eye-q: Eyeglass Peripheral Display for Subtle Intimate Notifications

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ABSTRACT
Mobile devices are generally used in public, where the user is surrounded by others not involved in the interaction. Audible notification cues are often a cause of unnecessary disruption and distraction both for co-located people and even for the user to whom they are directed. We present a wearable peripheral display embedded in eyeglasses that delivers subtle, discreet and unobtrusive cues. The display is personal and intimate; it delivers visual cues in the wearers' periphery without disrupting their immediate environment. A user study conducted to validate the design reveals that the display is effective and subtle in notifying users. Experimental results show, with significance, that the cues can be designed to meet specific levels of visibility and disruption for the wearer, so that some cues are less noticeable when the user is not under high workload, which is highly desirable in many practical circumstances. Hence, peripheral notification displays can provide an effective solution for designing socially acceptable notification displays, unobtrusive to the user and the immediate environment.

Categories and Subject Descriptors
H5.2 [**Information Interfaces and Presentation**]

General Terms
Design, Human Factors.

Keywords
Mobile devices, wearable devices, notification, eyeglass display, intimate interface, social acceptance.

1. INTRODUCTION
Electronic mobile devices, such as mobile phones and PDAs, provide ubiquitous connectivity and help us by bringing messages and appointments to our attention. Their use often involves interruption; every time a new message is received, an incoming call arrives or it is time for a meeting we get a notification that interrupts us while we are engaged in some other activity. While constant connectivity and personal reminders have great advantages, interruptions may be annoying, disruptive and in some circumstances even dangerous [1,10]. Moreover, mobile devices are often used in public spaces, where we are surrounded by others not involved in our communication. In these circumstances interaction needs to be subtle, discrete and unobtrusive [5,9,17,24].

Designers and researchers in HCI have addressed the notification problem to limit the negative effects related to interruptions while retaining the advantages of continuously being able to receive information. Weiser's definition of "calm technology" [34] inspired researchers and designers to propose a variety of peripheral displays: displays that provide information to the periphery of the users' attention. Examples of such "ambient displays" include devices highly integrated in architectural elements and pieces of furniture [11,23] and graphical interface widgets that sit on the border of the screen of the desktop computer [3,21]. Interest in the periphery is also found in earlier human factors work [25], where the focus is more strictly on visual periphery, for its potential as an independent channel for receiving information related to aircraft operation.

Notification is even more problematic if the setting is a mobile context rather than a controlled space or a desktop computer. Because users often keep mobile devices on them, there are more opportunities for undesired interruption. In addition, the amount of attention a user can devote to the interface while on the move is severely limited [19] and the limited size of graphical displays makes it impractical to dedicate part of them to peripheral cues.

The market for mobile consumer electronic devices and the field of wearable computing seem to be merging. Until recently, wearable computing was restricted to university researchers, technology enthusiasts and fiction literature. However, in 2004 Oakley, a popular sunglass manufacturer, introduced the "Thump" sunglasses with an integrated MP3 music player [32]. In 2005 the same company, in collaboration with Motorola released another model of sunglasses, "Razrwire," which include a mobile phone Bluetooth headset [29]. Orange, one of the largest mobile telephony providers, offers its mobile phone subscribers a high resolution eyeglass display by MicroOptical to connect to a Samsung Phone [26]. At the opposite end, the most recent prototype of the MIThril wearable computing platform is based on the mass produced Sharp Zarus PDA [12].

Our research explores whether and how wearable technology can improve the user experience with mobile devices. In particular, this paper presents the design and evaluation of a

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low resolution display embedded in eyeglasses which delivers subtle peripheral notification cues. We believe that a good model for mobile interaction is a matter of minimalism: provide just enough information to the users for them to decide whether to switch tasks or not, without disrupting their attentional focus nor their immediate environment. For example, if users are engaged in conversation, walking or other primary tasks, rather than presenting an entire email message, we want to provide information that enables them to decide whether to stop the primary task and switch attention to a mobile device, such as a PDA or laptop, to read the full text of the message. The cues can signal the users about information being available on higher resolution displays, such as mobile phone and PDA screens or even eyeglass displays [26].

A notable alternative approach to the notification problem and more generally the problem of "information overload," is to use an intelligent filtering system, such as context based artificial intelligence [15,17], to let the computer decide whether or not, for example, to interrupt the user for an incoming call. Our approach is different in that we want to leave the decision to the user.

The work presented in this paper is related to research about peripheral vision and peripheral displays, near-eye displays and notification systems. The next section provides an overview of relevant findings in these fields. Subsequently the motivation for the display, its design and implementation are presented. Finally, a user study to validate the design is described and the results discussed.

2. Related Work

2.1 Peripheral Vision

Peripheral vision is at the edge of the field of view; it is very sensitive to movement and less to detail and colour compared to central or *foveal* vision. In fact, the periphery of the retina is richer with rods (visual perception cells responding to movement) and has fewer cones (visual perception cells responding to colour) as compared to the centre. Peripheral vision is often used unconsciously and plays an important role in orientation and navigation. [35]. Even if not without criticism, research in cognitive psychology [18] suggests that peripheral vision can generally be treated as a separate (albeit not independent) channel from foveal vision.

Peripheral vision is affected by "visual field narrowing": studies observed that peripheral vision is temporarily reduced under conditions of high workload in the central visual field or stress [31,36]. Early studies suggest that the nature of this narrowing is perceptual: higher workload on a task in central vision would temporarily induce "tunnel vision" [37]. More recent studies [36] confirm the narrowing, but favour a "cognitive tunnelling" interpretation, according to which the narrowing is related to attention rather than perception. Stokes, Wickens and Kite [31] report that the tunnelling might be selective: it affects the recognition of targets but not the orientation function of peripheral vision.

2.2 Peripheral Vision Displays

Early examples of *peripheral displays* were built and marketed in the late nineteen fifties as instrument landing aids for aircrafts [31]. These displays were electro-mechanical devices designed to attract the attention of pilots while they were focussed on other parts of the aircraft instrumentation. Early laboratory experiments on aircraft peripheral displays were reported in the early sixties by Brown, Holmquist and Woodhouse [4]. They compared peripheral displays with traditional instrumentation and found that the latter performed better. Later studies report performance improvement if peripheral displays are used to show redundant information for tracking tasks [31]. A more recent peripheral display for aircraft instrumentation is the Peripheral Vision Horizon Display (or "Malcolm Horizon Display") [22], a laser projected line reproducing the horizon line. Overall human factors literature shows interest for the potential advantages offered by peripheral displays, however, their effectiveness had been often questioned (see [31] for a review). Recent studies [27] report stronger evidence of performance improvements.

2.3 Near-eye Displays

In a different application domain from aviation, Ebrahimi and Kunov proposed a wearable peripheral vision display to help lip-reading for profoundly deaf people [13]. The display is embedded in eyeglasses and connected to an audio processing system. Speech features that cannot be detected by lip-reading are visualized on the peripheral display, a 5 by 7 matrix of LEDs positioned in the side of eyeglass frames. Significant improvement of lip-reading performance for profoundly deaf patients is reported using the system.

Other near-eye displays, generally referred to as "head-mounted displays" (HMDs) or "eyeglass displays", have been reported since the nineteen sixties. These are graphic displays worn near the eyes, generally creating the perception of a large display about one meter away from the user. HMDs and eyeglass displays have been proposed both for specific and general purpose applications [2] often with the mixed reality interface paradigm. In all cases, the display has a limited field of view and it is positioned in the user's foveal vision.

2.4 Ambient Peripheral Displays

Researchers in the area of CHI and ubiquitous computing refer to *periphery* and *peripheral displays* in a more general sense, meaning the periphery of attention. In 1995 Weiser and Brown [34] introduced the concept of "calm technology" as technology that can easily move between the periphery and the centre of users' attention. Weiser and Brown refer to the art piece "Dangling String" (1993) as an early example of peripheral, calm technology. "Dangling String" is a piece of plastic wire hanging from the ceiling and connected to a motor that makes it spin according to the amount of traffic on an Ethernet network. According to the authors, users can "attune" to the movement and noise of the string, but only notice sudden changes, informing them of irregularities in the network traffic. After Weiser a number of researchers and designers proposed a variety of peripheral interfaces, both as separate devices [11] or as part of a computer's graphical user interface (GUI) [6,21]. In the first case the devices are generally referred to as *ambient displays*: pieces of furniture or architectural elements that change their appearance or move to display remote signals; examples are light fixtures connected to web page hits [11] and picture frames that display a remote person's health and personal information [8]. In the other case, information – generally text – is displayed on the border of a computer screen as part of a standard desktop graphical user interface; examples are "news tickers" [21] and applications that show notifications for incoming email messages.

Heuristics have been proposed to evaluate ambient peripheral displays in the physical environment but not many user studies have been reported to date (with notable exceptions [7]). More systematic evaluation has been reported for peripheral displays within GUIs. Maglio and Campbell [21] compared how three types of scrolling displays performed in terms of distraction and

Figure 1. The wearable peripheral display.

memorability of information displayed measuring the performance drop on a text editing primary task. They report that motion in the periphery can be profitably used to signal display update, while continuous motion has a distractive effect without increasing the memorability of the content displayed. Bartram et al. [3] studied how icons movement on computer screens can convey information and how much it negatively affects users in terms of distraction. Motion was detected better than changes in colour and shape, especially in the periphery. Contrary to the prediction of the authors, there was no significant interaction between central workload and distraction caused by motion.

2.5 Notification Interfaces

While some of the peripheral displays tackle notification, recent research examines the notification problem in the specific context of interaction with mobile devices. Hansson et al. [14] propose a classification of mobile notification systems according to subtleness and publicity. They suggest that it is desirable for notifications from mobile devices to be not only subtle but also public so that people co-located with the user are aware of the interaction. Following these guidelines the same authors propose the "Reminder Bracelet", a prototype wristband on which LEDs blink to notify reminder cues from a PDA. Marti and Schmandt [24] approach interruptions from a group voting perspective: each member of a (co-located) conversation group wears a finger ring that vibrates when any of the members has an incoming call, without indication of who the call is directed to. Any user can *block* or *veto* the incoming call by subtly pressing a button also embedded in the ring. Campbell and Tarasewich [6] explore the limits of minimal visual notification displays in terms of amount of information that can be displayed and user comprehension and learning. Two user studies are reported based on a desktop computer display simulating a small number of multicolour LEDs, which could be embedded in mobile or wearable devices.

An alternative approach to notifications from mobile devices is that of intelligent context aware filtering: the system combines data from environmental and body worn sensors as well as information about incoming alerts to determine whether and how to deliver the notification. Various prototypes [17] use information from body worn accelerometers, audio and location to infer whether notification is acceptable, either from the user or social points of view. Incoming notifications would then be blocked or delivered through a modality judged appropriate both for the users and those around them.

3. MOTIVATION

Mobile devices are generally used in public spaces where users are surrounded by co-located people generally not involved in the interaction, such as on a bus or in a meeting. In some cases users might even be engaged in person to person interaction with those around them. Alerts from mobile devices are often a cause of embarrassment and disruption for the immediate environment. It has been highlighted that mobile devices and the interaction with them should be unnoticeable [9,19, 30]. Costanza, Inverso and Allen [9] propose the use of subtle, motionless gestures detected through EMG to interact with mobile devices without disrupting those around the user, and hence increase social acceptance.

The disruptive effect of notifications should also be minimized for the addressee: while users generally want to receive notifications [14] arbitrary interruptions can have a negative effect on performance [1,10]. In this light, it would be ideal to interrupt users only when they are not focussed on other activities. Because mobile devices are carried with users for most of the day the chances of inopportune interruption are even higher than when dealing with desktop computers. If incoming alerts can be classified by priority or importance, a notification system should map these to "levels of disruption", making less important alerts result in less distracting cues.

We propose that these requirements are better met by designing interfaces that present the information in a subtle non-obtrusive way and enable users to make the decision if and how to react to incoming notifications rather than automatically filtering notifications based on context. In general, context aware intelligent filtering could be used to determine the importance of incoming information so that this factor can be made salient to users.

To summarize, a notification system for mobile devices should:

- deliver noticeable cues to the addressee;
- not disrupt the users' immediate environment;
- be subtle for the addressee without being distracting in sensitive situations
- allow an adjustable degree of disruption

Hansson, Ljungstrand and Redström [14] suggest that for interruptions to be more socially acceptable they should be public, so that co-located individuals can more easily understand and accept the behaviour of mobile technology users. It is not uncommon that mobile users want to ignore incoming notifications to continue the interaction with co-located people, in this case a public alert would only be unnecessary and distracting for the others. We propose that it should be left to the users whether and how to inform those surrounding them about the interaction with their mobile devices.

Vibrotactile displays provide a solution for subtle notification. However, vibrating motors are often audible and involve significant power consumption so an alternative solution is proposed.

4. Design and Implementation

To fulfil the requirements described in the previous section and deliver notification cues in a private, subtle and non-obtrusive way a low resolution peripheral visual display was embedded in a pair of ordinary eyeglasses. Cues are delivered to the user wearing the glasses without disruption to those surrounding them. The display is composed of two arrays of four small red LEDs and four small green LEDs, each placed at the end of the glasses' arms, near the lens, as illustrated in Figure 1. The LEDs are lit at very dim intensity to display moving patterns in the wearers' peripheral field. The position of the display allows users to easily monitor it – glancing to the side – without any occlusion in the foveal field of view. The patterns are displayed

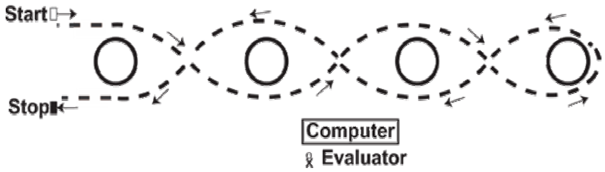

Figure 3. Route walked by participants in experiment 1.

at a low intensity to minimize irritation when users decide not to react to the cue. The display was designed to utilize the visual field narrowing phenomenon (as described in the related work section); and thus it tends to become unnoticeable if users are under a high workload. This effect makes the display *naturally adaptive* to users' cognitive workload and stress.

The display is controlled via Bluetooth to allow interfacing with existing mobile devices so that peripheral visual cues can be, for example, associated to incoming calls or messages on a mobile phone, and used instead of auditory or tactile cues. The LEDs are individually driven by an Atmel AVR 8-bit microcontroller through pulse width modulation to enable fine control of brightness and movement. In this way it is possible to design and visualize cues that are more or less disruptive showing fast, bright moving patterns or dim, slow ones; at an extreme the display can be turned on statically so that it would only be noticeable if users explicitly glance at it in a *polling* modality.

The total power consumption of the device is approximately 30 milliwatts, attributable to the various components as follows: the Bluetooth module consumes on the order of 10 milliwatts, the microcontroller about 12 milliwatts, and the LEDs 7 milliwatts in the worse case (in practice they are on for very short periods of time). A single small Li-Polymer battery is used to power the device for several hours. The sum of LEDs and microcontroller consumption is significantly less than a vibrating motor, which is at least 72 milliwatts [33], making the wearable peripheral display an attractive alternative.

5. User Study

A user study was designed and run to test the validity of the wearable peripheral display design. Two experiments were designed to test the following hypotheses:

1. The cues are generally noticeable, to a degree that depends on the intensity and movement of the displayed visual patterns.

2. The cues are comparatively less noticeable if received under conditions of higher workload.

In both experiments subjects were required to react as quickly as possible to stimuli presented on the wearable peripheral display, while sequentially engaged in different primary tasks. The study involved visual peripheral cues all of the same colour (red) but with different characteristics in terms of brightness and pattern velocity. Moving patterns on the display were

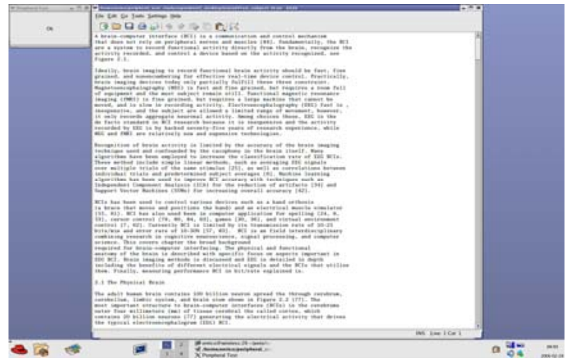

Figure 2 Graphical interface used for experiment 1; The reaction button is on top left corner.

designed as a combination of LED brightness and velocity of LED cycling: "dim" – brightness 8% of the maximum LED brightness; "bright" – brightness 20% of the maximum brightness; "slow" – the four LEDs are lit up in a cycle of period 1300 milliseconds; "fast" – the LEDs' cycle is twice as fast (period 650 milliseconds). These settings were determined in a pilot study.

5.1 Experiment 1

5.1.1 Experimental design

A fully counterbalanced, within-groups design was used where subjects were asked to report their perception of cues from the wearable peripheral display while engaged in two primary tasks: editing text on a personal computer and walking around obstacles in a trafficked walkway of our department. The tasks were designed to ensure ecological validity for usage of mobile devices. The comparison of a stationary task and a navigation task was considered necessary given the different role that peripheral vision has in each [35].

The editing task was performed on a laptop computer (14'' screen, external mouse) using a standard text editing application in two sessions lasting approximately 20 minutes each, interleaved by the walking task. Four different pattern types were presented during the editing task, resulting from the variation of speed and intensity: (dim, slow), (bright, slow), (dim, fast) and (bright, fast). Presentations were in balanced random order and at random intervals (uniform random distribution between 20 and 50 seconds). Subjects were asked to report perception of peripheral visual cues by clicking on a button in the computer graphical user interface, as illustrated in figure 2. The text was an excerpt from a scientific dissertation [16], modified to include errors in verb conjugation and word order, in a similar manner to the study performed by Maglio and Campbell [21]. The text was selected so that editing would require longer time than the duration of the experiment.

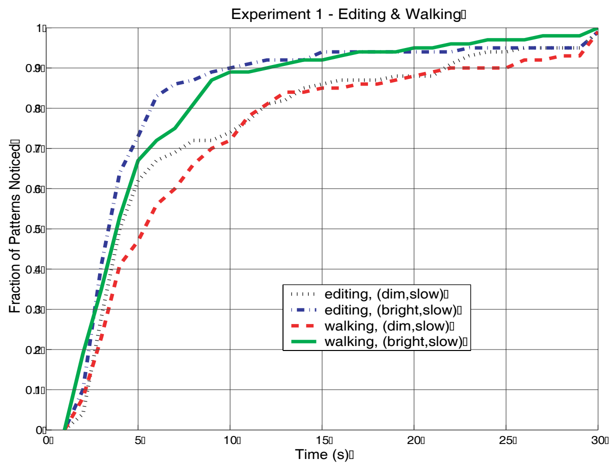

Figure 4. Cumulative distribution curves for (dim, slow) and (bright, slow) patterns in experiment 1.

For the walking task participants navigated 8 meter laps around obstacles set up in a regularly trafficked walkway in (omitted for blind review), see Figure 3. This setup was similar to the one reported by Pirhonen et al. [28], who noted that it allows measurements while preserving realism and ecological validity. The patterns presented during the walking task were of types (dim, slow) and (bright, slow). Presentations were balanced in random order and at random intervals. Subjects were asked to report perception of peripheral visual cues using a pushbutton connected to the glasses through a wire. For both tasks the cues were turned off when the subject reported seeing them or after a 30 second timeout. Reaction times were recorded automatically.

Ecological validity and realism were key factors in the design of the experiment to test the effectiveness of the glasses in real-world conditions. It must be emphasized that the experiment was designed to test the visibility of the cues, and not their effect on primary task performance, therefore there is no control condition where editing is performed without interruption. Performance degradation on the primary task can be interesting, but only in comparison with the degradation caused by other notification systems. Comparing different sensory modalities of interruption, though, involves different types of interaction between the sensory channel used for the primary task and that used for the notifications (e.g. visual-visual vs. visual-auditory) therefore this type of comparison was left out of the current study.

5.1.2 Description

Ten subjects were recruited from the (removed for blind review) university (students and staff) and were compensated for their time. All subjects had normal or corrected normal vision, four used contact lenses.

5.1.3 Results

Overall, 94.6% of the cues were noticed within 30 seconds of their presentation. Cues of type (bright, slow) were in more cases (96.5%) noticed before the timeout, compared to other types: 95% of (bright, fast), 94% of (dim, slow) and 93% of (dim, fast) were noticed within 30 seconds of their presentation.

Cues of type (bright, fast) were noticed faster than (dim, slow), both while walking and editing (means of 4.73 sec. SD = 0.36 and 6.63 sec. SD = 0.36 respectively, two-way one-factor ANOVA and Tukey-HSD $p < 0.001$). Two-way two-factor

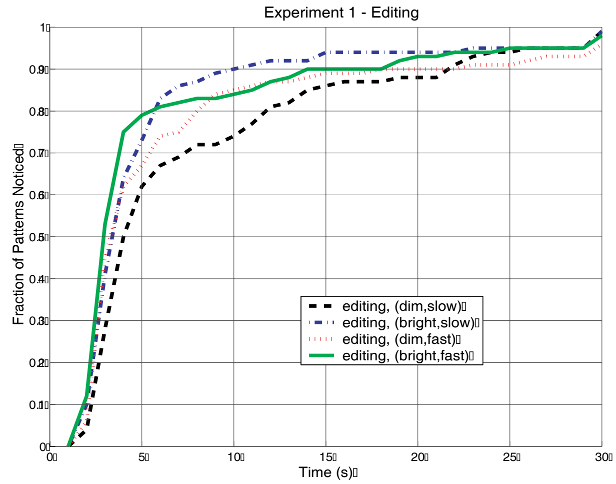

Figure 5. Cumulative distribution curves for the editing task in experiment 1.

ANOVA on cue intensity and cue velocity was used to compare reaction times of all four cue types in the editing task, and revealed that bright cues are noticed significantly faster than dim cues ($p<.001$ and Tukey-HSD $p < .001$), while the velocity did not have significant effect. The results are summarized in the cumulative distribution curves shown in Figure 4 and Figure 5. These curves show the fraction of total number of presentations that were perceived within a given time period; for example, in Figure 4, about 89% of all patterns of type (bright, slow) are seen within 10 seconds, while only about 74% of (dim, slow) were detected by the same time.

5.1.4 Discussion

The results of experiment 1 confirm that the wearable peripheral display can be used to deliver noticeable cues while users are engaged in everyday activities, even when mobile. Figures 4 and 5 show that in all conditions 94% of the most visible cues were noticed within 15 seconds of their presentation. The gradual response in reaction time confirms the first hypothesis, showing that the display is subtle in delivering cues. The distribution curves associated with patterns of different brightness and speed confirm that it is possible to adjust the level of disruption of the cues making them more or less noticeable.

A number of subjects (six) spontaneously reported to periodically monitor the display looking for incoming alerts, deliberately shifting their attention between the main task and looking for notifications. This behaviour is similar to what Weiser [34] argued for calm technology: technology that can be easily shifted between periphery and centre of attention. The shift is possible thanks to the selectivity of vision, while it would not be as simple to achieve with audio or vibrotactile alerts, which tend to instantaneously capture the user's attention.

5.2 Experiment 2

5.2.1 Experimental design

The second experiment was designed to measure the effects of primary task workload on the perception of the cues. To induce a different workload subjects were asked to read a narrative text from a computer monitor at two different speeds. Each reading task lasted approximately 10 minutes and was repeated twice (same speed, same text), for a total of 4 conditions ({high speed, low speed} x {first time reading, repeated reading}).

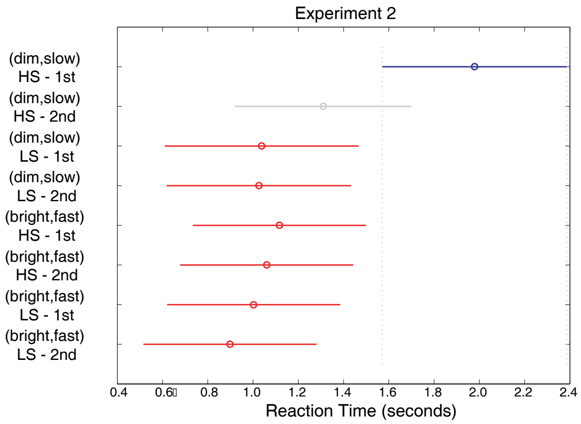

Figure 6. Comparison of mean reaction times for all the tasks and patterns of experiment 2, with 95% confidence bars. HS indicates High Speed and LS Low Speed, 1st and 2nd refer to first or repeated initial or repeated reading of the same text.

Subjects were instructed to keep one of their hands on the computer's keyboard spacebar and press it as soon as a peripheral cue was noticed.

The experiment used repeated measures, within-subjects design, counterbalanced by unique task and pattern. Patterns of types (dim, slow) and (bright, fast) were presented during each of the sessions in balanced random order at random intervals uniformly distributed between 25 and 70 seconds. Cues were kept on for a maximum of 15 seconds, if this timeout was reached the system passed to the next presentation.

The text was the beginning of a short story [20], and it was displayed on a standard 19" LCD computer monitor using 14 point font. A software application was written in Java to show the text two lines at a time and advance the content one line at a time automatically, a setup commonly used for reading speed experiments [39]. At the beginning of the experiment, using a different text [40], subjects were asked to adjust the display rate to be as fast as possible while still allowing them to read and understand. The resulting speed was then used as "high speed" while half of the value was used as "low speed". Each subject was then presented the text starting from the beginning at either high or low speed, for approximately 10 minutes. Then the subjects repeated the task with the same text at the same speed. Afterwards, subject continued reading the text (starting 2 lines before where they had left off) that was displayed to them at the alternative speed, and that presentation was repeated again. To ensure that subjects actually engaged in reading, they were given 5 questions about the content before the beginning of calibration, and were asked to answer them at the end of the experiment.

As with the first experiment, experiment 2 was designed to test the visibility of the cues, and any variation in reaction time depending on workload, rather than the cues effect on primary task performance. Hence the experiment includes no control condition where primary tasks are performed without interruption.

5.2.2 Description

Ten new subjects were recruited from (removed for blind review) population (students and staff) and were compensated for their time. All subjects had normal vision.

5.2.3 Results

Overall, 94% of the cues were noticed within 15 seconds of the onset of their presentation. All of the highly visible (bright, slow) cues were noticed before the timeout regardless of the primary task. The less visible (dim, slow) cues where noticed 80% of the time while users were engaged in the first time reading at high speed. The perception rises to 88% both during repeated reading at high speed and for first time reading at low speed, and to 96% during the repeated reading at low speed.

The cues were noticed faster when users read at low speed than at high speed (means of 0.99 sec. SD=0.09 and 1.37 sec. SD=0.09 respectively, two-way three-factor ANOVA $p < .01$, with factors cue type, reading speed, reading repetition, Tukey-HSD $p < 0.01$). Different cue types also caused significant differences in reaction times. Subjects detected (bright, fast) cues quicker than (dim, slow) cues (means of 1.02 sec. SD = 0.09 and 1.34 sec. SD = 0.09 respectively, $p < .05$). Figure 6 shows the comparison of reaction times marginal means for all the tasks and patterns used in the experiment, with 95% confidence intervals (Tukey-HSD). All subjects were able to correctly answer the questions about the text content.

5.2.4 Discussion

The results of this experiment confirm the second hypothesis: the visibility of the peripheral cues depends on the workload of the primary task. The data also reinforces the first hypothesis: the level of disruption and visibility of cues can be controlled through their brightness and velocity.

Figure 6 shows that different tasks cause significant differences to the perception of less visible (dim, slow) cues, while the effect on the more visible (bright, fast) cues is not as strong. Thinking of the primary task workload as a *barrier* for the perception of peripheral cues, this data suggests that the disruption level of different cues determines how high of a workload barrier the cue can overcome. These results suggest that tasks of very high workload might make some of the cues not noticeable at all.

6. Conclusion and Future Work

This paper has introduced a novel notification display embedded in eyeglass frames. The device delivers peripheral visual cues to the wearer without disruption to the immediate environment. The display is designed to take advantage of the visual field narrowing phenomenon, so that it tends to become less noticeable under high workload. Results from a usability study show that the cues can be effectively noticed by mobile users, and that they can be designed with adjustable degrees of visibility and disruption. Experimental results indicate also that the device is *less noticeable* when users are under high workload conditions, which often correspond to situations in which it is undesirable to interrupt. Therefore, the peripheral visual display can be used as a valuable alternative to other notification systems, such as auditory and haptic ones. The use of peripheral cues can also be an alternative to context aware notification systems, the filtering is performed (at no cost) by the human perceptual system, rather than by a machine.

Supported by the experimental validation of this novel approach for notification reported in the previous section, further work will explore the amount of information that can be conveyed by the display. Based also on the results by Campbell and Tarasewich [6], different messages can be encoded on the wearable peripheral display with different colours, different types of movement, and asymmetry between the two sides of the display – this can be especially appropriate when providing navigation information. Future studies will include application specific evaluations as well as longer term qualitative assessment, with day-long or week-long studies

The design of interaction devices and techniques for mobile application and services should take into account social acceptance. The design proposed, together with the results of the validating study, shows how wearable peripheral displays can increase the social acceptance of mobile technology providing a notification mechanism that is non-disruptive both for its users and those who are around them.

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