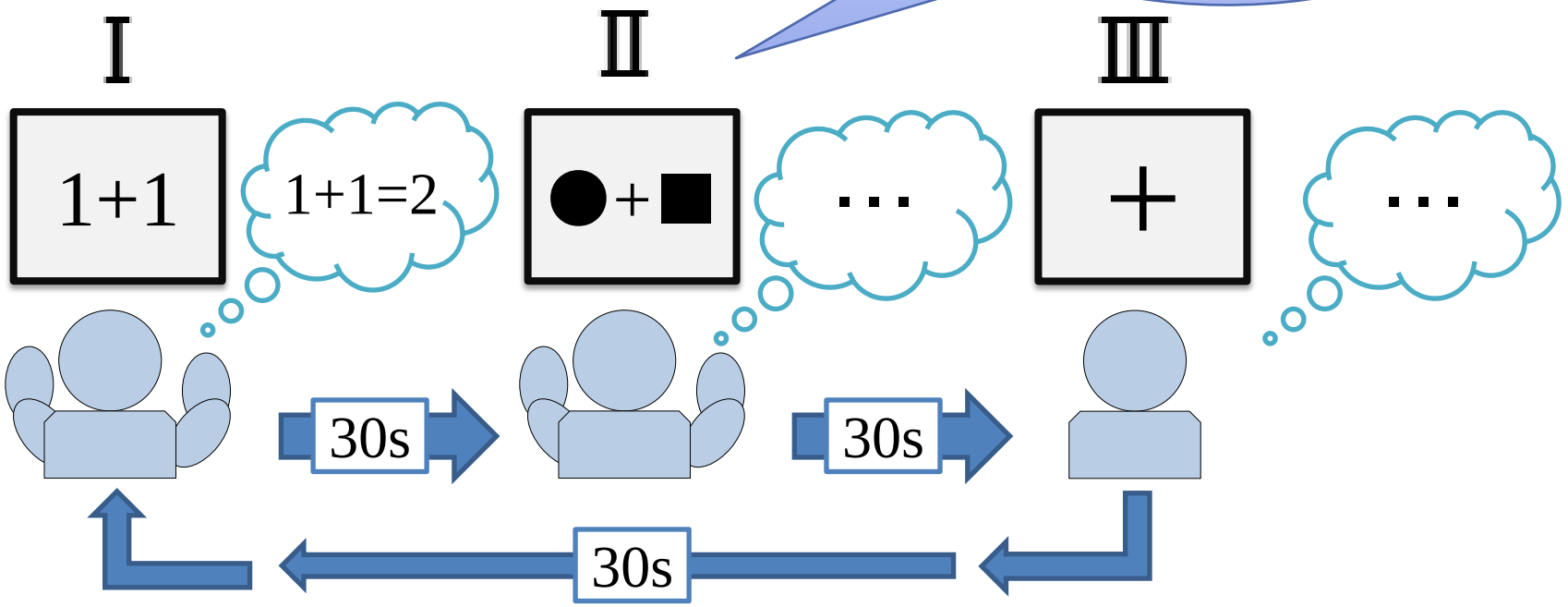
Measurement's procedure



Measurements

Contrastive state to condition Ⅰ

First measurement: Measuring training data to c



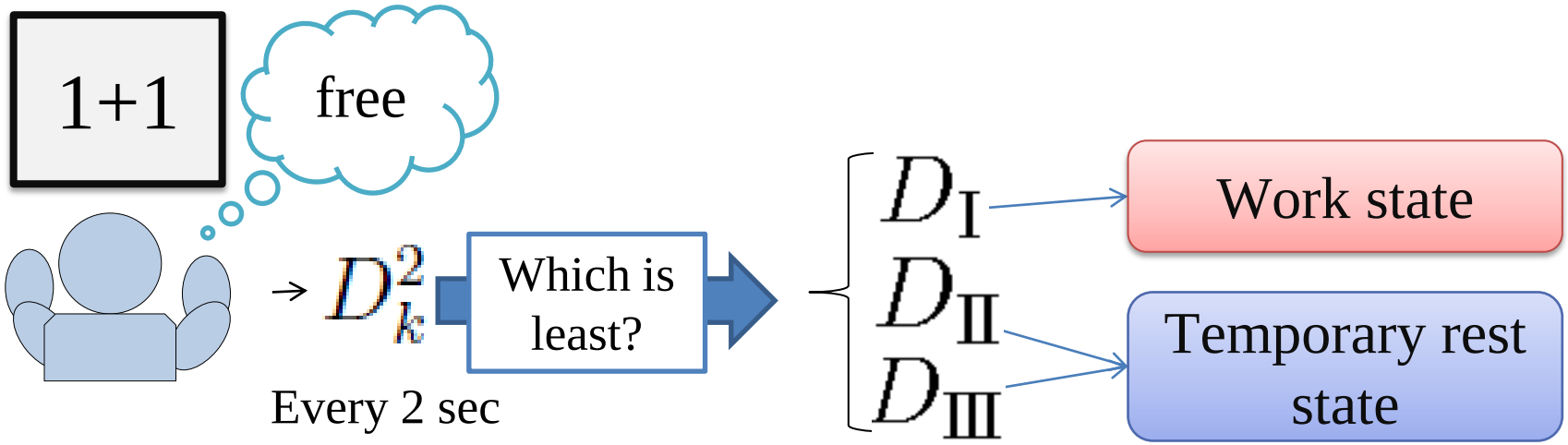
Based on training data, these classifier is calculated.

$\mu^{(\mathrm{I})}\ \Sigma_{(\mathrm{I})}$ $\mu^{(\mathrm{II})}\Sigma_{(\mathrm{II})}$ $\mu^{(\mathrm{III})}\Sigma_{(\mathrm{III})}$

Measurements

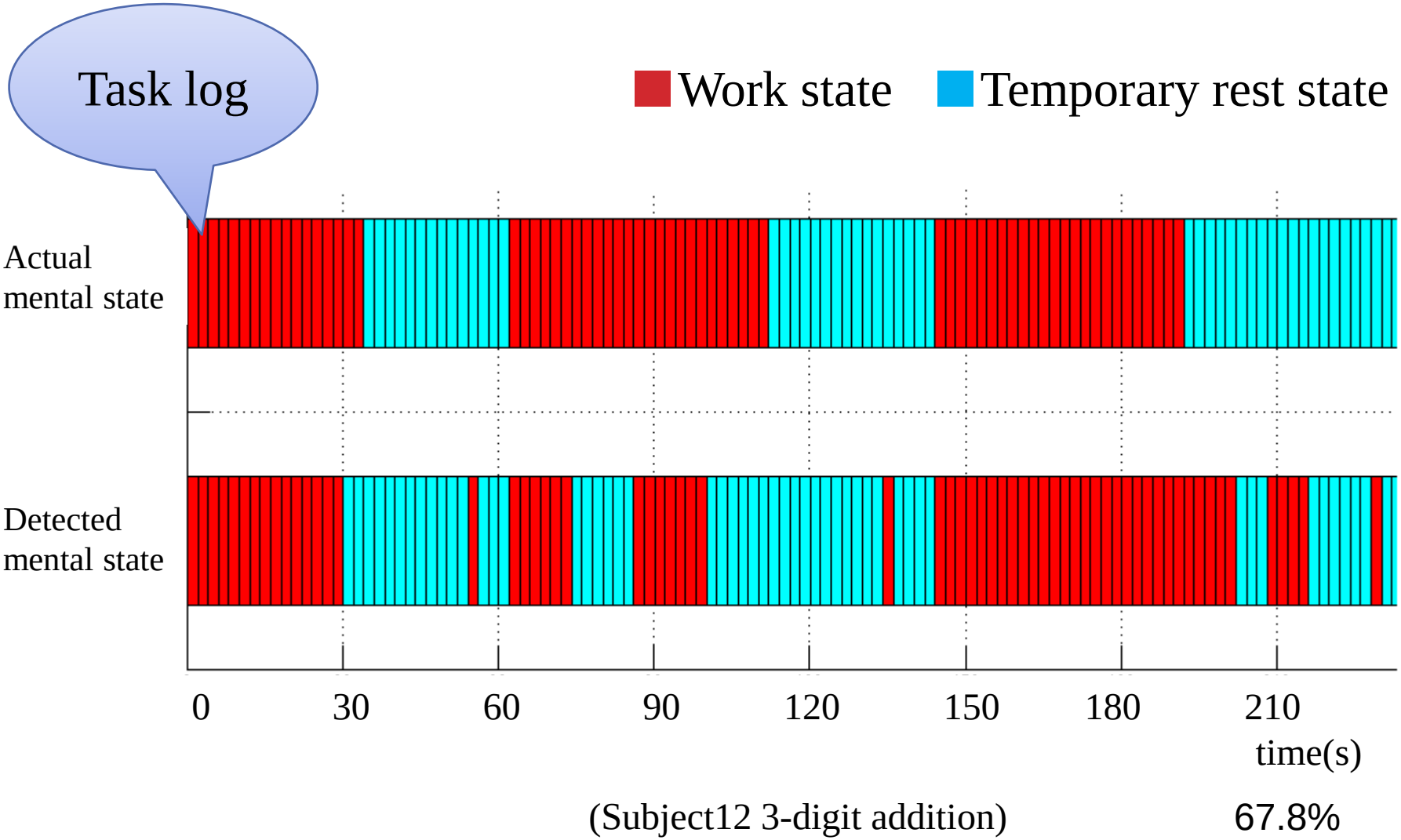
Second measurement : Measuring test data and applying them to classifier

Subjects switch conditions freely



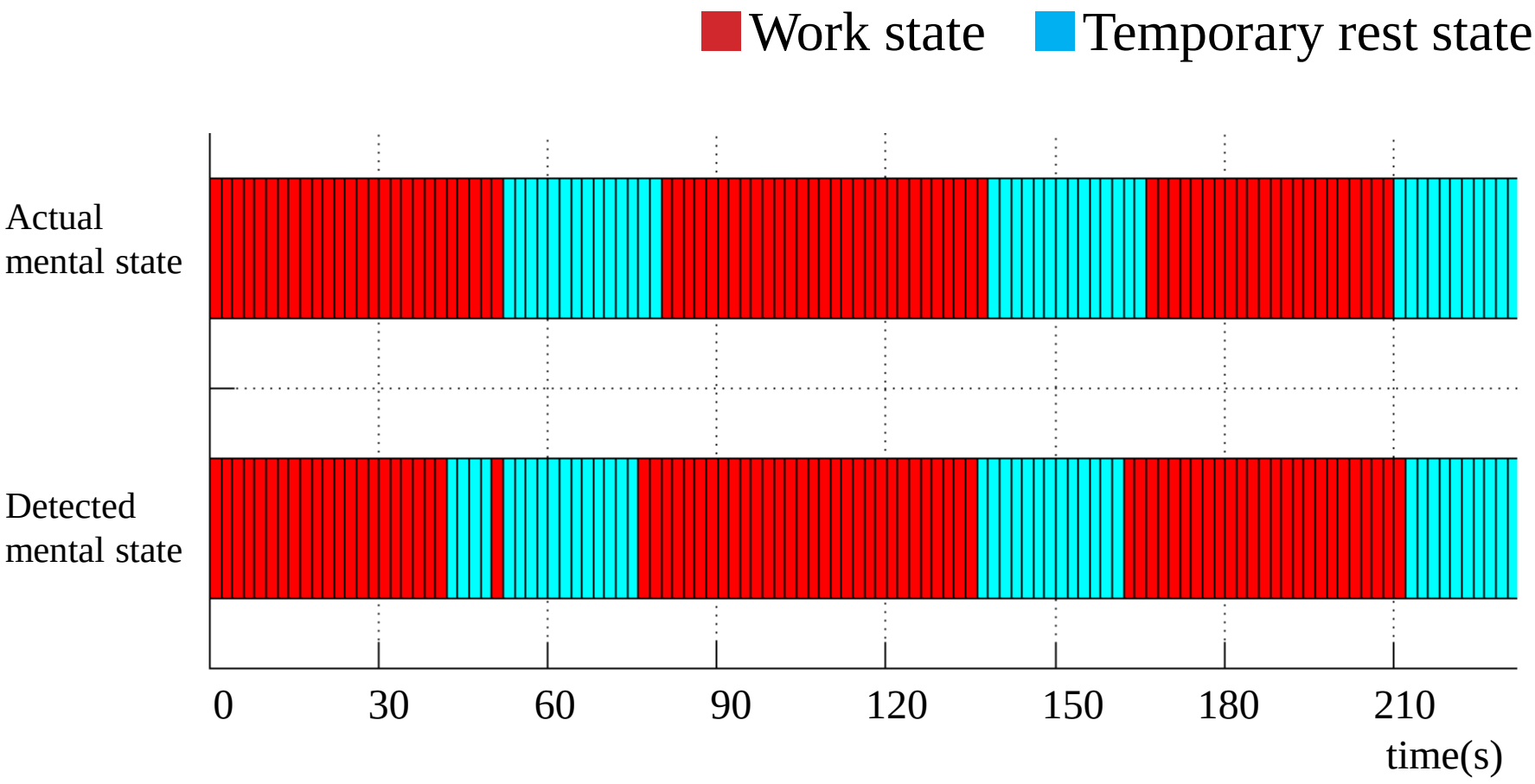
(Display is not changed)

Result



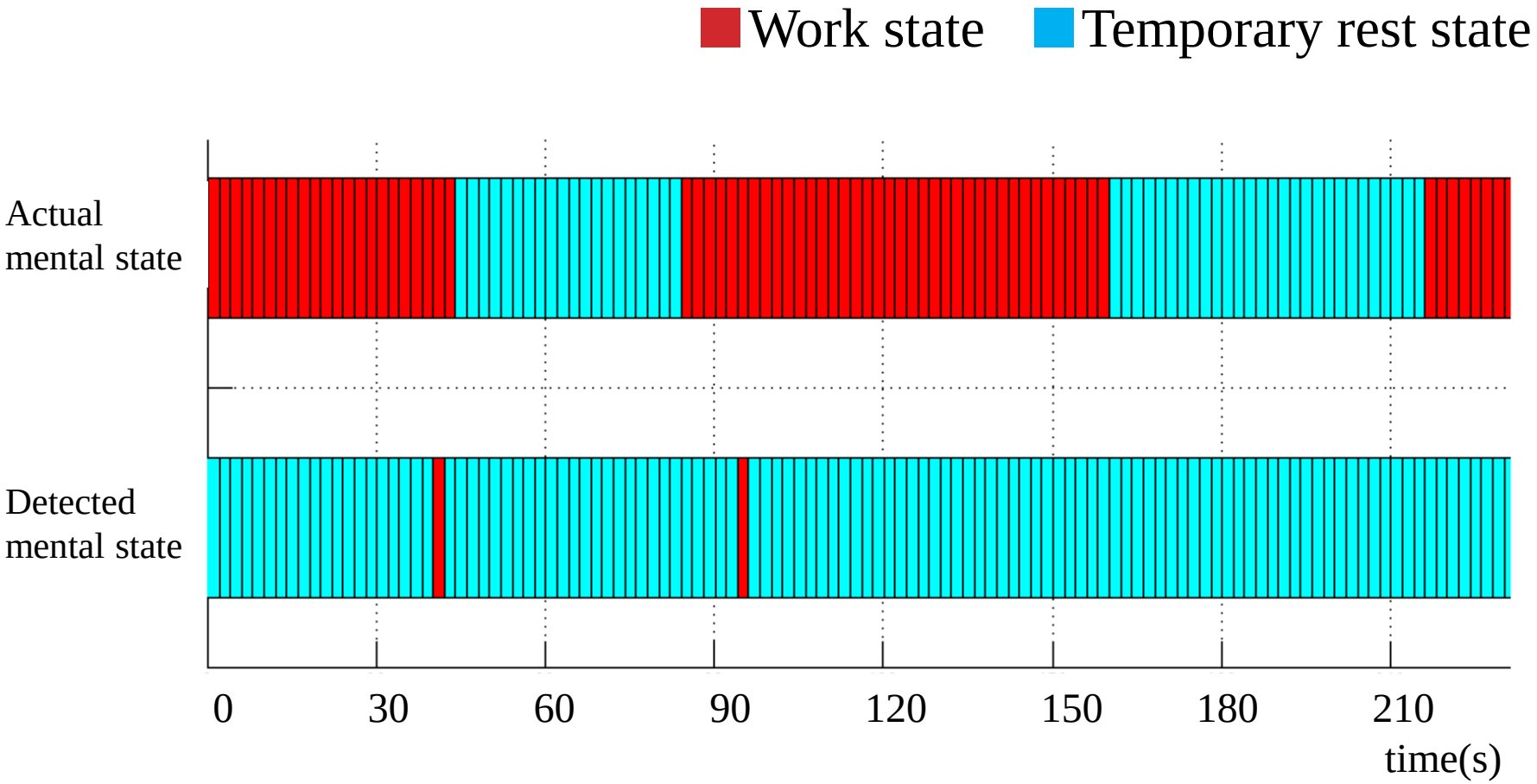
(Subject12 3-digit addition) 67.8%

Result



(Subject13 1-digit addition) 94.2%

Result



(Subject10 3-digit addition) 30.9%

Result

Subject	n	Correct detection rate			
		this algorithm		random guessing	
		Mean(%)	SD	Mean(%)	SD
Subject 1	5	61.2*	11.6	46.3	7.9
Subject 2	5	57.9*	8.3	45.2	5.2
Subject 3	5	57.2	12.5	44.6	4.6
Subject 4	4	67.3*	14.0	39.3	1.9
Subject 5	5	70.7*	14.5	45.1	1.1
Subject 6	5	63.3*	9.2	45.9	5.0
Subject 7	5	59.7*	13.2	37.5	1.5
Subject 8	5	66.4*	7.9	48.5	5.1
Subject 9	5	56.7	10.5	47.1	2.4
Subject 10	5	43.3	12.6	41.6	2.6
Subject 11	5	73.0*	13.6	45.4	3.3
Subject 12	5	64.1*	9.8	46.9	2.3
Subject 13	4	76.8*	11.4	41.4	1.9
Subject 14	5	61.2*	9.2	49.5	7.4
Subject 15	5	69.4*	13.7	43.4	1.9
Subject 16	5	66.7*	9.4	45.4	1.9
Subject 17	5	72.8*	5.0	50.3	1.3
Subject 18	5	64.4*	8.8	49.2	3.4
Subject 19	5	61.8	18.6	46.4	3.3
Subject 20	5	64.8*	4.3	51.1	1.5
Subject 21	5	70.1*	15.9	41.5	1.2

*: $p<0.05$

Result

**: p<0.01

Task	n	Correct detection rate			
		this algorithm		random guessing	
		Mean(%)	SD	Mean(%)	SD
1-digit addition	21	64.6**	17.0	44.2	3.8
3-digit addition	21	65.5**	12.5	46.4	5.1
Classification	21	66.5**	11.3	48.4	5.7
Block assembling	20	63.1**	10.9	43.9	4.7
Text typing	20	60.5**	14.5	44.0	4.1

The mean correct detection rate 64.1%

18.7% higher than random guessing

Further study

- Higher detection accuracy

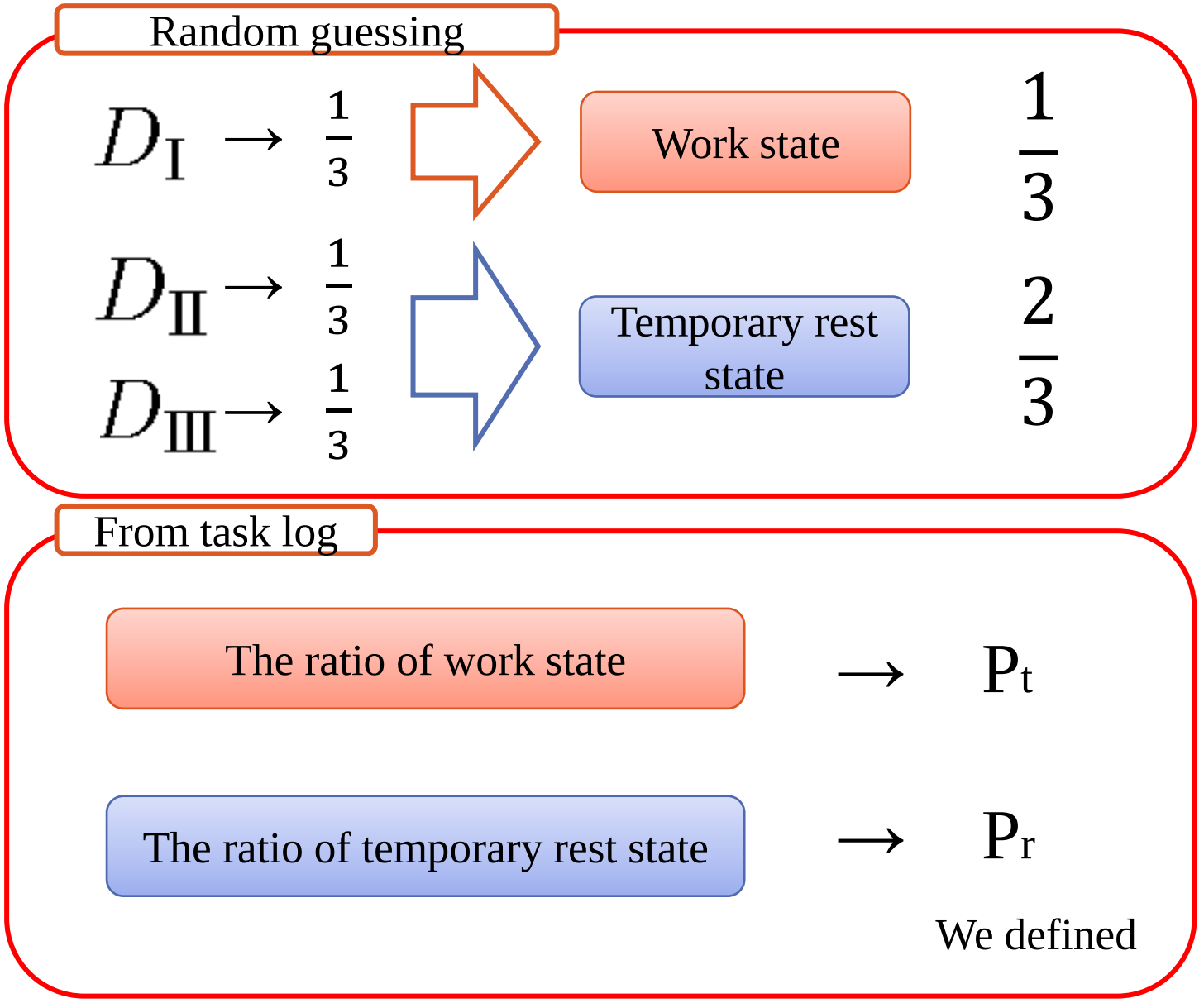
Many considerations
  - Physiological indices
  - Detection methods
  - Measurement's methods etc.

- In this study, we selected tasks which are able to be controlled easily.
  In further study, we will use actual office works and aim at evaluating intellectual productivity more accurately.

Thank you

for attention.

RANDOM GUESSING



RANDOM GUESSING

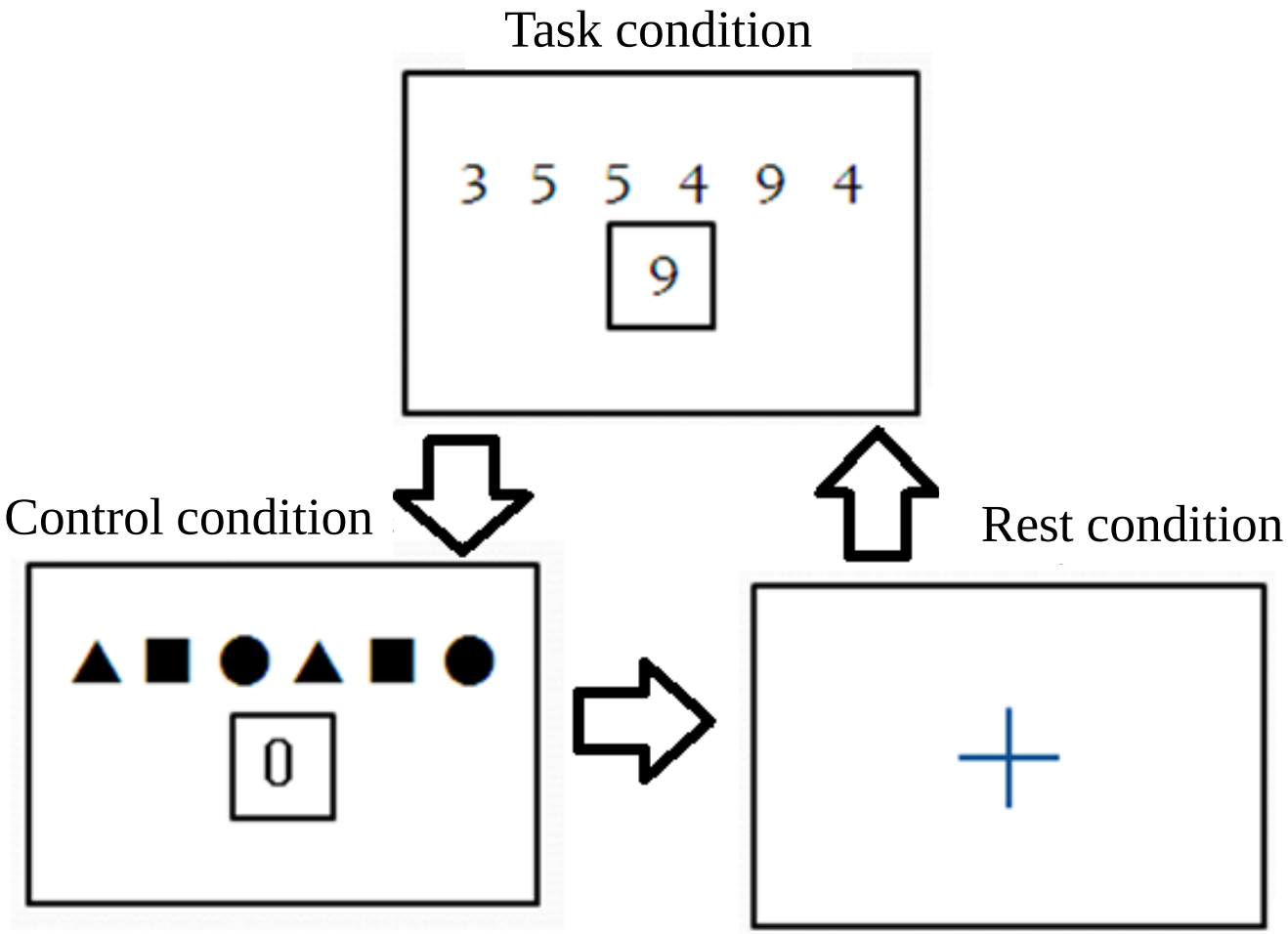
Detected state \ Actual state	Work state (*Pt*)	Temporary rest state (*Pr*)
Work state (1/3)	$\frac{Pt}{3}$	$\frac{Pr}{3}$
Temporary rest state (2/3)	$\frac{2}{3}Pt$	$\frac{2}{3}Pr$

Correct detection

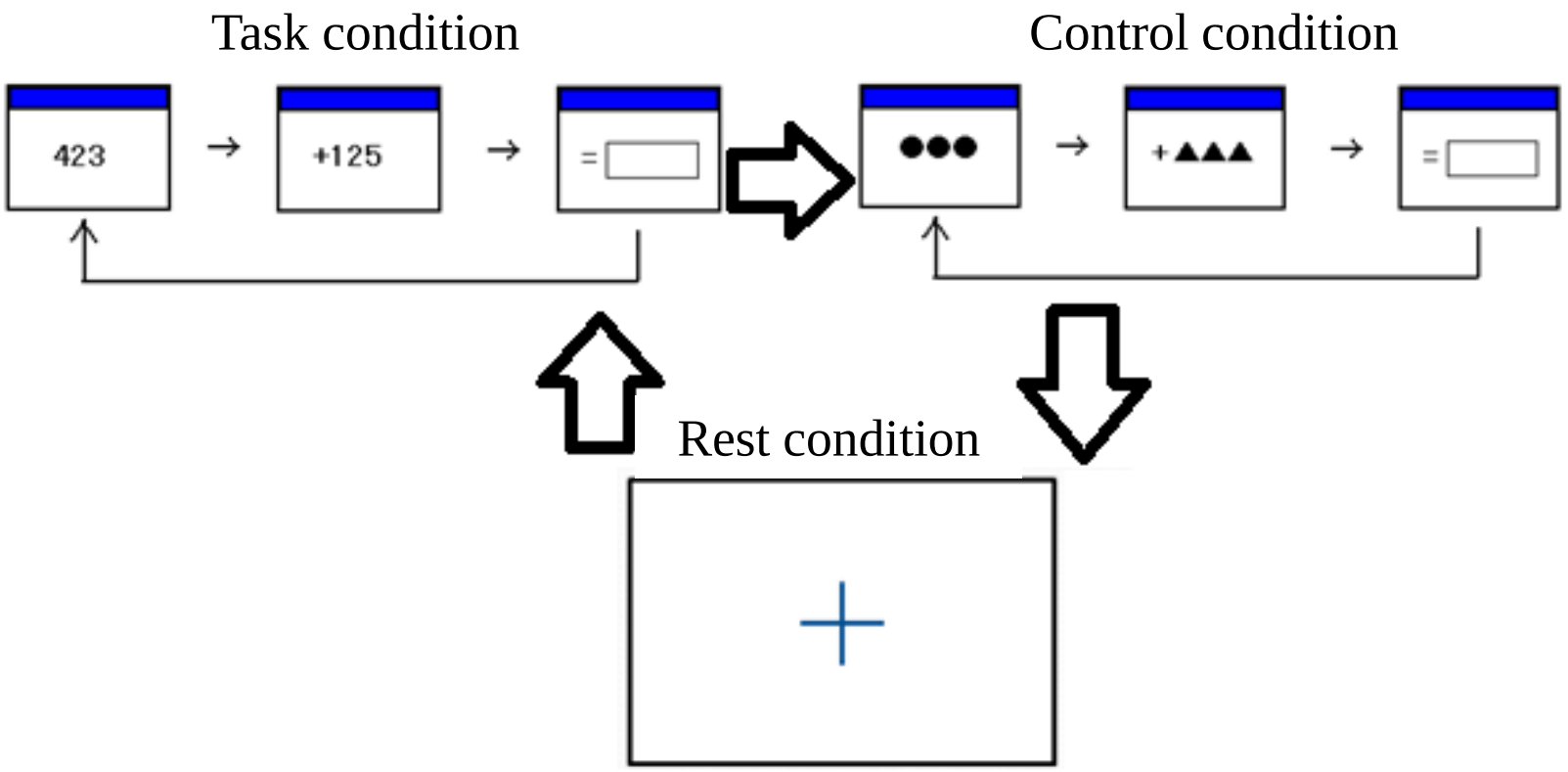
False detection

Based on this, the accuracy of random guessing is calculated.

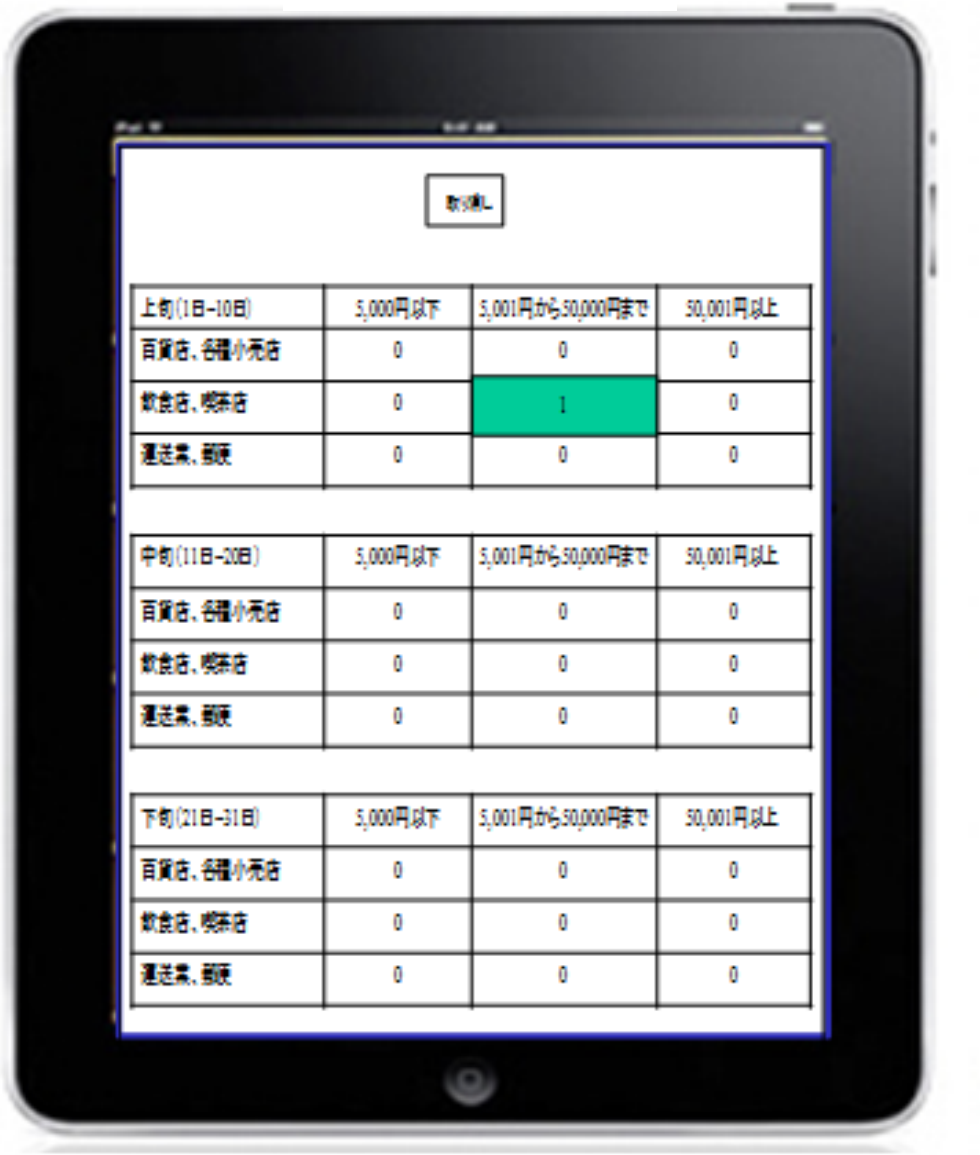
1-DIGIT ADDITION



3-DIGIT ADDITION



CLASSIFICATION (TASK CONDITION)



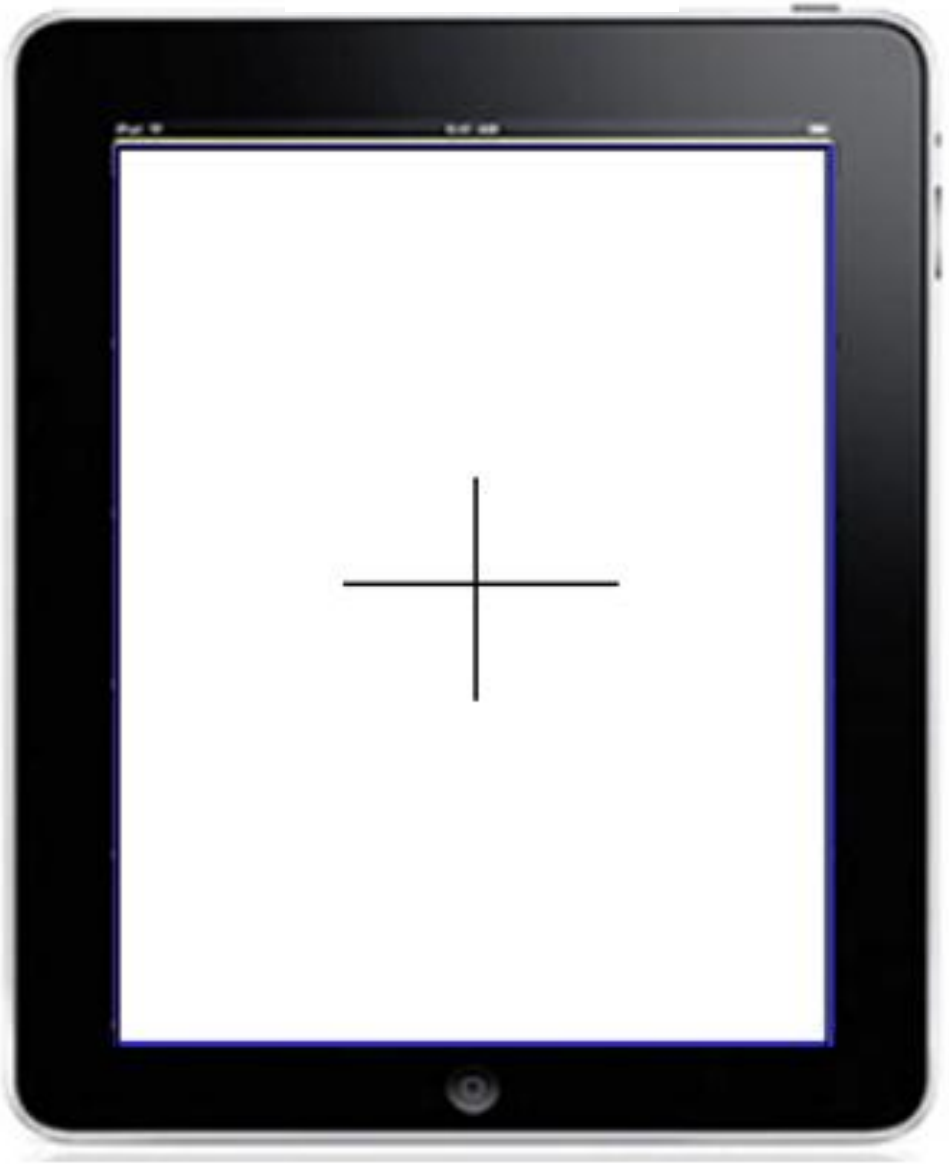
上旬(1日~10日)	5,000円以下	5,001円から50,000円まで	50,001円以上
百貨店、各種小売店	0	0	0
飲食店、喫茶店	0	1	0
運送業、郵便	0	0	0

中旬(11日~20日)	5,000円以下	5,001円から50,000円まで	50,001円以上
百貨店、各種小売店	0	0	0
飲食店、喫茶店	0	0	0
運送業、郵便	0	0	0

下旬(21日~31日)	5,000円以下	5,001円から50,000円まで	50,001円以上
百貨店、各種小売店	0	0	0
飲食店、喫茶店	0	0	0
運送業、郵便	0	0	0

CLASSIFICATION (CONTROL CONDITION)

CLASSIFICATION (REST CONDITION)



TEXT TYPING (TASK CONDITION)

ファイル：ことわざ・慣用句

悪貨は良貨を駆逐する↓

悪妻家を滅ぼす↓

空き樽は音が高い↓

相手のいない喧嘩はできない↓

愛されるより愛する方がすばらしい↓

新しい葡萄酒は古い皮袋に入れてはならない↓

逢うは別れの始め↓

過ちのない者は何も作り出せない↓

後は野となれ山となれ↓

あばたもえくぼ↓

TEXT TYPING (CONTROL CONDITION)

ファイル:

あいうえお↓

あいうえお↓

あいうえお↓

あいうえお↓

あいうえお↓

あいうえお↓

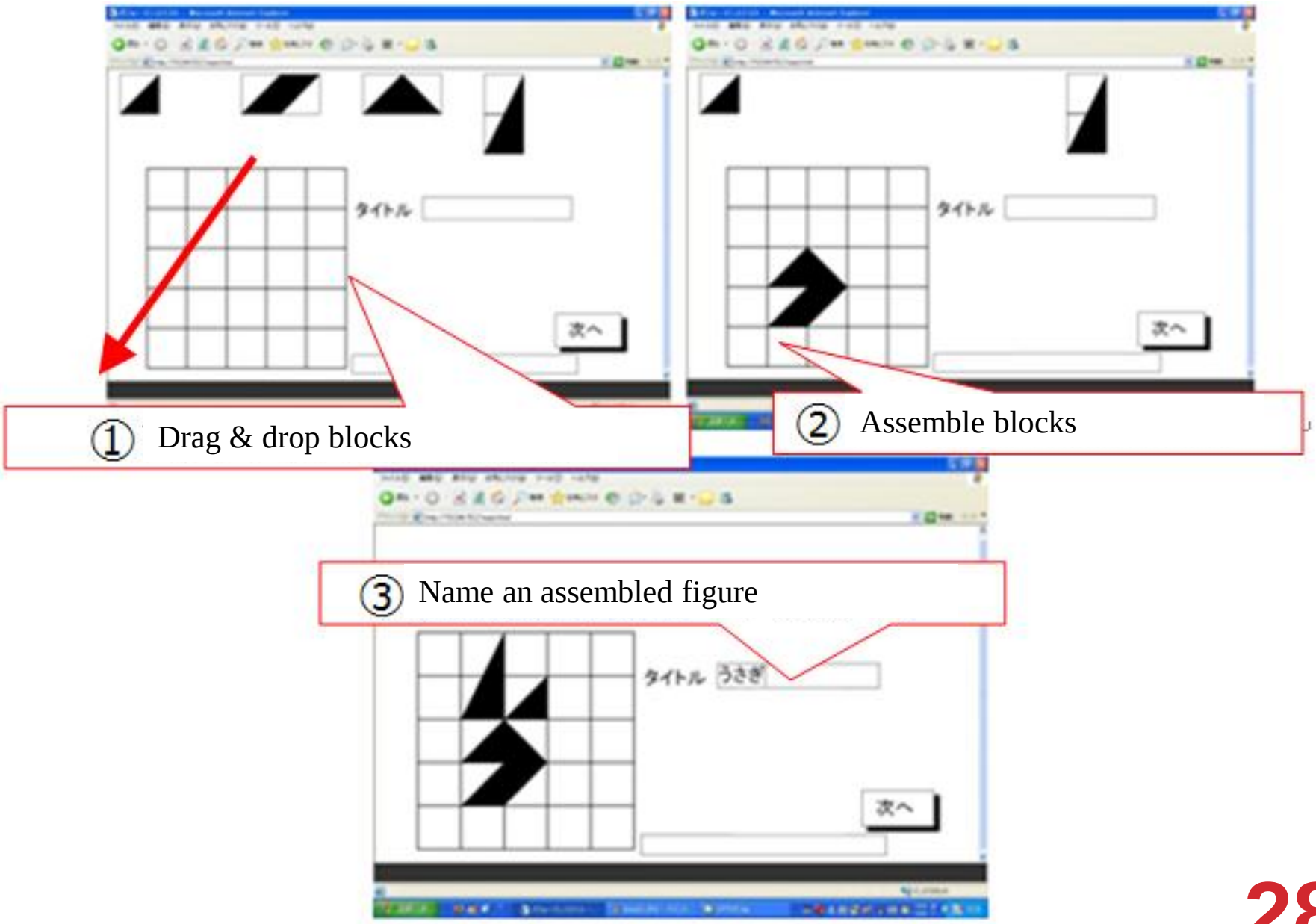
あいうえお↓

あいうえお↓

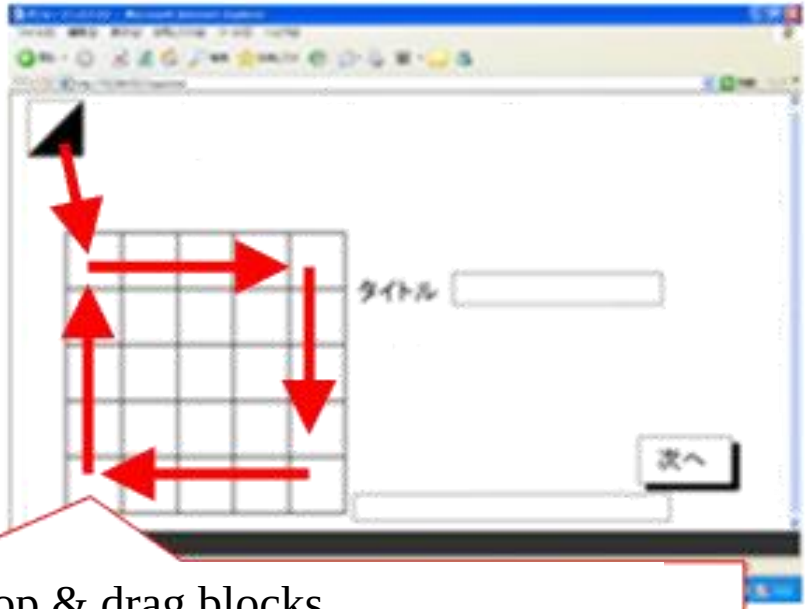
あいうえお↓

あいうえお↓

BLOCK ASSEMBLING (TASK CONDITION)



TEXT TYPING (CONTROL CONDITION)
(REST CONDITION)



Drop & drag blocks

QUESTIONNAIRE

年齢・性別	年齢と性別について
就寝時刻	実験前日の就寝時間
起床時刻	実験当日の起床時間
食事の有無	実験前に食事はしたかどうか
カフェイン	実験前にカフェインは摂取したか
飲酒	実験前日から今までで飲酒はしたか
服用中の薬	現在服用中の薬の種類
視力矯正	メガネ及びコンタクトレンズの有無
体調	実験前と後それぞれの体調。良い・ふつう・悪いの３段階評価。 また、だるい・眠い・風邪気味・頭痛・目の渇き・肩の痛み・ 腰の痛みがあるか
そろばん経験	そろばん経験の有無
過去の病気	過去に患った心臓病及び脳の病気の有無。および病名
電極装着経験	電極装着経験の有無
電極拘束感	頭部・目付近・耳朶・首・わき腹の電極装着が気になったか 気にならない・気になる・とても気になるの３段階評価 また、それぞれに対して作業の邪魔になったかどうかの有無
室温	寒い・やや寒い・ふつう・やや暑い・暑いの５段階評価
湿度	乾燥・やや乾燥・ふつう・ややじめじめ・じめじめの５段階評価
騒音	静か・やや静か・ふつう・ややうるさい・うるさいの５段階評価
作業状態	A 測定の、コントロール条件下で考え事をしたか レスト条件下で考え事をしたか