Comparing Modalities and Feedback for Peripheral Interaction

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Abstract
When executing one task on a computer, we are frequently confronted with secondary tasks (e.g., controlling an audio player or changing the IM state) that require shifting our attention away from the actual task, thus increasing our cognitive load. Peripheral interaction aims at reducing that cognitive load through the use of the periphery of our attention for interaction. In previous work, token- or tag-based systems alongside wearable and graspable devices were the dominant way of interacting in the periphery. We explore touch and freehand interaction in combination with several forms of visual feedback. In a dual-task lab study we found that those additional modalities are fit for peripheral interaction. Also, feedback did not have a measurable influence, yet it assured participants in their actions.

Author Keywords
Peripheral Interaction; Feedback; Touch; Freehand

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Int. Styles

Introduction
In our everyday lives, we carry out different activities in parallel with minimal or no attention (e.g., drinking a cup of tea while reading a book or walking while talking). In contrast, digital devices often require us to devote our full attention – particularly when interacting with display-based interfaces: for each additional task

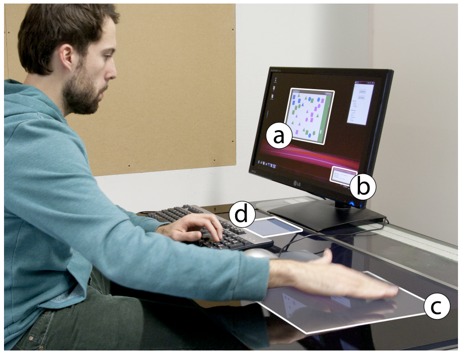

Figure 1. Participant during the study: (a) the primary task distracts/occupies the participant's attention and hands; (b) the email notification triggers the secondary task; (c) the interaction area; (d) the feedback area.

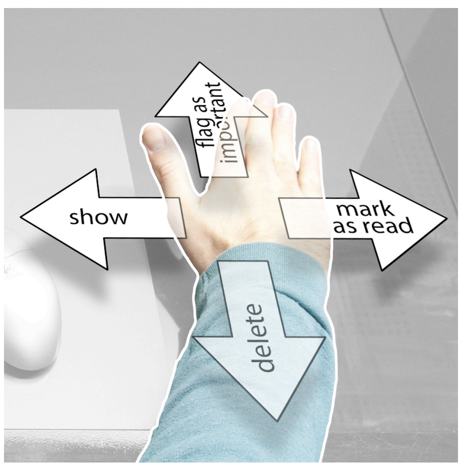

Figure 2. The four actions participants can apply to an incoming mail are mapped to the four canonical directions.

we perform, we have to switch between application windows or point at small icons, which then disrupts our actual task. One way of addressing this issue is to transfer some of our interactions with digital devices into our attention's periphery relying on divided attention, habituation and physical capabilities like proprioception. Thus far, research in this domain solely focused on graspable interaction (e.g., FireFlies [3], Polytags [10]). To fully explore the design space of peripheral interaction, we compared touch and freehand gestures to graspable interaction (Figure 1) and found that both are well suited for peripheral interaction. Regarding performance in the primary task, interruption and resumption lag [1], they also outperformed graspable interaction. As peripheral interaction is influenced by ambient information systems [11], we compared feedback types ranging from visual periphery to on-screen feedback and found that feedback did not influence performance but assured participants in their actions.

Related Work

Current research in peripheral interaction focuses on tangibles [6], graspable devices (e.g., tokens [5] or tag-based objects [10]), and wearable devices (either clipped on clothes [3] or worn around the wrist [1]). In addition, mid-air wiping gestures [7] towards or away from oneself have been explored. Research in the area of eyes-free [9] and micro interactions [14] does not address key characteristics such as interaction in attentional periphery, but already considers visual attention or parallel interaction. Previous work in these domains supports our assumptions in that we can extend the design space for peripheral interaction. Several of those projects already provide feedback through sound [3], light [6] or by their physical orientation or location [5][10]. Others offer functional feedback [13], which is inherent in the task itself (e.g., stopping a reminder animation [7], or lighting up devices to transmit information [3]). However, none of the experiments investigated the effect of provided feedback.

Designing the System

In our everyday life, interaction is motivated intrinsically. To study peripheral interaction in the lab, however, we have to trigger that interaction with a small, frequently executed task. We therefore chose notifications of incoming email (see Figure 1b), which are often stated to disrupt people during their work [8].

Interacting with new Emails

To interact with a new email, our system supports three modalities: (1) mid-air freehand gestures, (2) touch-based interaction, and (3) a tiltable, graspable device. To better compare these modalities, we chose to use the four canonical directions (see Figure 2) for the four most common actions performed on new emails. We based those directions on metaphors (with the interaction area being right to the keyboard): *down* to delete (throwing it into trash), *right* to mark as read (pushing it away as unimportant), *up* to flag (top indicates importance), and *left* to display the email (move closer towards oneself). To keep the interaction with the graspable similar to those of freehand gestures and touch interaction, we built a graspable device that can be tilted in the direction of the respective function (see Figure 3) as opposed to moving it back and forth. Through this, we keep interaction with the Graspable comparable to both freehand and touch interaction (i.e., starting from the same location in the periphery).

Feedback

Our system gives visual feedback as it is the most common and least disruptive for co-workers. We decid-

Figure 3. Graspable device equipped with markers: To interact, participants tilt the device, which subsequently moves back to its initial position on its own.

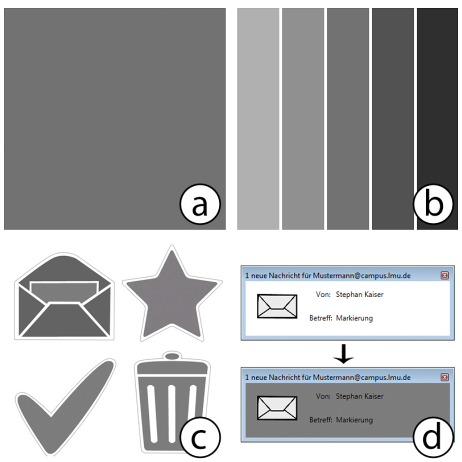

Figure 4. Feedback types: (a) Binary; (b) Animation; (c) Symbolic; (d) *Notification.*

ed to look at five types of feedback which differed in level of detail (see Figure 4) and location (i.e., in the user's periphery on the desk or on the display which holds the primary task): (a) *Binary*: feedback area changes color upon interaction; (b) *Animation*: animation in the feedback area indicates which direction was tracked; (c) *Symbolic*: symbol indicates the triggered action; (d) *Notification*: the notification (i.e., the original email notification shown on the display where the primary task is performed) is colored when an interaction is tracked; and (e) *None*: No feedback is shown. We designed all types in neutral greys to avoid a bias by personal color preferences.

Implementation

Our prototype runs on a Samsung SUR40 tabletop for tracking which allows for sensing touch and freehand gestures above. To mimic a regular desk, its display was set to black (except for feedback). The surface only detected touch in the interaction area. In addition, we placed a display, keyboard and mouse on the surface (see Figure 1). The interaction area (700 × 500 px, 32 × 23 cm, see Figure 1c) is located right of the keyboard and mouse. We designed the graspable device (see Figure 3) in Autodesk 3ds Max and printed it on a 3D printer. The handle ensures that it is easily graspable and makes identifying the correct rotation easier. After tilting the device and thereby pressing the tags onto the surface, it moves back to the initial position by itself. The feedback area (300 × 300 px, 14 × 14 cm, Figure 1d) is located between the display and the keyboard, and thus in the users' visual periphery.

Evaluation

Peripheral interaction is mostly evaluated in in-situ studies (e.g. [1][3][6]) to offer extensive learning. Previous work by Olivera et al. [10], however, tested peripheral interaction in the lab: they mimicked a dual-task situation by asking participants to count vowels in a text to distract them from the peripheral task. In addition, our primary task not only requires attention but also the use of hands, as they usually occupy mouse and keyboard in an office context.

Primary and Peripheral Tasks

Inspired by Square Click [12] our *primary task* required participants to click (and thereby delete) different items in different colors (see Figure 1a). Depending on the color displayed on the right participants selected all items in that corresponding color. In addition, they had to press a number on the number pad for each shape and color combination. Once all items of one color were deleted a new round started and new items appeared. This task supports continuous input but leaves room for the participants to decide when to interrupt the primary task, e.g. immediately after the pop up appeared or after one round was finished (about 10 seconds). In the *peripheral task* participants sorted emails. The appearance of a new email was triggered by notifications similar to those given by email clients. Instead of an email subject, the notification showed the action participants had to carry out (e.g., delete, flag).

Experimental Design and Procedure

We used a mixed-model design in our experiment. We chose to use the *3 Modalities* (*Graspable*, *Touch*, and *Freehand*) as between-groups factor to keep the duration of the study at a maximum of one hour. With their respective *Input Modality*, participants tested each of the *5 Feedback* (*None*, *Binary*, *Animation*, *Symbolic*, and *Notification*) conditions. To avoid learning effects, we applied a Latin square to counterbalance the order of *Feedback*. For each *Modality* and *Feedback* combination, 16 pop-ups appeared in randomized order. We set

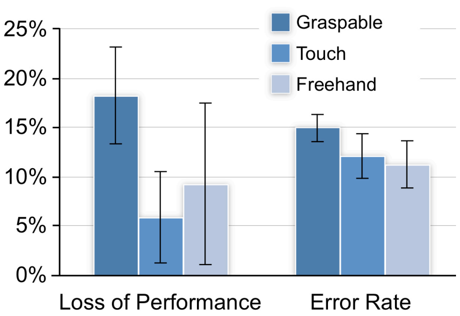

Figure 5. Loss of Performance and Error Rate for the primary task when participants also had to carry out the peripheral task. (Error bars: 95% confidence interval).

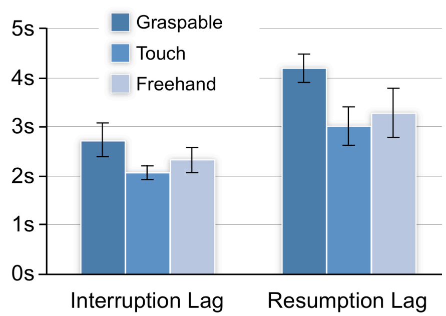

Figure 6. Resulting Interruption Lag and Resumption Lag when participants switched between the primary and secondary task (Error bars: 95% confidence interval).

the time between two pop-ups to at least 13 seconds to ensure that the time between notifications is longer than one round in the primary task.

After a general introduction we handed participants a questionnaire asking for demographic data and their experience with different input devices. We introduced both the primary and secondary task and let participants train them. While only training the primary task, we also collected a baseline measurement (i.e., without interruption). Subsequently, participants carried out both tasks in parallel for each *Feedback* condition with their respective *Input Modality*. We instructed users to focus on the primary task, and to react to each notification at their own liking (i.e., not necessarily immediately, but within a reasonable timeframe). Participants completed a questionnaire after each *Feedback* condition and a closing questionnaire at the end. We told participants about the modalities they had not used, let them interact with them and asked which modality they would consider their preferred one. We measured the *loss of performance* in the primary task as the number of clicked shapes in comparison to the baseline (i.e., without secondary task). We counted the *errors* in both the primary (i.e., wrong color/number) and secondary tasks (i.e., wrong or no action). In addition, we measured the *interruption lag* (i.e., time taken to leave the primary and start the secondary one) and the *resumption lag* (i.e., time needed from the end of interaction in the secondary and resuming the primary task). Finally, we collected *subjective data* through questionnaires.

Participants
30 participants (14 female), 10 for each modality, took part in our study. They were between 19 and 30 years old (avg. age 22). 63% use an email client and 89% of those get notifications about new mails.

Hypotheses
H1: Feedback in the peripheral task improves performance in the primary task.
H2: More detailed feedback (which action is carried out) is preferred.
H3: Peripheral feedback (Binary, Animation and Symbol) is less distractive from the primary task than feedback directly on the display (i.e., *Notification*).

Results
The *loss of performance* was highest when users interacted with the *Graspable* (*m*=18.2%, *sd*=7.9%), followed by *Freehand* (*m*=9.2%, *sd*=13.2%), and *Touch* (*m*=5.8%, *sd*=7.5%) as shown in Figure 5. A one-way independent ANOVA showed a significant difference ($p < 0.026$). A Tukey HSD post hoc test showed that performance in the primary task in the Graspable condition was worse compared to the Touch condition. We did not find any significant effect based on *Feedback*.

The *interruption lag* (see Figure 6) was shortest for *Touch* (*m*=2.06s, *sd*=0.23s), followed by *Freehand* (*m*=2.32s, *sd*=0.42s), and *Graspable* (*m*=2.73s, *sd*=0.55s). A one-way independent ANOVA showed a significant main effect between input modalities ($p < 0.007$). A Tukey HSD post hoc test revealed a significant difference between Touch and Graspable interaction ($p < 0.006$). As shown in Figure 6, the *resumption lag* showed similar results: *Touch* was the fastest (*m*=3.01s, *sd*=0.64s), followed by *Freehand* (*m*=3.28s, *sd*=0.80s), and *Graspable* (*m*=4.18s, *sd*=0.47). A one-way independent ANOVA showed a significant main effect between input modalities ($p < 0.002$). A Tukey HSD showed that both *Touch* and *Freehand* differed significantly from *Graspable* ($p < 0.02$). We did not find any significant effects for the resumption lag based on feedback conditions.

The *error rate* in the primary task showed no significant effect. As suggested in Figure 5, *Freehand* (*m*=11.2%, *sd*=3.9%), *Touch* (*m*=12.0%, *sd*=3.7%) and *Graspable* (*m*=14.9%, *sd*=2.3%) had similar error rates. We found the same for the different *Feedback* types. For the peripheral task, we observed most errors for *Freehand* interaction as positioning the hand was sometimes erroneously interpreted as interaction. With all errors being below 5% (including those where participants missed events entirely), we did not perform further statistical analysis.

We collected *subjective data* through questionnaires using 5-point Likert scales ranging from 1 (”I totally disagree”) to 5 (”I totally agree”). Participants rated the peripheral task as easy-to-learn (*median*=5), and the four actions as easy-to-remember (*median*=5). Participants did not consider peripheral interaction as physically demanding (*median*=1) and agreed that they were able to sort emails without thinking too much about it (*median*=4) as the interaction was not difficult-to-use (*Touch* and *Freehand*: *median*=2, *Graspable*: *median*=2.5). They had the impression that the primary task suffered from the peripheral task, especially when interacting with the *Graspable* device (*median*=4) but also *Touch* (*median*=3.5).

Feedback was considered important for sorting emails (*Touch*/*Graspable*: *median*=5, *Freehand*: *median*=4) and every participant confirmed that feedback was missing in the *None* condition (i.e., they could not tell whether the interaction was recognized). In general, users preferred feedback that indicated the kind of action (*Touch*: *median*=5; *Freehand*: *median*=4; *Graspable*: *median*=3). This is also reflected in individual ratings for recognizability: *Animation* and *Symbolic Feedback* were easiest to recognize (*median*=5), followed by *Binary* (*median*=4.5), and *Notification* feedback (*median*=4). The same order results from a Condorcet ranking. Participants liked *Symbolic Feedback* best, followed by *Animation*, *Binary*, *Notification* and *None*. Participants did not feel distracted by feedback from the primary task (*Binary*: *median*=1.5, others: *median*=2) but paid moderate attention to it (all: *median*=3)

Discussion and Future Work

We selected tasks and modalities that were an overall fit for evaluating peripheral interaction: they were easy to learn and remember and neither physically nor cognitively demanding. Although we envisioned *Graspable* interaction being comparable to *Touch* or *Freehand*, the latter two performed better in terms of overall performance, interruption and resumption lag. Possible reasons are that participants did not have to grasp a separate device but could interact in a relatively big interaction area. However, these results have to be confirmed in an upcoming field evaluation. Outside influences such as messy desks and unintentional gestures may pose difficulties in a real life scenario. This also means that our implementation needs to be adapted to standard desks (e.g., through LeapMotion[1]). We also found the interruption lag being shorter than the resumption lag across all conditions. While this is beneficial for some tasks (i.e., less mental load), it might not be a meaningful measure for systems that are meant to attract the user’s attention (e.g., a reminder system).

We did not find any quantitative differences for (and thus no influence of) *Feedback* on performance in the primary task (H1 rejected). However, participants strongly argued for feedback, especially that giving de-

[1] https://leapmotion.com

tailed information (*Symbolic* and *Animation*) about their actions (H2 accepted). We assume this effect to be less important in in-situ deployments where participants have time to get used to the system and gain trust in its reliability. On the other hand, errors in real-life scenarios have consequences. We are curious to find out which effect is stronger. Participants did vote for more detailed, peripheral feedback, but we did not find any measurable difference to on-screen (i.e., *Notification*) feedback (H3 rejected). Additional means to display feedback in the periphery have to be explored, as we cannot rely on an interactive desk. Enhanced keyboards (e.g., [4]) could help to solve that problem at least for abstract feedback (e.g. animation).

In summary, we showed that *Touch* and *Freehand* gestures can be used peripherally and outperform *Graspable* interaction in some cases. Feedback did not affect overall performance or error rates but gave participants assurance in their interactions. We hope to confirm these results in field deployments, and see how different modalities for peripheral interaction integrate into a standard computer setup with keyboard and mouse, which of course can still be used for the tasks.

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