Memory-based Web Advertising to Distract Rumination

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Abstract: Despite its benefits, technology has become a source of mental problems. This research supports the objective of positive computing through the development of the system that prevents rumination, repetitive negative thinking, during web searching. The system consists of two sub-systems: *data collection sub-system* and *distraction sub-system*. The former collects searching data on websites through Chrome extension. The latter is the ACT-R (Adaptive Control of Thought-Rational; Anderson, 2007) cognitive model that utilizes personal experience data as well as physiological data to detect rumination and provides an implicit intervention for rumination based on the concept of *nudge* (Thaler & Sunstein, 2009). The system displays an image based on user's memory on the screen as personalized advertisement and prompts a nudge when rumination is detected.

Keywords: ACT-R cognitive architecture, Rumination, Positive computing, Computational psychiatry, Advertising

1 Introduction

In recent decades, more and more innovative technologies have been invented to facilitate human lives. In the meantime, technology, especially the internet, has unconsciously changed human behavior and emotional stability. The side-effects of technology have widely become a source of mental problems [1, 2] such as stress, anger, anxiety and depression. One of the problems that we concern is repetitive, negative thinking about one's unpleasant experiences, namely rumination [3, 4].

There has been an interest in the field of *positive computing*: the design and development of technology to support psychological well-being and human potential [5]; and *computational psychiatry*: the use of computational method to provide diagnosis and treatment for mental illnesses [6]. In this research, we complied with the fields and developed a system that prevents rumination during web searching.

The developed system consists of two sub-systems: *data collection sub-system* and *distraction sub-system*. The former is the Google Chrome extension that collects individual's real-time searching data (e.g., the URL of websites that the user has visited and the URL of product pictures shown on the websites) and remotely saves to laboratory's database. In this research, this sub-system focuses on only Japanese online shopping sites: Amazon.co.jp and Rakuten. The latter is principally the ACT-R (Adaptive Control of Thought-Rational) cognitive architecture [7] that processes personal experience data as well as physiological data to detect rumination and output images based on user's memory. Distraction sub-system also provides an implicit intervention for rumination based on the concept of *nudge* [8] as it displays an output image on websites as personalized advertisement and prompts a distraction after rumination is detected.

We planned to evaluate the effectiveness of the system in four aspects: recognition, attraction, distraction, and yielding, in comparison with other conditions. We are designing the upcoming experiment, and at this stage, we expect the results of the model to outperform web advertising of other conditions in terms of recognition and attraction.

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2 Related Studies

2.1 Mental Illness

Rumination is commonly defined as repetitive, negative thinking about unpleasant experiences such as disappointments or past mistakes [3, 4]. Similar to depressive symptom, rumination prolongs dysphoric moods [9] and causes attentional biases towards negative information [10, 11]. The level of severity varies depending on individual. However, in some cases, people who often rumination were reported for facing a greater risk for depression [12].

In cognitive psychology's perspective, rumination is considered as a type of task-unrelated thoughts [13] (e.g., mind-wandering). This kind of mental states has the same characteristic of temporarily losing cognitive control of attention on the task on hand and deliberately engaging in contemplation–to continually recall past experiences or imagine about the future. While mind-wandering could affect the task both positively (i.e., improving creativity) [14] and negatively (i.e., losing focus) [15], rumination which relates to unpleasant experiences causes only negative effects.

2.2 Cognitive Model

As rumination relates to memory retrieval, we designed a solution for the mental problem and came up with cognitive architecture, a structural model of human brain that can simulate cognitive operations corresponding to brain regions. To construct the cognitive environment, in this research, we chose Adaptive Control Thought - Rational (ACT-R) cognitive architecture which is widely used and has modules relating to attention and human memory according to theories of memory [16].

2.2.1 Theories of Memory

To date, how human memory exactly works is still a black box even though there are various researches theorizing it, e.g., multi-store model [17] and working memory model [18].

The theories of memory in ACT-R cognitive architecture are referred to activation and association of chunks stored in declarative memory–in which they affect how likely a chunk will be retrieved successfully and quickly. In addition, memory decay and spacing effect has an impact on the activation. The forgetting curve theory [19] was hypothesized regarding memory decay–it shows the loss of information over time as long as it has not been recalled. On the other hand, according to the spacing effect theory [20], frequently recalling the information after a passage of time could strengthen its retention, i.e., a piece of information becomes harder to forget after being periodically recalled (Figure 1).

The connection of rumination mechanism and activation of memory chunks can be said that repetitive recalls of past experiences could raise priority of the memory chunks to be retrieved again and again so that it becomes rumination. Moreover, during rumination, the brain keeps retrieving memory chunks based on their priority; nonetheless, the negative experiences which are the cause of rumination are most likely to be recalled. Then the cycle continues.

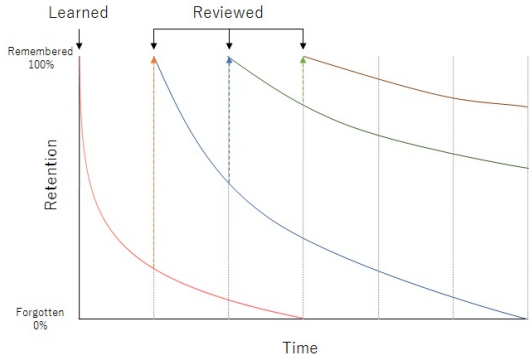

Figure 1: Ebbinghaus's forgetting curve and spacing effect.

2.2.2 Previous ACT-R models

A number of recent researches had explored the simulation of the task-unrelated thoughts by using ACT-R cognitive architecture. Van Vugt et. al. [21] created an ACT-R model that simulates the processes of mind-wandering from attending a task, keeping focusing on the task, getting distracted, falling into the mind-wandering state and continuously recalling past memories, to getting reminded and returning to the task. The model is able to describe the fundamental mechanism of mind-wandering according to relating theories: executive failure and perceptual decoupling. They continued working on building the ACT-R model to simulate other types of task-unrelated thinking. In another study, they applied the previous

ACT-R model with transition of mood chunks (cheerful, content, down, suspicious, and insecure) and implemented the model that simulates ruminating participants [22]. The model supports the assumption that the activation of negative mood chunks lead to higher priority to be retrieved as the cycle. They compared the simulations with the empirical study, and the results from simulation are similar to ones from empirical study in terms of retrieval frequencies and sequences.

Viewing from another point, rumination associates with emotions tied up with experiences, and there had been many researches that utilize ACT-R to model them and their effects. Dancy et. al. [23] integrated human physiology simulation into ACT-R and modeled effects of stress during mental arithmetic task. The results show correlation of performance between human and the models. Itabashi et. al. [24] created a reminiscent photo slideshow using ACT-R. They collected participant's personal photos in mobile phone, interfaced them with image recognition to extract metadata (person, place and time), and converted to memory chunks for the model. The model continually retrieves the image chunks, and at the end of each time window, it returns and displays an image relating user's memory the most on the screen. The aim of the research was to study emotional effects in participants when seeing and recalling memorable memories. They also studied physiological changes in participants when observing the photos using heart beat monitor. Heart rate variance (HRV) was assumed to determine level of stress and used to control noise parameter–which affects the stability of image selection based on activation formula in the model–in real time.

In this study, we aimed to apply the concepts of previous ACT-R studies, develop a system based on ACT-R cognitive architecture and physiological data to simulate rumination, and construct a protective environment for users.

2.3 Advertisement

The last component of the system is a solution to rumination. We reviewed the concept of *nudge*, an approach of implicit intervention that unconsciously improves individual ' s behavior and decision making [8]. Caraban et al. [25] reviewed 71 noble articles regarding the application of nudge in the Human Computer Interaction (HCI) field and categorized into 23 methods in six groups of purposes. We considered the extent of nudge mechanism that can be adapted to solve mental problems, especially rumination, and found that implicit intervention on human cognition has great potential to reinforce behaviors through prompting drawing attention at appropriate times. For example, Zhu et. al. [26] studied the effects of different strategies (explicit vs. implicit) and arousal (high vs. low) on encouraging computer users to correct their sitting posture. They used pop-up text reminder and screen moving to nudge users to stretch.

In this study, we used personalized web advertisement as a nudge to draw attention from rumination. Personalized advertising accords our preferences in terms of collecting data and matching user's interests. The data is images of products on shopping sites that individual has visited. Unlike other personalized advertisements, our method based on ACT-R model selects image that associates with the user's memory. We assumed that the output image is the product that the user thinks of the most, i.e., the product that the user has an interest in, and the user's attention would be drawn this way.

3 Objectives

Our main objective of this research is to build a system that detects and distracts rumination in users during web searching. We hypothesized that the ACT-R model that utilizes personal experience data as well as physiological data could yield accurate detection on rumination and the personalized advertising based on user's memory could effectively distract users from rumination.

However, it is difficult to accurately detect such task-unrelated thoughts. Bixler & D'Mello [27] used eye tracker to observe subject's mind-wandering state when reading texts. With an application of supervised machine learning algorithms, the result achieved only 72% accuracy rate at best. That can be said that, to date, the reliable method to accurately detect rumination has not been found yet. Therefore, at the current stage of this study, we only focused on the second hypothesis.

4 The System

The system is divided into two sub-systems: *data collection sub-system* and *distraction sub-system*.

4.1 Data Collection Sub-system

Data collection sub-system, as its name says, is simply to collect individual searching data (Figure 2). We created a Google Chrome extension that captures all images shown on websites that user visits within the screen, collects their URLs including the web URL and timestamp in real time, and remotely sends the data to laboratory's database. The extension can be installed on any computer that has Google Chrome, and we could collect data from anywhere and anytime through this way.

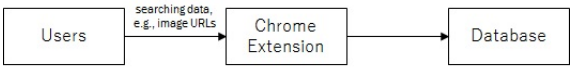

Figure 2: Data flow of data collection sub-system.

4.2 Distraction Sub-system

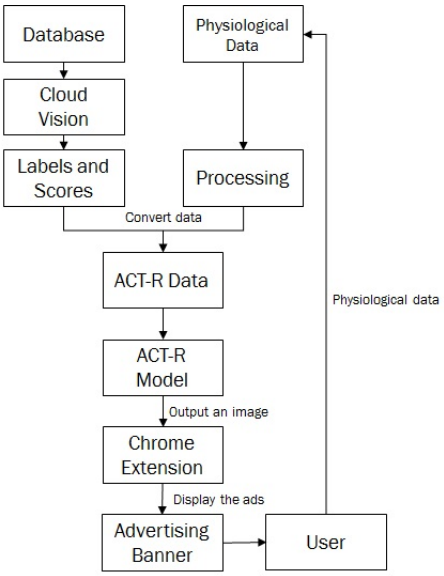

Figure 3: Data flow of distraction sub-system.

Figure 3 exhibits the flow of distraction sub-system which has ACT-R cognitive model as principal component of the system. On the top left of the figure, we integrated Google Cloud Vision, a machine-learning-based image recognizer, to the system to extract labels (i.e., types of product) and confident scores from the collected images in database, while on the top right, we included heart beat monitor to track heart rate variability, which is able to signify the level of stress in participant, from the user in real time. Such data is converted to ACT-R data in forms of declarative memory chunks and parameters. The model processes to simulate rumination in the user and outputs an image based on algorithms relating to human memory.

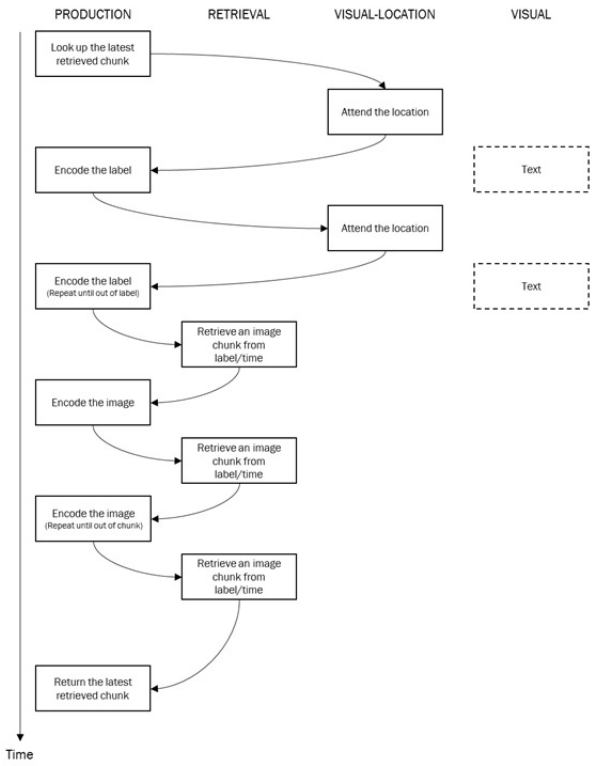

Figure 4: Operation sequence of the ACT-R model.

In detail, the operation of the model can be simply explained that the model searches for the latest retrieved chunk and virtually investigates labels of the image based on its confident score, i.e., the higher confident score the label contains, the higher tendency the label will be investigated–one by one. Then, the model continually retrieves image chunk that associates with previously retrieved chunks in terms of label and time, until it is unable to retrieve any related chunk. Then, the model returns the latest retrieved chunk as output (Figure 4).

To display the image on websites as advertisement, another Google Chrome extension is used. It retrieves

Figure 5: Output images from the ACT-R model.

the output image from the model and edits the websites to show the image. At the moment that the user ruminates, the ACT-R model outputs another image as a result of the repetitive thought, and the image correspondingly changes to draw attention and distract from rumination as shown in Figure 5.

5 Plan of the Experiment

The aim of the upcoming experiment is to evaluate the effectiveness of distraction sub-system. Giving the web advertising based on individual memory test condition (TC), we set two other conditions for result comparison. The first is random condition (RC) in which web advertising is selected randomly from the entire collected images. Another condition is fixed noise condition (FC) in which we use the ACT-R model to process memory-based data, but exclude heart rate variability and fix the noise parameter in the model. To analyze the result, we planned to assess the effectiveness in four aspects: recognition, attraction, distraction, and yielding.

5.1 Participants

We planned to recruit 30 Japanese student in Shizuoka university who often visit shopping sites. Prior to the experiment, we will send the Chrome extension to participants to collect searching data. After a fair amount of data is collected, we will invite participants to laboratory to complete the on-site experiment.

5.2 Procedure

Participants are required to sign a consent form in order to attend the experiment. They will be told to sit in front of a computer that has eye tracker set up, calibrate the gaze tracker, and wear heart beat monitor. Then, we will inform the tasks of the experiment.

The whole experiment is divided into three sessions: mood induction, main task, and report writing task. Mood Induction Procedures (MIPs) are a psychological method to influence emotions in participants prior to the experiment [28]. One of the common techniques is called *imagination technique* which is to evoke past emotional experiences. After participants are grouped into three for the between-subject experiment, they will attend the task which is to search for articles regarding failure and mistakes and recall self experiences. This is to influence concern and provide opportunities for participants to reminisce on the negative experiences.

The main task is to freely search for products on shopping sites. Assuming that participants are moving to Tokyo in the next Spring for starting their work after graduation, they will be told to look for any necessary items in preparation of moving. We will activate the model at the beginning of the main task. In test group, the ACT-R model with variable noise parameter from physiological data will be used to recommend images as advertisement, while in FC, we will use ACT-R model with fixed noise parameter instead. And in random condition, the images shown on websites will be picked randomly from the whole images without using ACT-R model.

The report writing task is to write a summary report regarding the first task and the second task. This task acts as a targeted task that participants have to think ahead and prepare information for it. We

designed multitasking experiment and planned to instruct all the tasks before starting the first session so that participants could plan for the next tasks in advance. In the first two session, participants are affected by negative mood induction and are given an open-ended task that requires to plan ahead for writing a report, and in the last session, they have to recall the articles that they have just read. We assumed that they are more likely to ruminate for such reasons. At the moment of rumination, we expected the system based on ACT-R model–that displays the image relating to the user's memory–to play a role in distracting participants from the repetitive, negative thinking. We will provide a questionnaire regarding the effectiveness of the system afterwards. The tasks take 20, 20, and 10 minutes respectively, and the entire experiment including answering the questionnaire should not be longer than 60 minutes in total.

5.3 Analysis

We planned to evaluate the effectiveness of the system in terms of recognition, attraction, distraction, and yielding. Recognition determines the correlation of selected images and user's memory. Attraction assesses how much a participant is interested in the ads and the products, while distraction defines the level of annoyance of the ads. Yielding can be interpreted into the efficacy of the ads in term of nudging users from rumination. The results will be mainly collected through 7-point Likert-scale questionnaire provided after the experiment. Also, we will track through physiological tools (e.g., eye tracker and heart beat monitor) and system logs. Analyzing aspects and methods for evaluation can seen from Table 1.

In this study that excludes rumination detection from the system, we expected the results from the system based on ACT-R model and user's memory to outperform ones from other conditions in terms of recognition and attraction.

Recognition
Questionnaire: I have seen those images before.
Result logs: Number of times that an image is picked compared to number of times that the image was seen in data collection sub-system.
Attraction
Questionnaire: I am interested in those products; I want to buy those products after seeing the ads.
Eye tracker: Gaze fixation in web advertising area.
Distraction
Questionnaire: I was frequently distracted by the ads; I cannot focus on the task after seeing the ads.
Yielding
Questionnaire: I had negative thinking during the task.
Searching behavior: Keywords used during the task.
Heart beat monitor: HRV changes throughout the task.

Table 1: Analyzing aspects for assessing effectiveness.

6 Summary

In conclusion, our study is to build a system based on ACT-R cognitive architecture that utilizes personal experience data to reinforce user's behavior–provide an implicit intervention on repetitive, negative thinking, i.e., rumination–during web searching. The developed system consists of two sub-systems. Data collection sub-system collects image of products on shopping sites that user has visited in real time and remotely sends to laboratory's server. Distraction sub-system consists of image recognizer which is to extract types of product from the collected images, physiological data (e.g., heart rate variability), and ACT-R cognitive model which processes such data and outputs an image relating to user's memory the most. The system displays the image on websites as personalized advertising and changes to distract users from rumination. We will assess the effectiveness of the system in aspects of recognition, attraction, distraction, and yielding.

At the current stage of the research, we omitted rumination detection from the system and focused on the potential of the ads from the developed system in terms of recognition and attraction. We will continue working on the upcoming experiment and improve the system's performance afterwards.

For future works, we planned to implement the more accurate rumination detection, include other types of physiological data for the ACT-R model, and develop the system to be applicable for general use.

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