Process of Evaluation Index of Intellectual Productivity Based on Work Concentration

Contents

1. Background
2. Measurement Tool
3. Analysis Tool
4. Experiment
5. Result & Summary

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Background

Office workers
- Do intellectual works
  - Information management
  - Document creation

Efficiency

Factors in Office Environment
- Illumination
- Noise
- Temperature
- Humidity

Design of optimal office environment

Intellectual Productivity
- Positive!
- Negative...
Objective

Previous Study:
For evaluation of intellectual productivity quantitatively
  0 Use a cognitive task and evaluate its performance

Problem:
  0 The learning effect affects performance of the task
    0 It causes a difficulty to measure influences of the office environment changing

Objective:
  0 To propose Concentration Time Ratio (CTR)
    0 CTR is not affected by the learning effect
    0 Can evaluate the change of productivity quantitatively for short time when the office environment is changed
Outline of Evaluation Method

One Office Environment

Measurement Tool → Analysis Tool → Index

Office worker

Another Office Environment

Measurement Tool → Analysis Tool → Index

Compare the indexes

Power Consumption 20% ↑ but Productivity 10% ↑
Work State Model

Concentration State

Non-Concentration State

Percentage of concentration state
Algorithm To Estimate States

parameters: $\rho, \mu_1, \mu_2, \sigma_1, \sigma_2$

$$f(t) = \frac{\rho}{\sqrt{2\pi}\sigma_1 t} \exp\left[-\frac{(\ln(t) - \mu_1)^2}{2\sigma_1^2}\right]$$

$$+ \frac{1 - \rho}{\sqrt{2\pi}\sigma_2 t} \exp\left[-\frac{(\ln(t) - \mu_2)^2}{2\sigma_2^2}\right]$$
Parameters Fitted by EM Algorithm

Two log-normal distributions were fitted by EM algorithm

In concentration state
Concentration Time Ratio (CTR)

Parameters of the first log-normal distribution: Mode $\mu_1$, Std. $\sigma_1$

Mean $Ex = \exp\left(\mu_1 + \frac{\sigma_1^2}{2}\right)$: Expectation time of answering one question [sec.]

Number of Answer: $N$
Total Time: $T_{total}$ [sec.]

Concentration Time Ratio (CTR) = \frac{Ex \cdot N}{T_{total}} \cdot 100 [%]
Experiment

Objective: To confirm

1. CTR is not affected by the learning effect
2. CTR can measure the concentration affected by change of office environment

Subjects: 19 males (20-55 years old)
Term: 3 days
Measurement Tool:
- Word classification task,
- Mental calculation task (dummy)
Measured sets: 2 sets per day

experimental room
## Illumination Conditions

- **Two illumination conditions**

<table>
<thead>
<tr>
<th>Illumination Conditions</th>
<th>Ambient Light</th>
<th>LED Task Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient (A)</td>
<td>750 lux (5,000 K)</td>
<td>0 lux</td>
</tr>
<tr>
<td>Task &amp; Ambient (T&amp;A)</td>
<td>100 lux (3,000 K)</td>
<td>650 lux (6,000 K)</td>
</tr>
</tbody>
</table>

Expect **T&A** condition is better than **A** condition for work concentration

- **Spot light**
- **High color temperature light** is expected that subjects wake more
- **Energy consumption:**
  - T&A condition is only 46% of A condition
Experimental Procedure

Day 1
- Explanation, Practice
- Experiment

Day 2
- Experiment

Day 3
- Experiment

09:00 - 12:00
- Lunch, Explanation, Practice

12:00 - 15:30
- Experiment

15:40 - 17:00
- Task set 3
  - Countermeasure of end effect
  - Word Class.
  - Mental Calc.
  - Questionnaire (30 min.)

17:40
- Group 1:
  - A
  - T&A

- Group 2:
  - T&A
  - A
  - T&A
Result 1: Performance [questions/min.]

The Same Conditions

(a) Group 1
(1st day) (2nd day) (3rd day)

(b) Group 2
(1st day) (2nd day) (3rd day)

*: p<0.05
**: p<0.01
Result 2: The Concentration Time Ratio

The CTR was not affected by the learning effect

(a) Group 1
(b) Group 2

*: p<0.05
Result 3: Comparison between Conditions

<table>
<thead>
<tr>
<th>CTR [%]</th>
<th>Ambient (A)</th>
<th>Task &amp; Ambient (T&amp;A)</th>
</tr>
</thead>
</table>

*: p<0.05
Conclusion

0 The CTR has been proposed as a new evaluation index of intellectual productivity.

0 As the result of evaluation experiment:

  0 CTR has a possibility that could be evaluated the changes of intellectual productivity by changing illumination conditions.
  0 in a short term experiment.
The Learning Effect and The Learning Curve

0 To do the same cognitive tasks are conducted in different office environments
0 The more the task is done, the more performance is improved → The learning effect
0 It can be corrected by the learning curve
0 To draw the curve, several dozens task sets are needed
0 It needs much time more than several weeks
1. Character: Hiragana
2. 1st vowel: “u”
3. Category: Artifact (Desk)
4. Record answering times per one question

Hiragana: つくえ, Katakana: ツクエ, Kanji: 机
Evaluation Tool

**Measurement Tool**
- Word Classification Task (Paper)
- Tablet Device (Answer)

**Analysis Tool**
- Record Answering Time
- Read a time array file

** Via Server**

**Output**
- Concentration Time Ratio
- Histogram of Answering Time
Analysis Tool

Result of measurement tool
(Answering Times per one question)

Concentration State

Non-concentration State

PERCENTAGE OF CONCENTRATION STATE
Result: Calculation of the CTR

- Examples that parameters were not calculated by EM algorithm were made N/A.
- There were some cases when subjects took a rest many times.

![Histogram of answering time vs occupation time with N/A indicated.](image)
1. Character: Hiragana
2. 1st vowel: “u”
3. Category: Artifact (Desk)
4. Record answering times per one question

Hiragana: つくえ, Katakana: ツクエ, Kanji: 机