Proposal of a System Based on Cognitive Architecture to Distract Rumination While Web Browsing

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Abstract

Despite its benefits, technology can negatively affect human behavior and emotion unconsciously. This research tries to support the attempt of positive computing through the development of a system based on ACT-R cognitive architecture to prevent rumination, repetitive negative thinking. The proposed system consists of two sub-systems: *data collection sub-system* and *distraction sub-system*. The former collects searching data (e.g., website URL, image URLs) immediately after the individual visits a website. The data will be collected through a browser extension so that it will be compactible for any computer and stored in local database. The latter includes an ACT-R cognitive model that utilizes such data as well as physiological data (e.g., eye movement, gaze fixation, heart rate variability) directly from the individual to predict rumination while searching through websites. The model is activated by a browser extension upon starting it. In addition to predicting rumination, it provides an implicit intervention for rumination based on a concept of *nudge* which affects human behavior and decision making. The system displays a product image on the screen as advertisement. After rumination is detected, the system changes the image to mildly intervene not to keep ruminating.

Keywords — Cognitive Architecture, ACT-R, Mental Illness, Rumination, Positive Computing, Computational Psychiatry, Website, 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. For example, some people are facing the internet addiction–that is, to have difficulties distracting oneself from the internet [1], [2]. Some are having less empathy and even involving in cyberbullying – an aggressive, intentional behavior conveyed towards other people like mean comments on social network sites and uploading embarrassing personal videos/pictures of others [3], [4]. These side-effects of technology are a source of mental symptoms such as stress, anger, anxiety and depression. Therefore, there has been an increase of interest in field of *positive computing*: the design and development of technology to support psychological well-being and human potential [5]; and *computational psychiatry*: a diagnosis and treatment of mental illness with computational method such as building computational model of human cognition and reinforcement learning to address psychiatric problems–in other word, mental illness [6]. In this paper, we will follow the objective and methodology of positive computing and computational psychiatry to build a cognitive model that provides a diagnosis and treatment for mental illness to people under controlled environment such as website.

2. Related Studies

2.1 Mental Illness

We have reviewed several papers regarding to mental illness, and depressive rumination—which is the preceded stage of depression and considered as serious mental symptom—is needed to be treated prematurely [7]. Depressive rumination is defined as the self-focused repetitive negative thinking about the cause of his/her depression [8], [9] which prolongs dysphoric mood and sadness [10]. Some researchers have claimed that rumination associates with mind-wandering, a state that one's thought is out of focus or unrelates to main task [11]. At the moment of mind-wandering, rumination distracts one's attention and concentration from achieving main task and replaces the position with thoughts about one's past memory such as disappointments and mistakes [12], [13]. In addition, many studies reported the symptoms of ruminating individuals: they are more likely to have attentional biases for negative information [14], [15], [16]. People who engage in depressive rumination are facing a greater risk for depression [7].

2.2 Cognitive Model

To address the problem of depressive rumination, we will

build a cognitive model that is based on Adaptive Control of Thought – Rational (ACT-R) cognitive architecture. The ACT-R [17] is capable of simulating human cognitive operation according to brain regions such as visual module in the model that simulates human vision is imitated from occipital lobe. In this research, we refer to two ACT-R models. First, van Vugt et al. [18] applied their recent computational model of mind-wandering and proposed a method of implementing the model to simulate rumination. The model simulated chunks of different moods (cheerful, content, down, suspicious, and insecure) of 100 normal participants and 100 ruminating participants. The model is able to produce frequencies of chucks in each mood that were recalled during mind-wandering and predict an effect of rumination against performance on attentional task. The simulation result suggests that ruminating participants tends to fall into mind-wandering because they retrieve negative moods more often than control participants who retrieve chunks equally. In addition to van Vugt et. al.'s model, Itabashi [19] created a cognitive model based on ACT-R to simulate a reminiscent photo slideshow. The model tries to select an image that matches participant's memory by using image data and physiological data. The former is from images in participant's photo library that were processed by image recognition–the image data are tagged from the viewpoint of who, what, when, where. The latter is from participant directly. Participants wore a heart rate sensor, myBeat, at the beginning of the experiment. The model receives heart rate data and uses it as a noise parameter.

2.3 Advertisement

By applying the framework of the above previous studies, the current study aims to construct a system to predict and distract rumination. The system includes a cognitive model predicting rumination through a simulation of memory chunks associated with moods. In addition, it includes an eye tracker to collect physiological data from user in real time and use it as parameters to predict rumination more accurately. To distract rumination, we focus on the concepts of *nudge* [20] which is an approach of implicit intervention that affects individual's behavior and decision making. As an example of nudge, we can consider the slight change of choice architecture where options are presented to lead individuals or group of people to positive cognitive biases encouraging them to choose the proper choice. Moreover, the previous study [21] suggests using nudge to prevent behavioral risk leading to major depressive disorder. One of the suggested methods is to influence subjects to employ adaptive coping mechanism over maladaptive one to deal with stressful situation. We also found that advertisement can used as a nudge to influence customer's behavior and decision making. For instance, an advertisement showing message "DRINK MORE WATER." followed by "YOU SWEAT IN THE HEAT: YOU LOSE WATER", is a form of nudge [20] which does encourage people without forcing them to drink water. Therefore, we see great potential to adapt Itabashi's model that recommends an image associated with memory to build the model that shows advertisement based on user memory to draw attention and mildly remind (nudge) user not to keep ruminating.

3. Objectives

In this research, we hypothesized that the cognitive model built with ACT-R could yield an accurate prediction of rumination—not just a simulation—by utilizing physiological data, and the concept of nudge used in form of web advertising banner could draw attention and distract user from ruminating while searching through websites.

4. System

In this study, we propose an intervention approach for depressive rumination by applying van Vugt et al.'s ACT-R model [18] to predict rumination and create a system based on Itabashi's model that distracts user from ruminating. Moreover, we try to improve prediction accuracy of the model by physiological data: heart rate variability (HRV) which is able to signify degree of depression including rumination [22] and eye movement and gaze fixation to indicate level of attention, etc. [23], [24]. The system will be in a form of browser extension that can be installed on any website. It will show an advertising banner of products that is images on websites that the user has visited before (encoded in user's memory). The advertisement is processed by the model to show most relevant image associated with user's memory in terms of recency and frequency. The advertising banner will function as a distractor: drawing user's attention from rumination while searching through websites. The system consists of two sub-systems: data collection and distraction.

Table 1: An example of a table in database that stores user's searching data: user ID, timestamp, website URL, and image URL

user_id	timestamp	web_url	img_url
1056724477	2019/7/3 12:12:09	https://www.amazon.co.jp	https://images-na.ssl-images-amazon.com/images/I/51%2BYxxM-PAL._SL1000_.jpg
1056724477	2019/7/3 12:12:09	https://www.amazon.co.jp	https://images-na.ssl-images-amazon.com/images/I/61p7Ozqex0L._SL1000_.jpg
1056724477	2019/7/3 12:12:09	https://www.amazon.co.jp	https://images-na.ssl-images-amazon.com/images/I/618m86YqQ3L._SL1000_.jpg
1056724477	2019/7/3 12:12:09	https://www.amazon.co.jp	https://images-na.ssl-images-amazon.com/images/I/61A75HOU2xL._SL1500_.jpg

5.1 Data Collection Sub-system

In this sub-system, we will create a Google Chrome extension that logs all image URLs on any website that user visits including web URL and timestamp and remotely inserts into database as can be seen from Figure. 1.

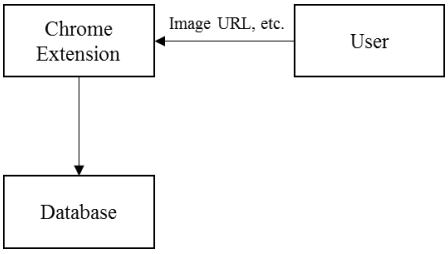

Figure 1: The flow of data collection sub-system

The chrome extension automatically inserts data into database in four columns: user ID, timestamp, website URL, and image URL as shown in Table 1. In the test trail, we obtained around 2,000 to 5,000 rows per hour.

5.2 Distraction Sub-system

Figure 2 displays the flow of distraction sub-system—the ACT-R model (the middle part of the figure) in this system receives data via two ways: physiological data (e.g., eye movement, gaze fixation, HRV) from eye tracker and heart rate monitor (the right side of the figure), and data obtained from user (the top left part of the figure).

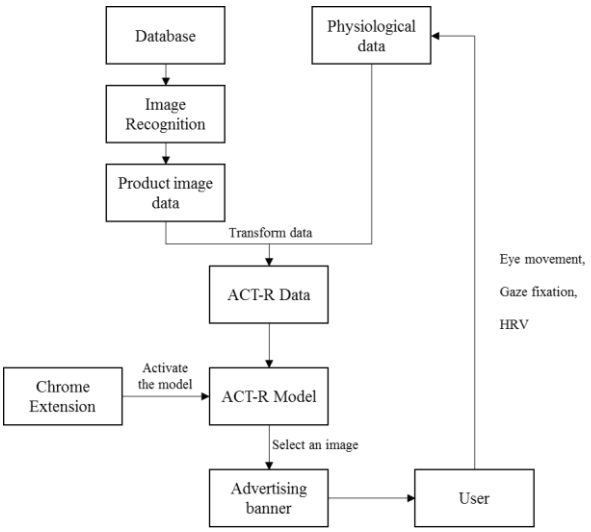

Figure 2: The flow of distraction sub-system

As stated above, we focus on product images that will be used as advertising banner. Therefore, we connect the system with Google Cloud Vision, a machine-learning-based image recognition software. The system retrieves image URLs from database, passes to Google Cloud Vision to categorize images which a certain user has seen and produce results such as type of objects, labels, and color. Figure 3 is the result from requesting Cloud Vision API to detect an image URL of a fan from a shopping site. It shows that, for example, the image is classified as product with 88% detection accuracy and is categorized as mechanical fan with 86% detection accuracy. The ACT-R model processes such data to select and display a product image on the screen, predict rumination, and distract user by changing the image to another. The image will be

chosen from criteria and parameters such as recency and frequency and is expected to be relevant to user's memory. Google Chrome extension initiates the model immediately after a web browser is opened. This way, the system is compatible to install on any computer. The ACT-R model transforms product image data and physiological data transmitted from the user in real time into ACT-R data to use as parameters. The model selects an image from the pool of images shown on the websites that user has visited and displays on the screen as advertising banner. While the user searches through websites, physiological data is constantly transmitted to the model as a cycle.

{"responses": [{ "labelAnnotations": [{
"mid": "/m/01jwgf",
"description": "Product",
"score": 0.8828333, "topicality": 0.8828333},
{"mid": "/m/02x984l",
"description": "Mechanical fan",
"score": 0.8628455, "topicality": 0.8628455},
{"mid": "/m/0h8n8m2",
"description": "Ventilation fan",
"score": 0.8209952, "topicality": 0.8209952}],
"localizedObjectAnnotations": [{
"mid": "/m/019dx1", "name": "Home appliance",
"score": 0.60034335, "boundingPoly": {
"normalizedVertices": [
{ "x": 0.18847057, "y": 0.13999999 },
{ "x": 0.80023533, "y": 0.13999999 },
{ "x": 0.80023533, "y": 0.7790588 },
{ "x": 0.18847057, "y": 0.7790588 }]}}]}]}

Figure 3: The result of Google Cloud Vision processing an image URL of a fan in a shopping site

5. Summary

This paper describes the fundament of a system based on cognitive architecture that predicts rumination and provides an intervention (distract) through the concept of "nudge" to user while browsing websites.

In the future, we expect a cognitive model that can detect rumination more accurately and a system that distracts rumination more effectively. We plan to apply the method that predicts mind-wandering which was proposed by Bixler & D'Mello [25]. They used an eye tracker to observe individual's attention (e.g., gazing data, pupil size) when reading a book. With an application of supervised machine learning algorithms, the result achieves a 72% accuracy rate to detect mind-wandering. Therefore, our future model would include supervised machine learning algorithms in a collaboration with ACT-R modeling to predict rumination.

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