An Eye-Tracking Analysis of the Effects of Emotional and Rational Stimuli on Consumer's Cognitive Load and Need-for-Cognition

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Abstract:-This study aims to analyze how much individuals' physiological responses change when they face two types of stimuli which is composed of advertising copies and images. Homogeneous stimuli are designed to consist of either emotional copies and emotional images, or rational copies and rational images. Homogeneous stimuli are designed to be composed of either emotional copies and rational images, or rational copies and emotional images. There exists no study in literature in which consumer's physiological data was analyzed when they are exposed to those two types of stimuli. To fill in the research void like this, this study adopts an eye-tracking approach and invited 80 participants for the sake of rigorous statistical analyses. We examined participants' cognitive load and nee-for-cognition to use them as important criteria for the sake of objective assessment of the physiological data. We used the fixation length data obtained from the eye-tracking analysis of the participants' eye-movement with the two types of stimuli. Results were such that participant's cognitive load increases more when they are exposed to heterogeneous stimuli, and that participant's fixation length changes significantly only when there exists interaction effect between cognitive load and need-for-cognition in response to the stimuli.

Keywords:- Creativity, Need for cognition, Cognitive load, Eye-tracking, Advertising messages

1. Introduction

We are living in a world where digital devices and power are dominating in every corner of our lives. We are dealing with every sort of information with digital power and devices. In that sense, we use our cognitive resources constantly to process tons of information. To make good decisions on the basis of various kinds of information, we need to understand cognitive load and need-for-cognition.

While exploring information, humans use

conscious processing at various levels. Information retrieval is obviously a natural cognitive process (Ingwersen, 1996) and human-computer interaction, which connects these forms of information processing, depends on a human's consciousness and cognition (Card et al., 1983). Cognitive load or CL has been used to predict, model, and evaluate human performance in various fields, including cognitive psychology, educational psychology and engineering psychology. The complexity of CL is the result of disciplinary differences in its conceptualization. Even within a single discipline, there is rarely agreement on a general definition of CL. In human factors and engineering psychology, CL is referred to as mental workload. Mental workload is understood as the relationship between demand for mental resources required for a particular task and a human's capability to supply such resources (Moray, 1979). In other perspectives, it is defined as the portion of a person's processing capacity that is actually needed to carry out a particular task (O'Donnell & Eggemeier, 1986).

Meanwhile, need-for-cognition or NFC is the desire to structure given situations with a meaningful and integrated method. It is the desire to understand and rationalize the experiential world (Cohen et al., 1955) and the tendency of individuals to carry out cognitive activity and enjoy cognitively effortful circumstances (Cacioppo et al., 1996). NFC could be an indicator of individual differences in the engagement in effortful cognitive activity as intrinsic motivation (Cacioppo & Petty, 1982). Therefore, NFC is referred to as intrinsic motivation related to problem solving. People with high NFC enjoy thinking intrinsically and put much effort into understanding the relationship between stimuli and circumstances, while people with low NFC have a tendency to minimize such cognitive endeavors.

Main objectives of this study are as follows. Firstly, this study aims to introduce the need of understanding CL and NFC in order to improve the quality of decision-making. Those CL and NFC are always needed when we try to process many kinds of information coming from digital devices and Internet. Secondly, on the assumption that most of information coming from digital devices and Internet belong to rational and emotional stimuli in forms of images and texts, we use rational stimuli and emotional stimuli to trigger our CL and NFC. Thirdly, we investigate the effects of CL and NFC on our physiological system. In literature, we found that there is no study in which how much our physiological resources like eye-tracking are used to handle CL and NFC when we are supposed to deal with rational and emotional stimuli.

2. Theoretical Backgrounds

2.1 Cognitive Load

The concept of CL is related fundamentally to the concept of finite mental resources. The multiple resource theory (Wickens, 2002) states that—when demands for one task are high—the mental resources devoted to that task cannot be used in a second task that requires the same kinds of resources. The limited capacity of working memory results in mental limitations on perception and cognition. Working memory is generally considered to include three types of subsystems: verbal information processing, visual information processing and controlling and coordinating the processing machinery (Baddeley, 1986).

Recently, many researchers have used various physiological experimental techniques to study CL. For example, Kun et al. (2009) have used "eye-tracker" as an experimental technique to obtain visual attention data. Eye-tracker may also be used to obtain physiological estimations of CL, as the pupils expand when people are faced with a challenging cognitive task. Therefore, the simple phenomenon in which task stimulates pupil expansion (Beatty, 1982) can be used to measure CL. The research related to CL measurement using eye-tracker was carried out. Pupillary response, which occurs during mental multiplication tasks, short-term memory tasks and aural vigilance tasks, was measured and the relationship between those and CL was studied. The conclusion was that eye tracking is a practical method to measure CL (Klingner et al., 2008).

2.2 Need-for-Cognition

NFC not only shows individual differences with respect to cognitive motivation, but also reflects stable individual differences with respect to the motivation to enjoy effortful cognitive endeavors (Cacioppo et al., 1996). Because of these characteristics, many researchers in various fields such as psychology are interested in NFC. For example, it was found that NFC affects cognitive elaboration and recall of various advertising stimuli (Peltier & Schibrowsky, 1994). It was also found that NFC affects formation and changes in attitude (Haddock et al. 2008) and problem solving (Nair & Ramnarayan, 2000).

Basically, NFC is closely related to elaboration likelihood method (or ELM). ELM provides a variety of cognitive processing levels based on an individual's motivation or ability. According to ELM, individuals with high NFC carry out effortful cognitive activity and have access to central information routes, while those with low NFC engage in fewer cognitive endeavors and have access to peripheral information routes (Petty & Cacioppo, 1986). People with high NFC were found to exhibit higher performance on recall and recognition tasks (Kardash & Noel, 2000) and actively explored new information (Verplanken et al., 1992). They showed better performance in cognitive endeavors such as appropriate decision making (Levin et al., 2000). Those people with high NFC can be told as creative people.

2.3 Eye-Tracking Approach

The strength of general psychophysiological measures is the objectivity of the data, which minimizes the distortion of discretionary evaluation of participants' results compared to the subjective evaluation of a self-reporting method. Self-reporting like questionnaire survey is likely to be affected by unconscious tendency to describe oneself positively, or to react in a socially acceptable manner. However, a psychophysiological approach measures the process of a particular psychological phenomenon by activation of the autonomic nervous system, which individuals cannot control consciously. Therefore, psychophysiological measures can provide objective information about psychological reactions that participants cannot recognize consciously (Ravaja, 2004).

Among psychophysiological approaches, studies related to eye movement have a long tradition. A human's eye gathers the largest amount of information of all the sensory systems. People obtain more than 70% of external information through visual processing. Also, in working memory, more than 90% of information used for cognitive activity is obtained from visual information (Solso, 1997). Eye movements triggered by visual stimuli indicate that an individual perceives selectively and actively (Arnheim, 1969). Therefore, eye movement can be considered an important measurement for understanding cognitive activity triggered by visual stimuli (Glenstrup & Engell-Nielsen, 1995). Eye-tracking enables automatic chasing and exploration of information without interrupting the automatic process of eye movement. It also provides a measure of fixation duration through which we can achieve a better grasp of cognitive processing (Velichkovsky et al., 2002). Eye-tracking is a useful tool not only for a user's interaction with a particular service, but for the measurement of human behavior. Further, it provides considerable help to companies and researchers in the development of products and services that appeal effectively to consumers' emotions. Eye-tracking has proven to be a strong approach to measure performance in the interaction between products, services and customer, and its use is expanding to help better understand the reception of visual stimuli in information handling processes (Mealha et al., 2012).

3. Methodologies

3.1 Hypotheses

An individual's eye movements are an important clue to understanding cognitive activity related to a particular visual stimulus (Glenstrup & Engell-Nielsen, 1995). Kun et al. (2009) obtained visual attention data by using eye-tracker, while Klingner et al. (2008) also used eye-tracker to carry out research related to the measurement of

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CL. By measuring the duration of visual fixation, we gain insight into an individual's cognitive processing (Velichkovsky et al., 2002).

Many researchers have investigated the relationship between individual cognitive processes and eye movement (e.g., Velichkovsky et al., 2002). In particular, fixation length increases in direct relationship to the level of cognitive processing.Thus, simple scanning is related to short gazing, while an in-depth cognitive process, such as serious information consideration, showed a cursory cognitive processing level that is inferred to be related to longer staring. In a similar context, through eye-tracking research, It was showed that more automatic processes, such as silent reading, are related to shorter gazing, while cognitive processes that require more effort, such as typing, lead to longer gazing (Rayner, 1998). Results of previous studies show that fixation length increases as the level of cognitive processing increases. Therefore, the first and second hypotheses this study proposes are that fixation length will be greater when CL and NFC take place.

H1: The level of CL will affect participant's fixation length.

H2: The level of NFC will affect participant's fixation length.

Meanwhile, it is usual that CL and NFC are interacting with each other because they are triggered by the cognition-processing parts of our brain. In addition, we know that the cognition-processing parts of our brain are also affected by the emotional brain which is called limbic region. Therefore, the third hypothesis is organized as follows.

H3: The interaction between NFC and CL will affect participants' fixation length.

3.2 Stimuli

We used advertising messages and images as stimuli to check the level of NFC and CL. We set up experimental stimuli that were expected to have different levels of CL and NFC. Experiment participants were exposed to the stimuli. By using an eye-tracker device, we obtained eye movement tracking data and then conducted a survey to assess participants' self-reports about the level of CL and NFC that they perceived through the stimuli. To secure rigorous validity of our experiment results, the experiment stimuli were composed of rational and emotional copies and images. Those stimuli consist of advertising copies and images.

3.2.1 Advertising Copies

We prepared 20 examples of advertising copies (10 "emotional copies", and 10 "rational copies") to carry out the eye-tracking experiment. To secure validity of the stimuli, a professional market research company was recruited to produce those advertising copies. To obtain qualified advertising copies, two filtering sessions were carried out. At first, 474 copies (227 for iPhone and 247 for Galaxy) provided by the company were submitted to 1 professor, 6 doctoral students for the sake of further proof-reading and double-check. They assess the copies to check whether they possess adequate messages from the perspective of being rational and emotional. Here, a rational copy indicates that it appeals to facts and reasoning, and an emotional copy means that it appeals to our feeling.

After the first session, a survey was carried out to divide the qualified copies into rational copy and emotional copy. 50 raters were asked to rate, on a scale from 1 to 9, how appealing a copy was, with 1 being "emotional very much" and 9 being "rational very much". These measures were adapted from Rosselli et al. (1995). The raters received no more than 40 copies, considering their capability to rate without mental fatigue. Finally, 376 advertising copies (179 for iPhone and 197 for Galaxy) were rated as qualified to be either rational or emotional. If copies have a rating score less than median, they were classified as emotional ones. If rating score is greater than median, the copies were categorized as rational ones. As stated previously, we selected 10 rational copies and 10 emotional copies to conduct the eye-tracking experiments. The final copies to be used as stimuli are summarized in Table 1.

<Table 1> Twenty Advertising Copies used as Stimuli

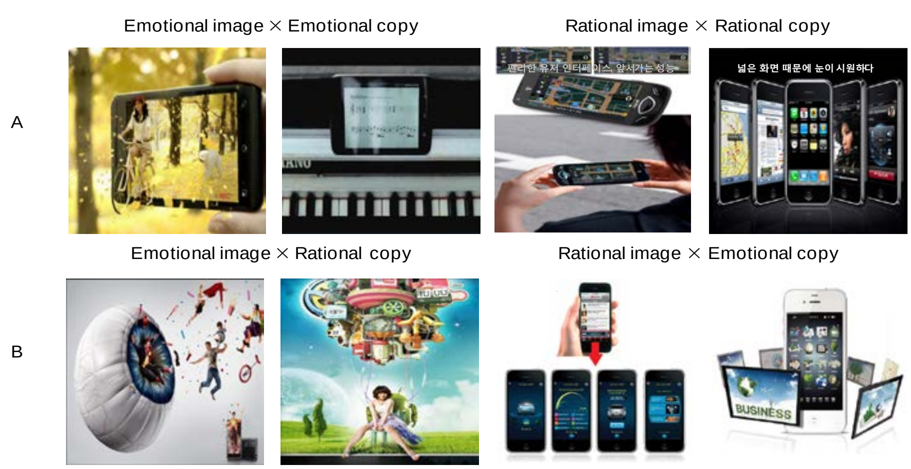
Emotional Copy	Rational Copy
I can even look into your heart.	It is really good to see because of wide screen.
The phone that expresses human heart	Amazing processing speed with Quad-core
The way of expressing love	Long lasting battery and comfortable to use
The friend for lonely me	Wide screen and excellent performance
Smartphone, soft and catching my fancy	The harmony of fast speed and wide screen
Life as the main character in a movie	The vivid screen as reality.
Always in my embrace, You are.	The high definition display with various functions, comfortable use.
You are holding a jewel in your hand	Excellent grip and wide LCD
Closely touching and embracing voice	The high definition display and various functions
Soul, reflecting emotion	Comfortable user interface, advancing performance

3.2.2 Advertising Images

We invited three graphic design experts to prepare for the 10 advertising images which were to be used for our eye-tracking experiments. To determine validity of the images, 40 raters were invited- 24 male (60%) and 16 female (40%). We divided them into two groups of 20 each. One group was shown only emotional images, while the other group was exposed to only rational images. We asked them to rate each image on a seven-point Likert scale, with one being "emotional very much" and seven being ''rational very much". There exists significant difference (p <0.05) between the two groups. Therefore, we were convinced that those advertising images are qualified to be used as proper stimuli for our experiments.

3.2.3 Stimuli Group

To obtain statistically reliable results, we organized stimuli into four groups- "emotional image × emotional copy", "rational image × rational copy", "emotional image × rational copy", "rational image × emotional copy." Then the two groups such as "emotional image × emotional copy" and "rational image × rational copy" are classified as homogeneous stimuli, and the two groups "emotional image × rational copy", "rational image × emotional copy" are termed as heterogeneous stimuli. Fig. 1 depicts two stimuli groups.



Note: A: Homogeneous stimuli, B: Heterogeneous stimuli

<Fig. 1> Samples of Homogeneous and Heterogeneous Stimuli

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3.3 Participants

In literature, most studies using eye-tracker have been carried out on 10-40 participants (Bayram & Bayraktar, 2012). However, it is difficult to conduct highly complex statistical analysis with those few participants. In this study, we invited 90 participants. If a participant's eyesight or corrected eyesight was at a generally acceptable level, regardless of whether they wore glasses, they were allowed to join our experiment. We excluded 10 participants from our final sample because the eye-tracking results from them were of very low quality with their eye movements having been not captured precisely. Therefore, 80 participants were used as the analysis was performed on results from 80 participants. 37 (46%) of them were male, and 43 (54%) of them were female. 75 of them (94%) were under 25 years old.

4. Experiment and Results

The experiment was carried out on the laptop where the eye-tracker was set up. The overall procedure for the experiment was introduced to the participants. Then we carried out calibration of the eye-tracker with the participants. The minimum gaze time was set to 100 milliseconds in the 30 pixel of gaze area (Cutrell & Guan, 2007). Also, for each experimental stimulus, the area in which advertising copy appeared was set as "the area of interest (AOI)." AOI and the rest of the area were distinguished with each other. The fixation length data were extracted for the AOI. The fixation length is related to obtaining cognitive processing data (Henderson, 2003).

4.1. Cognitive Load and Need for Cognition

Firstly, descriptive statistics with reference to the level of CL depending on the level of homogeneous and heterogeneous stimuli and NFC are shown in Table 8. The CL that individuals with high NFC perceived was 2.05 on average and 2.32 when they were exposed to heterogeneous stimuli. We carried out a two-way ANOVA to determine the significance of these results, which are shown in Table 2, 3 and Figure 2.

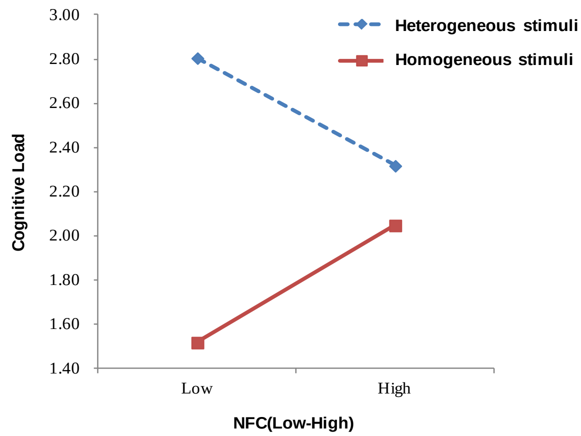
<Table 2> Descriptive statistics on cognitive load

Category		NFC	N	Mean	Std. deviation
Cognitive Load	Heterogeneous Stimuli	Low	18	2.806	1.816
		High	22	2.318	1.237
		Subtotal	40	2.538	1.524
	Homogeneous Stimuli	Low	14	1.518	0.668
		High	26	2.048	1.051
		Subtotal	40	1.863	0.961
	Total	Low	32	2.242	1.555
		High	48	2.172	1.136
		Total	80	2.200	1.311

<Table 3> ANOVA on cognitive load

Source	Sum of squares	Df	Mean Square	*F*
Stimuli	11.507	1	11.507	7.189***
NFC	0.009	1	0.009	0.005
Stimuli × NFC	4.910	1	4.910	3.067
Error	121.653	76	1.601	

*Note: ***Statistically significance at p < 0.01*



<Fig. 2> Cognitive Load in line with NFC

From Figure 2, we found that the level of CL was lower in the group exposed to homogeneous stimuli compared to the group exposed to heterogeneous stimuli. This means that if two heterogeneous stimuli (*"emotional image × rational copy"*, *"rational image × emotional copy"*) are presented, the participant's CL to process that information increases. Such mental workload may be understood in terms of the relationship between demand for mental resources required for the task and the capability of individuals to supply such resources (Moray, 1979). This indicates that, because there are limits on cognitive processing, the amount of information that can be activated or processed and the degree of cognitive processing that can be handled is also limited. However, there was no interaction effect with NFC in terms of CL. Regardless of the level of NFC, the heterogeneous stimuli increase CL.

4.2. Fixation Length

Table 4 addresses means and standard deviations of fixation length depending on stimuli type (homogeneous or heterogeneous stimuli). The level of NFC is categorized into high when its NFC value is greater than average NFC, and otherwise into low. With higher NFC, fixation length was longer when participants were exposed to heterogeneous stimuli than when they were exposed to homogeneous stimuli (0.59>0.42). On the contrary, with lower NFC, the opposite results were obtained (0.39>1.07). The statistical significance of the results in Table 4 was analyzed with a two-way ANOVA and the results are shown in Table 5 and Figure 3.

<Table 4> Descriptive statistics on fixation length

Category		NFC	N	Mean	Std. deviation
Fixation length	Heterogeneous Stimuli	Low	18	0.39	0.698
		High	22	0.59	1.098
		Subtotal	40	0.50	0.934
	Homogeneous Stimuli	Low	14	1.07	0.616
		High	26	0.42	0.703
		Subtotal	40	0.65	0.736
	Total	Low	32	0.69	0.738
		High	48	0.50	0.899
		Total	80	0.58	0.839

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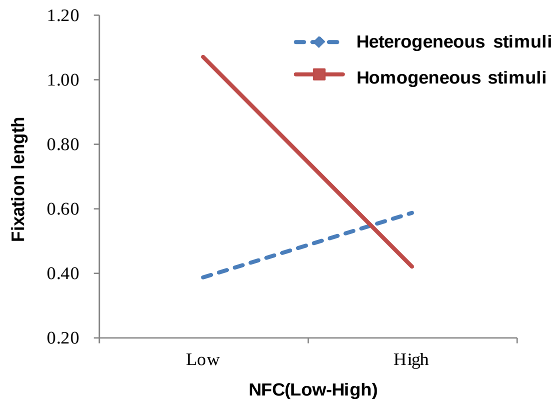
<Table 5> ANOVA on fixation length

Source	Sum of squares	df	Mean Square	*F*
Cognitive load	1.001	1	1.001	1.514
NFC	0.628	1	0.628	0.949
Cognitive load × NFC	3.789	1	3.789	5.729*
Error	48.944	76	0.661	

*Note: *Statistically significance at p < 0.05*



<Fig. 3> Fixation length

From Figure 3, when participants have high NFC, the fixation length increases as CL increases. However, neither the main effect of NFC nor that of CL on fixation length was statistically significant. In the end, we could demonstrate that fixation length changes only when interaction effect between NFC and CL exists. Therefore, we reject hypotheses 1 and 2, but accept hypothesis 3.

Human gaze is related to obtaining information and cognitive processing (Henderson, 2003). When individuals find it difficult to extract information or are interested in an object, the length of eye fixation increases (Just and Carpenter 1976). People with high NFC have the tendency to accept cognitively effortful situations naturally, and therefore, when they are presented with heterogeneous stimuli, as in this experiment, they will process that information willingly, accepting the CL. As a result, their fixation length increases as they try to deal with the CL derived from NFC. On the other hand, if homogeneous stimuli are presented (low CL condition), there is no need to handle the problem caused by discord among stimuli. This results in straightforward decrease of fixation length as a result.

5. Concluding Remarks

On the basis of two types of stimuli which is composed of advertising copies and images, we conducted an experiment using eye-tracking approach. The results were promising. Lessons we learned from the experiment can be summarized as follows. Firstly, participant's CL increases more when they are exposed to heterogeneous stimuli. Secondly, participant's fixation length does not change significantly when there are changes in either CL or NFC level. Thirdly, participant's fixation length changes significantly under 90% confidence level only when there exists interaction effect between CL and NFC. Fourthly, physiological signals derived from the experimental data on eye movements provided further objective information. In literature, we already know that eye fixation increases as the level of CL increases (Velichkovsky et al., 2002). However, this study is unique because it examined participant's fixation length depending on types of stimuli (heterogeneous vs homogeneous), and level of CL and NFC. Fifthly, when participants with high NFC were exposed to heterogeneous stimuli, fixation length increased.

This is similar to Henderson (2003), which insisted that eye fixation is related to information acquisition and cognitive processing. Also, this result is in accordance with Just and Carpenter (1976), which reported that eye fixation lasts longer when information extraction is difficult or the participant is gazing at an interesting stimulus.

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