

# The Relationship between Flow, Sleepiness and Cognitive Performance: The Effects of Short Afternoon Nap and Bright Light Exposure

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**Abstract:** “Flow” is a positive emotional state which typically occurs when a person perceives a balance between the challenges associated with a situation and his or her capabilities to accomplish these demands. While flow often occurs along with positive feelings and high introspective performance, only a few studies have investigated how it is associated with cognitive performance (i.e., objective performance). In the present study, we investigated the relationship between flow, emotions, and cognitive performance. A short nap (20 min) and bright light (>2,000 lux) techniques were used as experimental manipulations to enhance flow. Fifteen participants (31.3 ± 7.19 yr old) took part in four experimental conditions: rest, short nap, bright light, and nap and bright light. Pearson’s correlation coefficients were calculated for flow and other indices using standardized data. Results showed that flow scores significantly increased after a short nap and under bright light exposure. The correlations between flow and reaction time were also significant. Flow was significantly associated with positive emotion and sleepiness. These results suggest that a short nap and bright light can be employed as a flow facilitator and that flow status can be used as an indicator in evaluating work efficiency and occupational mental health.

**Key words:** Sleepiness, Nap, Bright light, Flow, Emotion

## Introduction

“Flow” is a positive emotional/affective state that typically occurs when a person perceives a balance between the challenges associated with a situation and his or her capabilities to accomplish or meet these demands (p824)<sup>1</sup>. Flow is often experienced in various activities, such as sports<sup>2</sup>, musical performance<sup>3</sup>, car driving<sup>4</sup>, and Internet use<sup>5</sup>. At work, flow is defined by characteristics such as

absorption, work enjoyment, and intrinsic/autotelic work motivation<sup>6</sup>. During flow, workers’ subjective performance (i.e., introspective performance) and occupational mental health improve, and thus flow is thought to be an important factor in maintaining workers’ subjective well-being<sup>7</sup>.

While the relationship between flow and subjective performance (i.e., questionnaire scores) has been reported<sup>2, 8</sup>, relatively few studies have investigated the relationship between flow and objective performance (e.g., cognitive skills) due to difficulties evaluating objective performance in natural settings, such as during sports activities<sup>2</sup>. Evaluation of objective performance with flow, however, would be an important research topic in light of not only

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workers' well-being but also work efficiency and injury prevention in the workplace. The present study therefore focused on the relationship between flow and objective (i.e., cognitive) performance in a quiet laboratory setting.

The present study also focused on the relationship between flow and sleepiness. Previous studies have demonstrated that sleepiness may relate to low levels of positive emotion and high levels of negative emotion in a sleep-restricted condition<sup>9</sup>), and that treatments to reduce sleepiness (e.g., napping, bright light) not only improve cognitive performance<sup>10–12</sup>) but also increase positive mood<sup>13</sup>). According to the cognitive-energy model proposed by Zohar *et al.* (2005), sleep loss would reduce “cognitive energy” to cope with a goal-disturbing event, and positive emotion for a goal-enhancing event would also be reduced by sleep loss<sup>14</sup>). The cognitive-energy model seems to fit with the flow theory because challenging tasks would require high cognitive energy (i.e., less sleepiness) through which stronger flow experiences would be induced<sup>1</sup>).

In the present study, a short nap (20 min) and bright light (>2,000 lux) were used as countermeasures to sleepiness. Many previous studies have reported that a short nap (see reviews<sup>15–18</sup>) and bright light<sup>12, 19–21</sup>) reduce/improve sleepiness and performance, while some studies failed to demonstrate an effect of bright light on performance<sup>12, 20, 21</sup>). Moreover, it has been reported that a short nap and bright light enhance positive feelings (i.e., pleasantness, satisfaction, and relaxation)<sup>13</sup>). Thus, it can be assumed that a short nap and bright light could facilitate positive feelings in flow experience, which would then improve performance.

The hypotheses of the present study are: (1) a short nap and bright light facilitate flow, and (2) flow will be significantly related to task performance, sleepiness, and positive emotions.

## Methods

### *Participants and experimental design*

Fifteen healthy volunteers (8 males; 31.3 ± 7.19 yr old) participated in the study. All participants met the following criteria: a normal sleep-wake cycle not classified as extreme “evening type” or “morning type” according to the Morningness-Eveningness questionnaire<sup>22</sup>), no physical or mental health problems (less than 15 points on the Center for Epidemiological Studies-Depression Scale; CES-D), no travel to a different time zone within 3 months before the experiment, no shift work within 3 months before the experiment, no use of medication, non-smoker status, and body mass index (BMI) less than 25. Participants' Morn-

ingness/Eveningness score, CES-D score, and BMI (mean ± SD) were 48.3 ± 6.31, 6.9 ± 4.79, and 21.0 ± 1.78 kg/m<sup>2</sup>, respectively.

### *Conditions*

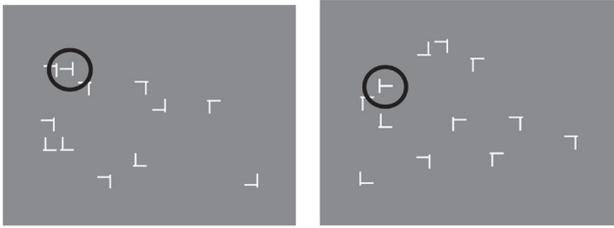
Participants carried out four experimental conditions following one preparation day, which were afternoon short nap (NAP), bright light (BLT), bright light and afternoon nap (BLT+NAP), and control (CNT, i.e., neither bright light nor nap) conditions. The order of the conditions was counterbalanced among the participants. A sleep diary was recorded by participants in order to monitor their sleep-wake cycles during the experimental days. The days of each condition were separated by at least three days to avoid accumulation of sleep restriction or sleep debt. The experimental protocol was approved by the Ethics Committee in Research Involving Humans at the National Institute of Advanced Industrial Science and Technology, Japan.

### *Flow check list (FCL)*

The Flow Checklist (FCL), which was originally developed by Ishimura (2008) in Japanese, was used. The FCL is composed of 10 items (7-grade Likert scales ranging from 1 = “does not apply at all” to 7 = “applies very much”) which are categorized into three independent factors, namely, “confidence in competence,” “challenge to goals,” and “positive emotion and absorption.” Each factor consists of 2 to 4 items: “Everything is going well,” “I am able to control situations,” “I am confident in managing matters,” and “I behave/move with everything in control” for the first factor (i.e., Confidence); “I feel my work is challenging” and “I am getting ahead toward goals” for the second factor (i.e., Challenge); “I feel time flies,” “I am in a state of complete concentration,” “I am completely immersed,” and “I am enjoying work” for the third factor (i.e., Immersion). The reliability of the FCL has been confirmed in an earlier study (Cronbach's  $\alpha=0.663$ )<sup>23</sup>). Participants were asked to circle the scale number indicating their feelings at the moment.

### *Positive and negative affect schedule (PANAS)*

The positive and negative affect schedule (PANAS) was used to measure positive affect (PA) and negative affect (NA)<sup>24</sup>). The Japanese-translated PANAS scale used in the present study consists of 20 items (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, active, attentive, jittery, afraid, distressed, upset, guilty, scared, hostile, irritable, ashamed, and nervous). Items



Sample 1 (Left direction) Sample 2 (Right direction)

**Fig. 1.** Examples of stimulus of the contextual cueing task.

Circles in the figure indicate the target stimuli “T” among the distractors “Ls.”

were rated on a 6-point Likert-type scale (1 = “not at all or very slightly” to 6 = “extremely”). The reliability of Japanese-translated PANAS has been confirmed (Cronbach’s  $\alpha=0.85$  for positive affect and  $\alpha=0.88$  for negative affect)<sup>25</sup>.

### Sleepiness

Before and after the tasks, participants completed the Karolinska sleepiness scale (KSS)<sup>26</sup>. The Japanese version of the KSS is a 9-point Likert-type scale ranging from 1 = “very alert” to 9 = “very sleepy, fighting sleep”<sup>11</sup>. KSS is sensitive to sleep loss in its responses<sup>27, 28</sup> and is closely associated with vigilance performance and physiological indicators of sleepiness<sup>11, 26</sup>.

### Cognitive performance task

The contextual cueing task<sup>29</sup>, which can reveal implicit learning of spatial layout during visual search, was used as a performance task in the present study. In this task, two types of performance can be evaluated, namely, visual search performance and the amount of the implicit learning effect. The search array consists of one target and 11 distractors. The target and distractors were presented at randomly selected locations, as shown in Fig. 1. The target and distractors were a rotated T(90° or 270°) and Ls (0°, 90°, 180°, and 270°), respectively. Participants were asked to detect a target as quickly as possible and answer the direction of the target (right or left) using a gamepad button. Reaction times (RTs) and response accuracies were recorded on the computer. The search arrays were displayed on a 17-inch LCD monitor (1,024 × 768 resolution). All arrays were presented in white on a gray background in a dark room. The light intensity from the computer screen was less than 5 lux on the face of the participants. The participants observed the search array at a normal distance (570 mm from the display).

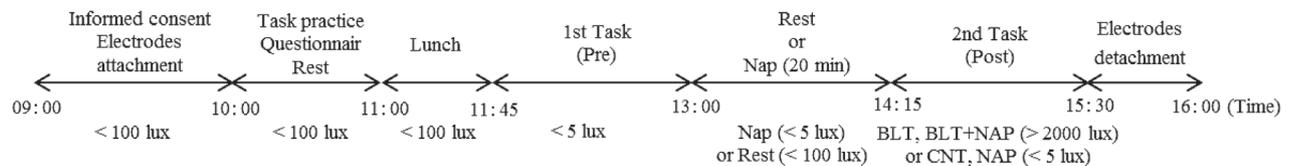
The participants performed 12 blocks of trials. Each block was composed of 24 trials consisting of 12 each of *old* and *new*. In the first block, 24 configurations (i.e., target and distractor locations) of the search array were randomly generated. Half of them were repeated in random order within each block through following blocks (the *old*), while new configurations were generated within each block for the remaining half (the *new*). It is known that the repeated configurations (the *old*) can be learned implicitly and facilitate visual search.

### Procedure

Participants came to the laboratory a day prior to the experiment and gave written informed consent after the procedures were fully explained, and then they practiced the performance tasks. Participants were asked to abstain from food and beverages containing caffeine and alcohol for 24 h prior to study participation.

To induce sleepiness, participants curtailed their normal sleep time by 20% the night before the experiment. Sleep was reduced by delaying their time to go to bed while they still woke up at the usual time. Participants were asked to keep a sleep diary to facilitate adherence.

All experimental procedures were carried out in less than 100 lux of illumination, except during light exposure in the BLT and BLT+NAP conditions. Illumination of horizontal and vertical planes was measured at the eye level of the participants using an illuminometer (T-10, Konica Minolta Holdings, Inc., Japan). Participants arrived at the laboratory at 9:00 and were connected to electrodes, followed by practice of the performance tasks and collection of subjective ratings (flow, PANAS, and KSS; scored twice before and after the task). From 11:00 to 11:45, participants ate a lunch served by the experimenter. From 11:45 to 13:00, the first task was carried out to confirm a baseline. From 13:00 to 14:15, the participants took a nap in a dark bedroom in the NAP or BLT+NAP conditions (i.e., nap conditions). During the nap, their polysomnogram was monitored by the experimenter who stayed in the next room. The duration of the nap was fixed at 20 min by monitoring their polysomnogram (started from the point in which they reached three consecutive stage 1 sleep segments, i.e., 60 s, occurred). In the CNT and BLT conditions (i.e., no-nap conditions), the participants stayed and read books and magazines in less than 100 lux surroundings while the experimenter supervised. To prevent sleep inertia, the second task was started at least 15 min after the nap. From 14:15 to 15:30, the second task (the same task as the first task) was carried out. In the BLT



**Fig. 2.** Time schedule of the experiment. Participants took a 20 min nap between 13:00 and 14:00. During the rest, the participants read books or magazines under sleepiness monitoring in a less than 100 lux light environment.

CNT: control condition. NAP: nap condition. BLT: bright light condition. BLT+NAP: bright light and nap condition.

and BLT+NAP conditions, the participants were exposed to bright light (>2,000 lux) by four fluorescent light tubes (color temperature 7,000 K). The lighting devices were put at a distance of 580 mm from the face of the participants. Participants carried out the task in dark surroundings (<5 lux) in the CNT and NAP conditions. The schedule of the experiment is shown in Fig. 2.

### Recording

Electrodes were attached at C3 and O1 on scalp sites for an electroencephalogram (EEG) referenced to the average between A1 and A2. The electrodes were positioned above and below the left eye, and the outer canthus of both eyes for the electro-oculogram recordings (EOG). Additionally, a bipolar submental electromyogram (EMG) was recorded. The sampling rate for recording was 1,000 Hz (16-bit AD conversion), and the time constants were 0.3 s for the EEG, 3.2 s for the EOG, and 0.03 s for the EMG, where the high-cut filter was set at 30 Hz. These data were recorded with a portable digital recorder (Polymate AP1000, Digitex Laboratory Co., Ltd, Japan).

### Data analysis

For the analyses of FCL and PANAS, the scores of related factors were averaged separately. In addition to the separate three factors of FCL described earlier, a “general flow score” was calculated by summing scores of these factors. PANAS was divided into the two factors of positive affect (PA) and negative affect (NA). Including two performance indices (visual search time and implicit learning amount) and sleepiness score, 9 factors in total were used in the correlation analysis. All subjective scales (FCL, PANAS and KSS) were scored twice per each task (i.e., before and after the task), and these two scores were averaged to obtain stabilized data for the statistical analysis.

### Contextual cueing task

Median reaction times (RTs) were calculated for each block. Implicit learning amounts were computed by sub-

tracting RTs of the *old* from *new*.

### Sleep variables

Sleep stages were visually scored using C3 site every 20 s, from which sleep variables were computed according to the criteria of Rechtschaffen and Kales (1968)<sup>30</sup>. Starting time of the nap was chosen by on-site visual scoring by an experienced sleep researcher (K.K.) according to the criteria (three consecutive segments of Stage 1 sleep). The sleep stages were rescored off-line later and used for the analysis.

### Statistical analysis

A “BLOCK” × “NAP” × “BLT” repeated-measures analysis of variance (ANOVA) was performed for each flow subcategory. In this analysis, comparisons were conducted between the following: 1) no light conditions (i.e., CNT and NAP) and light conditions (i.e., BLT and BLT+NAP); and 2) no nap conditions (i.e., CNT and BLT) and nap conditions (NAP and BLT+NAP). To compute covariance between flow scores and the other indices, post-treatment data were subtracted from pre-treatment data [60 data parameters (4 conditions × 15 participants) collected for each variable of the correlation analysis]. Outlier rejection was applied for the 60 data parameters using the criteria of more than 2.5 standard deviations. As a result, the number of data in some parameters was reduced, but it still remained more than 56 in all parameters. The data were used in the calculation of Pearson’s product-moment correlation coefficients.

## Results

### Sleep variables during nap

Average sleep time during naps (i.e., duration from judged sleep starting time to waking time) in the NAP and BLT+NAP conditions were  $19.7 \pm 1.43$  and  $20.6 \pm 2.25$  min, respectively. There were no significant differences in sleep stages between the conditions.

### Flow checklist

A significant main effect of “NAP” was observed in the “general flow score” [ $F(1, 14)=13.07, p<0.05$ ]. Interactions between “NAP” and “BLOCK” [ $F(1, 14)=19.98, p<0.01$ ] and between “BLT” and “BLOCK” [ $F(1, 14)=4.93, p<0.05$ ] were also significant, as shown in Fig. 3A.

For “confidence in competence” factor, the main effect of “NAP” [ $F(1, 14)=5.79, p<0.05$ ] and the interaction between “BLT” and “BLOCK” were significant [ $F(1, 14)=6.14, p<0.05$ ] (See Fig. 3B). For “challenge to goals” factor, a significant main effect of “NAP” [ $F(1, 14)=20.09, p<0.01$ ] and an interaction between “NAP” and “BLOCK” were observed [ $F(1, 14)=23.54, p<0.01$ ] (Fig. 3C). For the “positive emotion and absorption” factor, the significant main effect of “NAP” [ $F(1, 14)=6.91, p<0.05$ ] and the interaction between “NAP” and “BLOCK” were observed [ $F(1, 14)=5.66, p<0.05$ ] (Fig. 3D).

Results indicate that all three subcategories of flow scores increased after the short nap, while only one subcategory (“confidence in competence”) increased under the bright light exposure.

### Correlation coefficients

Table 1 shows the Pearson’s product-moment correlation coefficients (i.e.  $r_s$ ) between the flow scores and other indices (significant level was set at  $p<0.05$ ). The flow scores were correlated with the search time of the contextual cueing task ( $r_s$  ranged from  $-0.26$  to  $-0.45$ ); the correlation between general flow score and performance is depicted in Fig. 4). Correlations between flow indices and PA were significant ( $r_s$  ranged from  $0.32$  to  $0.71$ ), while relatively low in NA ( $r_s$  ranged from  $-0.01$  to  $0.26$ ). Flow indices were negatively associated with sleepiness ( $r_s$  ranged from  $-0.31$  to  $-0.46$ ).

## Discussion

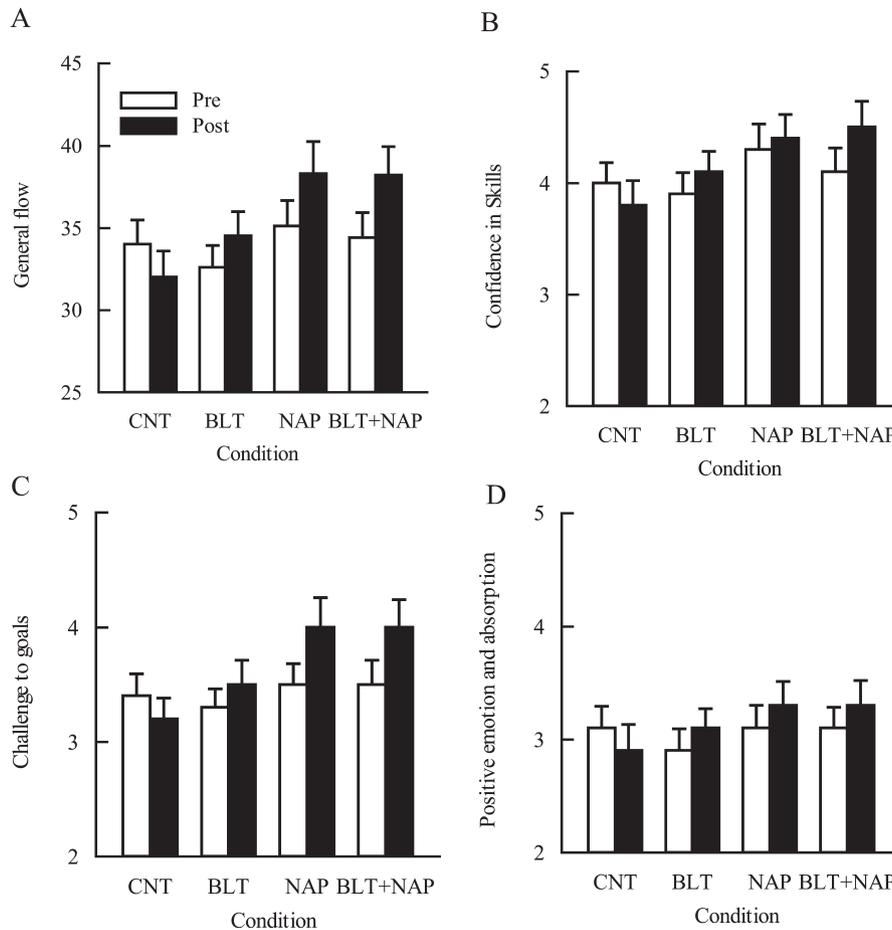
The present study revealed that flow scores became significantly higher in short nap conditions relative to other conditions, that is, a short nap induced a flow experience. In addition, flow scores were positively associated with positive emotion and negatively associated with subjective sleepiness and search time in the contextual cueing task. These results suggest the following: (1) flow tends to be induced after a short nap or in a less sleepy condition; and (2) flow experience is associated not only with subjective feelings (i.e., positive emotion and sleepiness) but also with objective performance (i.e., visual search time).

These results imply that workers experiencing flow can make more use of their capabilities in their tasks, and that this contributes to better performance at work. Such workers would possibly increase their work satisfaction, and thus flow can be thought as an important factor to influence occupational mental health at work. While the original flow theory asserted that flow experience enhances objective performance<sup>1)</sup>, few studies have supported this based on a behavioral experiment. A clear association between flow and objective performance demonstrated in the present study could serve to help workers understand that flow experience could improve work efficiency.

As mentioned earlier, low cognitive energy in sleep-deprived conditions could decrease motivation and weaken one’s ability to cope with disturbing events<sup>14)</sup>. Consistent with this, “challenge,” one of the subcategories of flow, namely, the motivation-related category, was the most strongly correlated with performance ( $r=-0.45$ ) compared with the other subcategories (“confidence,”  $r=-0.26$ ; and “immersion,”  $r=0.34$ ). Interestingly, “challenge” also showed the strongest correlation with sleepiness ( $r=-0.46$ ) and positive affect ( $r=0.71$ ) compared with the other flow subcategories. These results imply that the feeling of being challenged, which is associated with motivation, is a key aspect of flow in improving performance that could contribute to reduced sleepiness.

Contrary to our expectations, significant correlations were not found between flow and implicit learning amount. This result, as well as the negative correlations between flow and visual search time, could be due to type of task or type of abilities<sup>31)</sup>. Although previous studies reported that positive emotion facilitates flexible thinking<sup>32)</sup> and verbal ability<sup>33)</sup>, implicit learning in contextual cueing might occur almost independently from emotional responses, including flow. It has also been shown that positive emotion impedes a logical<sup>34, 35)</sup> and careful way of thinking<sup>36)</sup>. The present results, on the other hand, demonstrate that the influence of positive emotion on implicit learning is neutral (i.e., it neither improves nor impedes). The advantages and disadvantages of positive emotion or flow should be systematically investigated in future studies, which could identify ways to achieve better emotional balance at work.

In relation to emotional balance, Fredrickson (2009) proposed that experiencing positive emotion in a 3-to-1 ratio with negative emotion is the appropriate balance for maintaining well-being<sup>37)</sup>. In this view, a positive ratio of balance would lead us to a tipping point beyond which we naturally become more adaptive to our modern society.



**Fig. 3.** (A) Score of “general flow.” The “general flow score” was calculated by the addition of scores of the three factors of the flow check list (FCL). (B) Score of “confidence in skills.” (C) Score of “challenge to goals.” (D) Score of “positive emotion and absorption.” Bars on the figures show standard errors (SEs).

Pre: pre-treatment (white bar). Post: post-treatment (black bar). CNT: control condition. NAP: nap condition. BLT: bright light condition. BLT+NAP: bright light and nap condition.

**Table 1.** Pearson’s product moment correlation coefficient

		Performance		PANAS		Sleepiness
		Implicit learning	Reaction Time	PA	NA	
Flow	General	0.12	<b>-0.45</b>	<b>0.58</b>	0.08	<b>-0.35</b>
	Confidnece	0.22	<b>-0.26</b>	<b>0.58</b>	<b>0.26</b>	<b>-0.33</b>
	Challenge	0.10	<b>-0.41</b>	<b>0.71</b>	0.10	<b>-0.46</b>
	Immersion	0.13	<b>-0.34</b>	<b>0.32</b>	-0.01	<b>-0.31</b>

Bold types are significant at  $p < 0.05$ . General: “general flow score.” Confidence: “confidence in competence.” Challenge: “challenge to goals.” Immersion: “positive emotion and absorption.” PANAS: the positive and negative affect schedule. PA: positive affect. NA: negative affect.

To keep emotional balance in this ratio is of particular importance from the evolutionary perspective as explained in the “broaden and build theory”<sup>38</sup>). According to this theory, negative emotion is essential for keeping us away

from life-threatening dangers but positive emotion is also important in order to feel enjoyment and curiosity, which should help us to function effectively in searching for new resource potential or in building long-term relationships

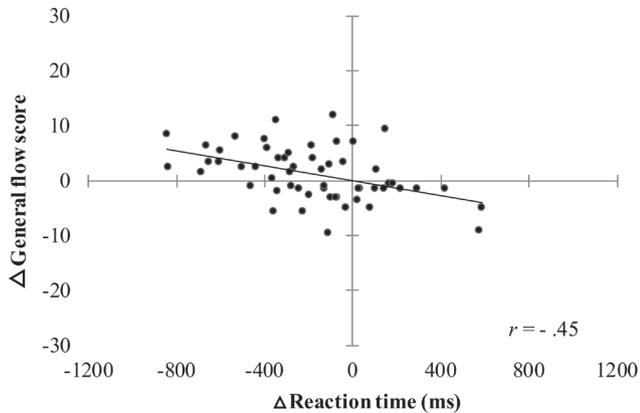


Fig. 4. Correlation between the subtracted general flow scores and the subtracted reaction times (search times).

with others. Based upon the behavioral point of view, we suspect that flow might be related to speed of skill acquisition (i.e., a learning curve). If the appropriate balance of challenge and skill levels accelerates skill acquisition at work, individuals should feel flow in their assignments. Demonstrating this assumption using behavioral science methods is a compelling future research topic.

Many practical methods to keep the “golden ratio” of emotional balance have been proposed, such as exercising<sup>39, 40</sup> and meditation<sup>41</sup>. Naps<sup>42</sup> and bright light<sup>13</sup> exposure could also be among these methods. These techniques, however, would presumably influence flow differently. In the present study, bright light improved only “confidence in competence” and no association with bright light was found in terms of “challenge to goals” and “positive emotion and absorption.” In contrast, all three flow components increased after a short nap. The detailed effects of executing these techniques on flow components should be investigated in the future studies.

In conclusion, the present study found that flow is facilitated after a short afternoon nap and under bright light exposure during a contextual cueing task and that flow correlated positively with objective performance and negatively with subjective sleepiness. These results suggest that a short nap and bright light can be employed as a flow facilitator and that flow status can be used as an indicator in evaluating work efficiency and occupational mental health.

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