Peripheral Agent: Implementation of Peripheral Cognition Technology

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Abstract
Information notification on a display for e-mail arrival, micro-blog updates, and application updates is becoming increasingly important. We propose a novel information notification method, the peripheral agent (PA) as an implementation of peripheral cognition technology (PCT) that uses the human cognitive properties that a human does not recognize subtle changes in a peripheral area of cognition when he/she concentrates on a task and that he/she automatically recognizes the changes when not concentrating on the task. By only setting a PA in the peripheral area, a user automatically and easily accepts the notification only when his/her concentration breaks. We conducted two experiments to investigate a VFN area and evaluate the effectiveness of PAs.

Author Keywords
Information notification; peripheral cognition technology; visual field narrowing

ACM Classification Keywords
H.5.2 [[Information Interfaces And Presentation]]: User Interfaces - Theory and methods;

General Terms
Experimentation; Design; Human Factors.

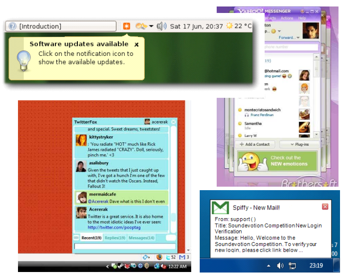

Figure 1: Information notifications.

Introduction

In the current office and home environment connected to the Internet, a user tends to frequently receive various *notifications* [4] for e-mails, tweets, instant messages, and alerts of application updates on displays, cellular phones, and smart phones (Figure1). Although some notifications are quite emergent, most of them are not, so a user should get such information only when he/she is not busy. Such a user state in which he/she can accept notified information and can access the information is called *interruptible*, and the opposite user state is called *uninterruptible*. A typical interruptible state is when a user is not involved in completing a task and has time to access the information.

A problem with such notifications is that they appear as soon as they occur, i.e., without the system being aware of whether the user is interruptible or not. If the notifications arrive when a user is uninterruptible, they can cause significantly stress and reduce the user's productivity [1]. One way to deal with this would be to control the notification period in accordance with the period of time in which the user is interruptible.

To estimate a user's interruptibility, various studies have been done [2][4]. Most of them applied machine learning techniques to identify interruptibility. The input for classification learning was implicit feedback, which included keyboard typing patterns, the trajectory of mouse operation, visual information of a user's face, and posture. Although this approach provides a general framework, it is difficult to build an accurate model for estimating a user's interruptibility because much training data are necessary and capturing a user's face and posture is problematic in terms of privacy.

A peripheral display [6][5] provides another approach to information notification, that does not estimate interruptibility. In this approach, information itself, not the notification, is constantly displayed on a small sub-window (or a sub-display) on the side of a main window (or a main display) in which a user works on a main task. A user is assumed to recognize the displayed information and understand the contents while he/she works on the main task. Although this peripheral display has an advantage in that it does not need user state estimation, ad-hoc implementations have been done in various fields and more complicated information that is difficult to understand, such as the content of e-mails and application updates, can not be dealt with.

We propose a novel information notification method, the peripheral agent, as an implementation of peripheral cognition technology (PCT) that uses human cognitive properties such as visual field narrowing and inattentional blindness[10]. PCT provides notification by using the human cognitive property that the visual field narrows when he/she concentrates on a task intently. The core idea of PCT is that humans do not recognize subtle changes in a peripheral area of cognition when they concentrate on a task, and they automatically recognize the changes first when not concentrating on the task. With the peripheral agent, by only making a software agent appear in a region where visual field narrowing occurs, a user automatically and easily accepts the notification only when his/her concentration breaks.

PCT: Peripheral Cognition Technology

Peripheral cognition technology (PCT) is cognitive interaction design for information notification. "Cognitive" interaction design means a design method of interaction that uses human cognitive properties [8], e.g., visual field narrowing and inattentional blindness. By using such human properties, we can design an effective

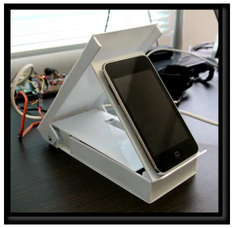

Figure 2: Device for shape shifting notification.

user interface that does not force a high cognitive load without user state estimation.

Visual field narrowing (VFN) [9] is a primary human cognitive property used in PCT. A visual field is the area that an individual can see when looking straight ahead without moving the eyes or gaze. It can be measured in degrees from a fixation point; the normal vision field is about 160-180 degrees horizontally and 120 degrees vertically. This visual field is significantly affected by cognitive load or concentration on a task [9]. When a human concentrates on a hard task and the cognitive load becomes heavy, his/her visual field significantly narrows. This phenomena is called *visual field narrowing* and studies have been done in various tasks [9].

Inattentional blindness [7] means that without attention, observers do not recognize visual features of the environment at all. On the basis of this property, we are experimentally developing a *shape shifting notification device* [10] shown in Figure 2.

We define these above human cognition properties that occur in the peripheral areas of "cognition" and define the interaction design that uses such human cognitive properties as peripheral cognition technology (PCT).

Peripheral Agent

The peripheral agent (PA) is an implementation of PCT by using visual field narrowing (VFN). The peripheral agent has a simple human-like appearance and notifies a user of information such as e-mail arrival, micro-blogs, and application updates (Figure 1) by appearing on a display in a VFN region. The functions are the following.

1. A PA appears in a *VFN region* as soon as information to be notified occurs.
2. If a user clicks the peripheral agent, it will display the content of the information by opening a sub-window.

When we can adequately place a PA in the VFN region, a user does not notice a notification when he/she is uninterruptible and he/she automatically notices the notification just when he/she becomes interruptible.

To realize a PA, we first need to define the VFN region mentioned above as a peripheral visual field that can be narrowed by VFN phenomena. Figure 3 shows a visual field when a user is concentrating on a task and is uninterruptible, a VFN region outside of the visual field with an inner boundary, and a PA. We assume the inner boundary of the VFN region is squared and the VFN region can be defined by the absolute positions of the four sides of the inner boundary. Although the boundaries of a VFN region might be changed depending on the user's viewpoint on a display, the variance of the movement is considered to be relatively small because the user's viewpoint does not move greatly outside of the center area of the display in office work. Even if the VFN region significantly moves because of the movement of the user's viewpoint, we can use various methods to estimate the viewpoint with ordinary sensors like a mouse and a web-cam [3]. When the VFN region is defined, we can realize a PA only by placing it there as a notification occurs.

Investigating a VFN region

We conducted an experiment with participants to investigate the VFN region (the inner boundary of the VFN region in Figure 3) on a PC display. We used a dark room-like editor with black background and green foreground, and we asked participants to simply type the letters scrolling horizontally in the squared area

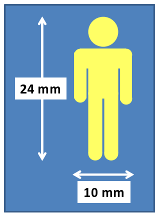

Figure 4: PA's appearance.

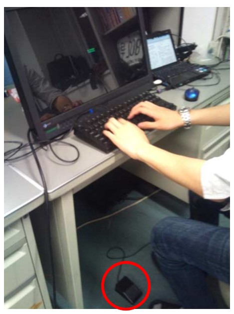

Figure 5: Experimental environment.

(40 mm×6 mm) in the center of the display and the typed letters appeared under the scrolling area. This typing is the main task in this experiment and we adjusted the scrolling speed so that each participant would be uninterruptible when concentrating on the main task. Participants were also asked to step on a foot switch as soon as they noticed the PA as a sub-task. The display size was 23 inches with 1920×1080 pixels and the display was located about 50 cm from the head of each participant.

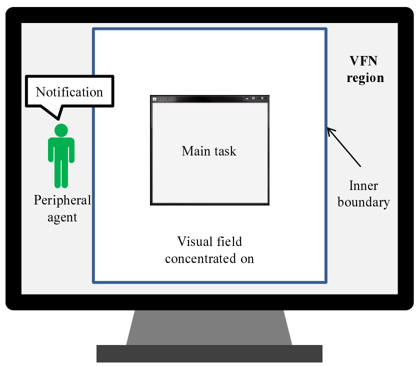

Figure 3: Peripheral Agent.

The shape, size, and color of a PA was also tuned as shown Figure 4 so that a participant would not immediately notice it when uninterruptible. We made a PA to randomly fade in for 3 sec in eight positions on the edges of the screen (the eight dotted circles from far to near the center of the display by 5 mm. This random appearance prevented participants from predicting the appearances of the PAs.

Participants were asked to join a training in which they performed the main task without the sub-task before the experiment with a sub-task. The experiment consisted of three trials with short breaks. The numbers and the timing from the start time of the PA's appearances were three, 40 sec, 30 sec, and 50 sec for the first trial, two, 30 sec, and 40 sec for the second one, and one and 50 sec for the third one. These different times and timings were also for avoiding participants' prediction. All the typing logs and the positions and the time when participants noticed the PA were recorded.

Since the dark room-like editor is considered to be an extreme situation in which a user most easily notices a peripheral agent, the estimated VFN region corresponds to the smaller limit region. Thus, in practical application on a display with a practical desktop and a certain background image, the VFN region becomes larger than this estimated one. An experimental environment with a display, a keyboard and a foot switch with a red circle is shown in Figure 5.

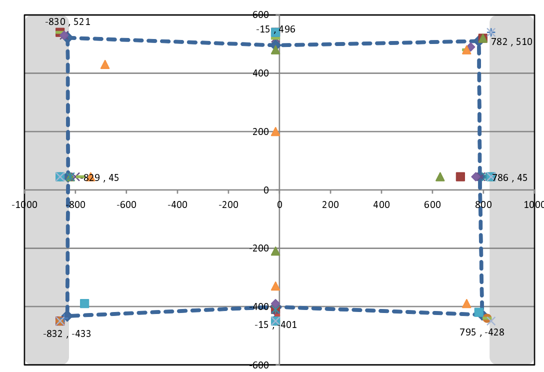

Figure 6: Experimental results of VFN region.

Data of the inner boundary of the VFN region obtained from the 20 participants (9 females, 11 males, ages

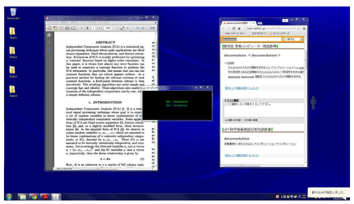

Figure 7: Snapshot of the evaluation experiment.

23∼51) are plotted on a x-y coordinate of a display in Figure 6. The broken line connects the average positions in the eight directions, and we verified the VFN region in a display from these data of this preliminary experiment. As seen from this graph, since the vertical variances were relatively large and the horizontal ones were small, we used horizontal boundaries to evaluate a PA. Eventually, we defined two rectangle regions located about 60 mm from both left and right edges of this display (shaded regions in Figure 6), and a PA appeared within these regions in the next evaluation experiment.

Evaluation experiment for peripheral agent
Next we conducted an experiment to evaluate the effectiveness of a PA in a more realistic environment. We prepared an environment similar to one in everyday office work on a computer with a main task window and two sub-windows on both sides, as shown in Figure 7. In this environment, the main task and the sub-task were the same as those in the previous experiment. Participants were told to suppose that notifications were application updates and e-mail arrival, and they were asked to accept the notification by using a mouse to click on a PA if necessary.

We prepared a traditional balloon-like notification (the left-bottom in Figure 7) that appeared on the right-bottom corner of a display for comparison with our PA notification and conducted a within-participant experiment because there was no learning effect. Thus, the independent variable was a notification method with two levels of a traditional notification and a PA notification, and the dependent variables were various timing mentioned later.

The time-line of this experiment is shown in Figure 8 and both of the two levels were made on this time-line. The task load (attention) was uninterruptible with the text scrolling for 0∼80 sec and was then made interruptible by stopping the text scrolling. A notifications appeared at 40 sec when a user was still uninterruptible; hence, the user's optimal noticing, ONT of the notification was just after 80 sec. We recorded each user's actual noticing timing, NT, by monitoring the foot switch, and measured the difference between ONT and NT, $d(ONT, NT) = \{ONT - NT \text{ if } ONT > NT, 0 \text{ if otherwise }\}$, where $d = 0$ as the NT was after ONT because the notification was not emergent and the delay of a user's noticing from the ONT was not problematic. When the $d(ONT, NT)$ was smaller, the notification was better. Also, we asked participants to answer some questionnaires on usability based on NASA-TLX with a seven-point scale that included "Did the notifications bother you?," "Did you worry about the notification?," and "How good were the notification timings for you?"

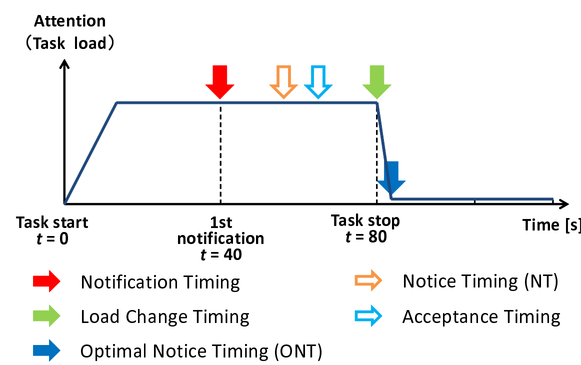

Figure 8: Time-line of the evaluation experiment.

Fifteen participants (6 females, 10 males, ages 21∼49) joined this experiment. The average and SD of d for the PA and traditional notification is shown in Figure 9. We

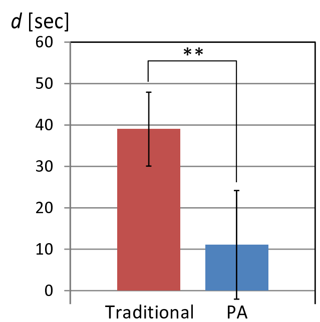

Figure 9: Results of d in the evaluation experiment.

applied a t-test to the results, and there was significant difference between the two levels ($p = 4.0 \times 10^{-7}$). Thus, we found that the results showed that our PA notification was better than the traditional notification in terms of notification timing.

Discussion

The environment might be restricted and small even in the evaluation experiment. However, the typing task is one of the most general office and home tasks performed on PCs, and the two sub-windows are considered to be a popular layout. Hence, we think the experimental results and knowledge derived from them have much generality.

We are currently analyzing the results of the participants' questionnaire results. For the questionnaires on "notification's bothering," the PA notification was significantly better than the traditional one. However there was not a significant difference between them on "notification timing's suitability." We need to discuss them more.

Conclusion

We proposed a novel information notification method, peripheral agent (PA), as an implementation of peripheral cognition technology (PCT), which uses human cognitive properties such as visual field narrowing (VFN) and inattentional blindness. Notification on a display of e-mail arrival, micro-blogs updates, and application updates, is becoming increasingly important. In contrast with conventional approaches to notification, such as a user model-based approach and a peripheral display, a PA does not need to estimate a user state and can deal with notification of complicated contents. We conducted two experiments to investigate a VFN region and evaluate the effectiveness of PAs. We then defined the VFN region where a PA should be placed and obtained results showing the advantages of using PAs.

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