

## *The Influence of Affordance on Cognitive Workload*

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### **Abstract**

In the study, it was demonstrated that whether there was a difference between an affordance condition and a no-affordance condition in the aspect of negative compatibility effect and cognitive workload. In case of the negative compatibility effect, even though the object's orientation and arrow's orientation are corresponded, when a prime object is displayed very briefly motor system is inhibited.

Twenty five students volunteered to participate in the experiment. The experimental design was 2 (Affordance condition & No-affordance design) X2 (Congruence & Incongruence) X2 (Task difficulty: High & Low), within subject design. Using RSVP paradigm, first of all, object stimuli presenting for 70ms is followed by arrow's orientations which are right or left for 70ms. As soon as arrow is presented, participants should respond arrow's orientation with keyboard. After then participants memorize numbers, 2-digit numbers or 3-digit numbers for 3500ms or 500ms. Cognitive memory task follows 2-digit numbers or 3-digit numbers. In the last section, subjects are asked subjective effort induced by memory task. Totally 192 trials are repeated randomly.

As a result, Negative Compatibility Effect was showed in the affordance and the congruent conditions by a difference between reaction time, not error rates. However, in case of cognitive memory task there are no differences in both of the affordance conditions and the congruent conditions. Therefore, it was confirmed that the Negative Compatibility Effect was determined repeatedly, but the hypothesis of the cognitive workload was not demonstrated.

Keywords: Affordance, negative compatibility effect, cognitive workload

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## Introduction

According to Gibson (1979) who suggested the concept of affordance firstly, affordance means things that look like what they are. On the other words, it was defined that the quality of an object, or an environment, that allows an individual to perform action (Son, 2008). This concept has played an important role in the area of product design, cognitive psychology, and architecture as well. For example, the affordance concept has been applied to panic hardware which helps people to escape in dangerous situation. People in panic tend to push a door, when they try to open the door. Hence, the door which should be pulled for opening in the building could be harmful to escape in panic. In practice, in England and United States laws panic hardware should be installed in the building were enacted. Furthermore, in 2012 panic bar function which could push to open easily in emergency was added in door lock product made by Samsung. As above, affordance has been in an integral part of the design area (Kim, 2012, Dec 20).

So far there are studies for demonstrating the advantages of affordance. According to the Csibra and Gergely (2007) study, affordance is advantageous for users to expect and predict functional characteristics rapidly. Other benefit is learning of a tool function by observation should be facilitated when a person uses a tool in a way that fit the observer's biomechanical expectations of behaviours that minimize the muscular and/or articulator costs, and should be impediment in the case where these expectations of behaviours that increase the muscular and/or articulator costs are violated. (Jacquet et al., 2012).

Also in case of imaging actions of tool, the neural responses in Extrastriate Body Area (EBA) of an agent can be distinguished by different agents imagined who use tools (Kim et al., 2012). Above the result focused on the role of EBA. Therefore, according to Kim et al., (2012), it is suggested that the EBA incorporates functional affordance of tools into the body schema in order to enhance the sense of agency and to guide our own actions. It demonstrated affordance can guide our behaviour. Based on Vainio et al.,(2011), it is suggested that tool-specific affordance presented in a short time make motor be inhibited. In the study, in the condition which Stimulus Onset Asynchrony (SOA) between prime stimuli and target stimuli was over 300ms and stimuli's orientation was congruent, positive compatibility effect (PCE) was shown. On the other hand, in the condition which SOA was under 100ms, negative compatibility effect (NCE) was shown. The compatibility effect could be measured by reaction time and error rate. However, in case of tool-no affordance negative compatibility effect was disappeared. This phenomenon could be explained that the role of affordance helps to perceive objects as object's own functions. Vainio et al., (2011) insisted that objects are just perceived as abstract visual attribute by eliminating affordance.

So far only benefits of affordance in experiment condition which participants do just one task have been demonstrated. However these days, people usually face with multi-tasking situation. Therefore it is needed to demonstrate advantages of affordance in the multi-tasking condition. Thus, in the study it is figured out that negative compatibility effect can be shown differently with manipulating affordance condition and no affordance condition and affordance can influence to cognitive workload and adding an extra memory task.

These hypotheses are as below:

- i. In the condition which SOA of prime stimuli with affordance under 80ms, reaction time is slower and error rates are lower than the no affordance condition.
- ii. In the condition which SOA of prime stimuli with affordance and congruent with arrow's orientation under 80ms, reaction time is slower and memory task's correct responses are lower than the incongruent condition. And mental efficiency (ME) is lower than the incongruent condition.

## Experiment

### Method

#### *Participants*

Nineteen students of Yonsei University (10 females and 9 males, mean age 24.6 years, six participants removed) participated on the experiment. Informed consent was obtained from each subject prior to commencing the task. After finishing the experiment, they obtained 2 credits.

#### *Stimuli and design*

The experimental design was 2 (Affordance condition & No-affordance condition) × 2 (Congruence & Incongruence) × 2 (Task difficulty: High & Low), within subject design. Each condition was repeatedly presented for three times and prime stimuli consist of six types which are a mug cup (2), a pan (2), an opener (2), a spoon (2), a glass (4) and a butterfly (4) pictures. A mug cup, a pan, an opener and a spoon pictures belong to affordance condition. On the other hand, a glass and a butterfly pictures belong to no-affordance condition.

Target stimuli were arrow pictures with right and left orientation. In congruent condition, handle of prime stimuli and arrow's orientation (target stimuli) are compatible and in incongruent condition the orientations are incompatible. In case of no-affordance condition there are arrow's orientations were randomly presented. Task difficulty indicates memory task's level. When 3-digit numbers were presented for 500ms, it is called a difficult task condition, whereas 2-digit numbers were presented for 3500ms, it is called an easy task condition. In total, 192 trials were consisted.

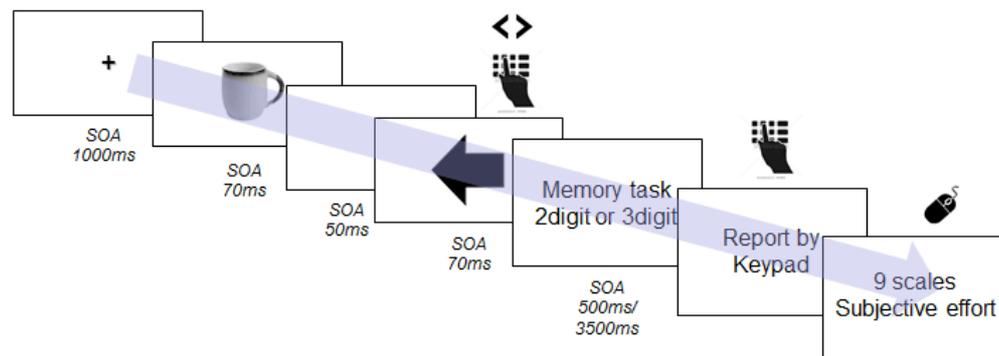
	<i>Affordance</i>	<i>No affordance</i>
<i>Congruence</i>		
<i>Incongruence</i>		

Table 1. Experimental conditions and stimuli described

### *Procedure and task*

First of all, fixation was displayed for 1,000ms at the beginning of each trial in empty white screen. Then the prime stimuli presented for 70ms is followed by blank screen for 50ms.

When arrow's orientations which are right or left for 70ms are presented, people should respond arrow's orientations with keyboard as soon as possible. After then participants memorize numbers, 2-digit numbers or 3-digit numbers for 3500ms or 500ms. In the memory task, people should report the numbers on N-1 trials. In the last section, subjects are asked subjective effort induced by memory task.



Picture 1. Experimental design

### *Dependent variables*

Dependent variables are reaction time, error rates of the arrow's orientations, correct response rates of the memory task and subjective effort with 9 scales (Tasir & Pin, 2012). Furthermore, mental efficiency (E) was calculated according to the formula  $E = (P - ME) / 2$ , using z-transformed perceived mental effort values (ME) and performance measures (P). According to this equation, mental efficiency is null when performance and mental effort z-scores are equal ( $P = ME$ ), positive when performance scores are higher than mental effort scores, and negative when performance scores are lower than mental effort scores (Paas & van Merriënboer, 1993).

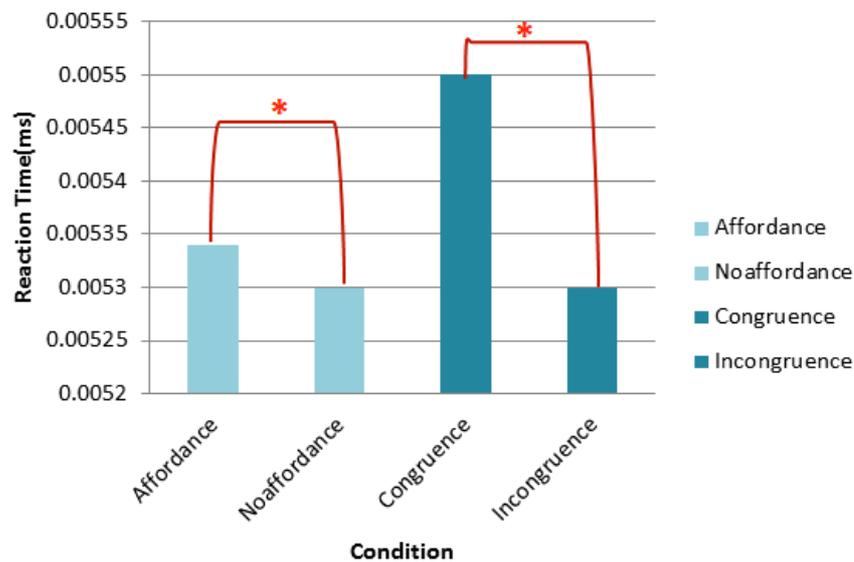
### **Results**

Reaction time and Error rate of arrow's orientation were analysed by one-way repeated-measure ANOVAs.

#### *Reaction time*

Only correct response results were analysed and data over 3SD (standard deviation) were rejected. As a result, there is a main effect of affordance condition (affordance and no-affordance conditions),  $F(1, 1183) = 4.649, p = .031$ . Specifically, reaction times of no-affordance condition ( $M = .0053, SD = .0013$ ) was faster than ones of affordance condition ( $M = .0054, SD = .0013$ ). Furthermore, there is a main effect of congruent condition (congruent and incongruent conditions) within affordance condition,  $F(1, 602) = 9.289, p = .002$ . Specifically, reaction times of incongruent

condition ( $M=.0053$ ,  $SD=.0013$ ) was faster than ones of congruent condition ( $M=.0055$ ,  $SD=.0013$ ).



Picture 2. Result of reaction time

#### *Error*

As a result, no significant main effect of affordance condition (affordance and no-affordance conditions) and congruent condition (congruent and incongruent conditions) within affordance condition was observed,  $p>.05$ .

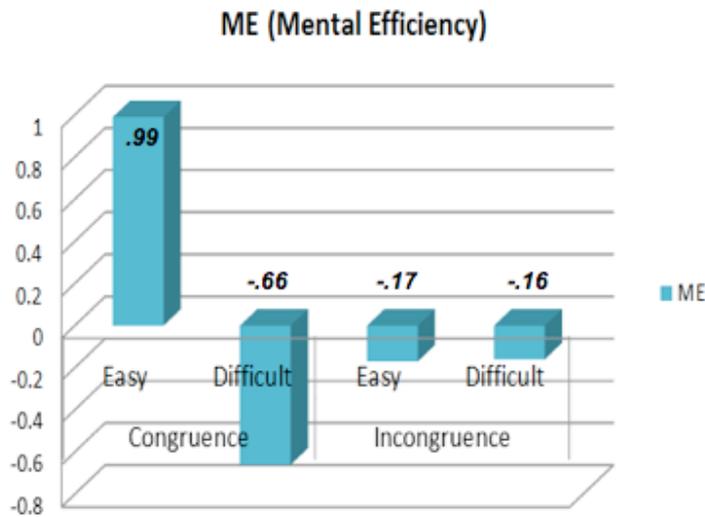
#### *Correct response rates of memory task*

Correct response rates were analysed by McNemar test. According to the results, there is a no significant difference between affordance condition and no-affordance condition,  $p=.302$ . Also, there is a no difference between congruent condition and incongruent condition,  $p>.05$ .

#### *Mental efficiency*

Using the formula  $E = (P - ME) / 2$  ((Paas and van Merriënboer, 1993), mental efficiency was calculated. After then results were analyzed by an independent sample T-test. As a result, there is a no difference between congruent condition and incongruent condition,  $p>.05$ . However, interestingly in the easy task condition mental efficiency ( $ME=.99$ ) in the congruence was higher than one ( $ME= -.17$ ) in the incongruence. Negative compatibility effect was not shown in the easy task condition. On the other hand, in the difficult task condition mental efficiency ( $ME= -.66$ ) in congruence was lower than one ( $ME= -.16$ ) in the incongruence. Only in the difficult task condition, negative compatibility effect was shown.

Therefore hypotheses were partly demonstrated.



Picture 3. Result of mental efficiency index as a function of task difficulty and congruence

### General discussion

Results of this study revealed the relationship between affordance and cognitive workload. Furthermore, negative compatibility effect in a short SOA was demonstrated consistently as Vainio et al., (2011)'s experiment. Although all of hypotheses were demonstrated perfectly, it is meaningful that experimental conditions participants had to do two tasks were suggested for revealing affordance's advantages in the study. The advantage of affordance revealed is affordance help to reduce cognitive workload in only a difficult task.

A reason why there are different results depending on task difficulty and time pressure could be explained by germane mental workload (Sweller, 1988 Galy, Cariou, Mélan, 2012). According to Sweller's theory suggested intrinsic, extraneous and germane cognitive load, germane cognitive load was indicated the load placed on working memory during schema formation and automation (Paas et al., 2003; Sweller et al., 1998). Sweller (1988) insisted that an individual requires extra mental resources in high mental workload for mental process. In the experiment, easy memory task was manipulated by 2-digit number and low time pressure, so participants' mental resource were enough to memorize numbers in congruent and incongruent conditions. On the other hand, in case of difficult memory task manipulated by 3-digit number and high time pressure, participants should allocate their extra resource to entering information. Consequently, the demand for extra resources influenced to mental efficiency, not memory task's performance. Moreover, a reason why the negative compatible effect was shown in mental efficiency is the characteristic of affordance influenced to mental efficiency. If affordance were not related to cognitive workload, positive compatibility effect would be generated in mental efficiency. The results tell there is a relationship between affordance and cognitive workload.

However, a limitation is there is a no difference between affordance, no-affordance conditions, congruent and incongruent conditions in the memory task. This is because it is possible for participants to acquire learning strategies during 192 trials. Therefore learning strategies had an effect on the correct responses of memory task. Furthermore, psychophysiological measures should be needed as Galy, Cariou, Mélan (2012) study. According to Galy, Cariou, Mélan (2012) experiment, they used subjective, performance and psychophysiological measures. Therefore psychophysiological measure such as heart rate or skin conductance response should be added for getting more objective data in further study.

Affordance has played a significant role in design area. So far there have been studies related to affordance, but no exists about effect of affordance to workload before. Therefore, this study is meaningful to demonstrate a relationship between affordance and workload especially in the difficult task condition.

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