# Collaborative Use of Mobile Phones for Brainstorming

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## ABSTRACT
Mobile phones have traditionally been utilized for personal and individual use. In this paper we explore shared co-located interactions with mobile phones. We introduce a phone-based application that supports ad hoc brainstorming sessions. The prototype allows a workgroup to create, edit and view virtual mind-map notes on any table surface. The prototype encourages people to use the devices interchangeably and thus engage in social interactions. Evaluations show that participants were able to easily create mind maps and that the prototype supports different strategies in mind-map creation.

## Categories and Subject Descriptors
H.5.m Information Interfaces and Presentation: Miscellaneous.

## General Terms
Design, Experimentation, Human Factors.

## Keywords
Co-Located Interaction, Mobile Devices, Tangible User Interface.

## 1. INTRODUCTION
Mobile phones were originally conceived and have traditionally been utilized for personal use. The improvement in wireless networks and handheld computing platforms offers possibilities to explore shared use of mobile phones. In this paradigm shift, co-located users engage in collaborative activities using their devices, thus going from *personal-individual* towards *shared-multiuser* experiences and interactions. Our *Social and Spatial Interactions (SSI) platform* extends the current individual use of these devices to support shared co-located interactions with mobile phones. The question the platform addresses is if people are willing to share their devices and engage in collaborative interactions.

In this paper we present the *MindMap* prototype that supports the creation of mind maps during brainstorming sessions. The prototype encourages participants to use the devices interchangeably and thus engage in social interactions.

The paper is structured as follows. First, we provide background information and discuss related work. Second, we introduce the design principles and interaction techniques of the *MindMap* prototype. Third, we present the evaluation of the prototype and its results. Finally, we present conclusions and future work.


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## 2. BACKGROUND
We have involved end-users in the process of coming up with new playful artifacts and interactions for the *SSI platform*. This has allowed us to gain a better understanding of how people might use these technologies. First, we conducted a probes study [2] with 14 mixed-nationality students where we observed people's pervasive use of (mobile) technologies. Participants reported things to us like using their laptops while sharing the same table, constantly switching and transitioning between an individual and a social situation. Subsequently, we invited participants from the probes study to co-design sessions. In these sessions, we first presented a simple demonstrator showing the possibilities of *SSI* and later we engaged in brainstorming sessions that resulted in 20 possible application areas for *SSI*.

## 3. RELATED WORK
Tangible user interfaces (TUIs) allow people to interact with digital information by manipulating physical objects where the data is coupled with the object [7]. Bricks [1] introduce the notion of 'physical handles' to manipulate virtual objects. DataTiles [10] build on that notion by projecting data on a transparent modular tile. Others like the I/O Brush [11] take on a different approach by using everyday physical artifacts to suggest interaction semantics. Most of these systems require complex projection displays to couple the information onto the object. In our work we explore the use of a mobile phone as a physical interface to manipulate data.

Luyten et al. [8] have studied ad-hoc co-located collaborative work using mobile devices. Personal displays are tracked and used to share a common information space, providing 'peepholes' [12] to the data set. Their setup requires external equipment in the form of 3 infrared towers for 3D tracking of the devices. Siftables [9] are perhaps the closest to our work. This TUI consists of a group of compact display devices that communicate wirelessly and form a sensor network. The main differences are that Siftables were developed with a single user in mind and they are able to detect where other Siftables are only when perfectly aligned adjacently one next to the other. We provide a solution that allows us to connect several devices in different orientations (at 90-degree intervals) and positions (i.e. displacements are also possible), which allows to dynamically tile different views of the workspace.

## 4. THE MINDMAP PROTOTYPE
We took one of the 20 possible *SSI* applications and implemented it to demonstrate the potential of the *SSI platform* and some of its principles. The *MindMap* prototype is a brainstorming tool that allows a workgroup to create, edit, and view virtual notes on any table, not requiring hanging Post-it notes to a board or wall.

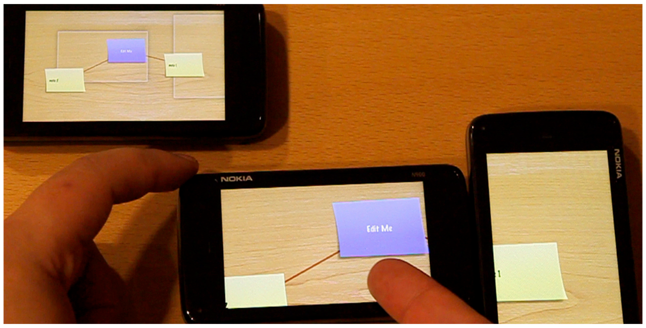

**Figure 1. The *MindMap* prototype. The zoomed-out view (top-left device) plus two devices connected at a 90-degree angle.**

## 4.1 Design

The idea behind this concept was to allow a small group of people to collaboratively create, edit, and view virtual mind-map notes on any table surface. We use an office metaphor to suggest interaction semantics. In practice, the users would interact with a set of mobile devices that show a view of the mind map. In the design we assumed that all the mobile devices used in the application have a touchscreen for displaying a view of the mind map, and that at least two devices are in use. While in a real world situation each device would likely belong to one of the users, the design encourages using the devices interchangeably, to support more flexible interaction within the group.

At this point we lacked the necessary sensors to track the relative positions of the phones on a table surface. The design accommodates this by allowing panning the view with a finger, and by letting two devices know that they are connected to each other with a pinching gesture. Using accelerometer data, Hinckley [4] explores an alternative way of connecting devices by physically bumping them together. Bumping enables users to dynamically tile displays, however it does not allow physical displacements of the connected devices. Hinckley et al. [5] introduced a new way of connecting pen-enabled mobile devices. Stitching is a pen gesture that starts on the screen of the first device, skips over the screen bezel, and ends on the screen of the second device. Technically, stitching can be used as an alternative to connect displays, also with displacements. Semantically, the gesture indicates a direction that is better suited for copying files.

We made a distinction between two modes of use: when the device was resting on a table, and when it was held in a user's hands. By default a device on the table would be showing the mind map at a 1:1 scale, as if the mind map was physically on the table surface and the device was a window into it, similar to a peephole interface [12]. The view shown by a device in a user's hands would zoom out to show an *overview* of the full mind map. This overview was automatically updated in real time to accommodate changes to the mind map: for example, if a new note was added beyond the edges of the overview, the overview would zoom out further to also include the new note. The zoomed-out view also displayed the locations of the all the views of the other devices running the prototype application (Figure 1).

## 4.2 Interaction Techniques

Most of the interaction was done while in the 1:1 scale views. In this mode, the user was able to create, edit, move, connect, and delete notes, and pan the view by dragging a finger on the touchscreen. In the zoomed-out overview, the interaction was limited to panning other views, and moving and connecting notes.

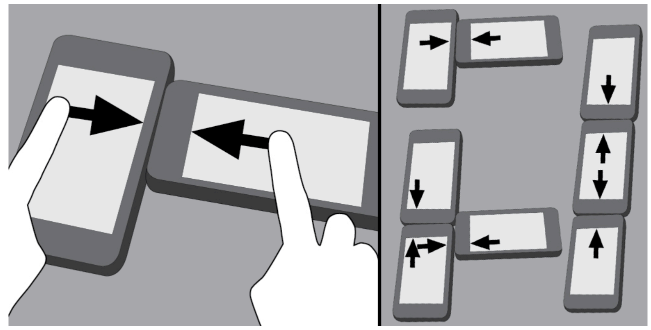
**Figure 2. The pinch gesture (left) plus different position and orientation options to connect different views (right).**

To create a new note, the user would perform a long press (0.7 seconds) on the touchscreen in an empty part of the table. A new note would appear under the user's finger. The note was automatically placed in *edit mode*, meaning it was presented as hovering a few centimeters over the table surface with a blinking cursor, waiting for the user to enter the text for the note. After the text was entered, there were two ways to end the *edit mode*. One was to place the device back on the table (assuming it had been picked up for more convenient text entry) or by tapping the touchscreen somewhere on the note.

When a long press was done over an existing note, it would be placed in *edit mode* and the view would automatically pan to center on the note. In addition to allowing changing the text of existing notes, this also made it possible to move the note around. Notes in *edit mode* were considered affixed to the view, so that when the view was panned while a note was being edited, the note would move with the view. This allowed a user to change the position of the note while another was editing the text of the note.

When a note was moved partially over another note, a connection was formed between the notes: the bottom note became the parent note of the note being moved in the mind map. This way it was possible to form a hierarchy of connections to construct the structure of the mind map. Note connections were visualized as red lines between the notes. When moving a note with child notes, the children would automatically move as well to retain the layout of the mind-map branch. The parent note of a note could be changed at any time by moving the note over its new parent.

When the device was picked up from the table while a note was in *edit mode*, the view would zoom away slightly to allow the user to see a bit more of the surrounding area around the edited note. This was to facilitate making connections to surrounding notes.

While a note was in *edit mode*, it could be deleted by flipping the device upside down. As the screen is then no longer visible, feedback for the deletion was given in the form of a trashcan sound effect.

At the 1:1 scale, it was possible to connect the views of adjacent devices by performing a pinch gesture on the screens of the devices. While thus joined, the views would stick together when panning, allowing the formation of larger 1:1 scale composite views. Any number of views could be joined in any configuration. The pinch gesture was used not only for determining which views to connect, but also to figure out the relative orientations of the views (at 90-degree intervals) and the positions of the views relative to each other (Figure 2). Picking up a device from the table would also detach the view if it was joined to another one.

## 4.3 Implementation

The hardware platform for the prototype was the Nokia N900 mobile computer because it has a powerful graphics processor and versatile wireless networking capabilities. Also, installing custom software on the N900 is effortless due to the open Linux-based operating system. The prototype software was implemented in C++ on top of the Qt 4.5 framework.

Since the prototype application was running on several devices simultaneously in a distributed manner, there was a need to share information about the application state and user actions between the devices. This was accomplished by setting up a wireless personal area network, onto which all the devices were connected. A Wi-Fi network was used in addition to point-to-point Bluetooth serial links. Together all the Wi-Fi and Bluetooth data links formed a network on which messages sent by one device were automatically transmitted to all other devices, regardless of whether the endpoint was behind a Wi-Fi or Bluetooth link. A mixed network like this allowed us to connect part of the devices over Wi-Fi and the rest over Bluetooth. This provided us with lower latencies and better reliability when compared to Wi-Fi-only or Bluetooth-only configurations. On the Wi-Fi network, the devices were able to detect each other's presence with broadcast UDP packets. Compared to Bluetooth service discovery, this resulted in a faster and more reliable network setup phase.

The user interface was drawn using OpenGL ES 2.0, allowing applying fluid animations to view panning, rotation, and zooming, and utilizing 3-D effects such as shadows when drawing the notes.

To detect when a device was picked up from the table, we used the N900's internal accelerometer. The algorithm was as follows: when the sensor showed a constant pull toward the back of the device, it was deduced that the device was on the table – otherwise, it was considered to be in the user's hands. The accelerometer was polled at a frequency of 10 Hz. If all samples from the last 0.6 seconds were indicating the same state, it was used as the new state of the device.

# 5. EVALUATION

Hedonic and pragmatic aspects of the *MindMap* prototype were tested in a user evaluation. First, we wanted to see if the *MindMap* prototype is a relevant application for users in the context of the *SSI platform*. Second, we wanted to test some of the interaction techniques in terms of naturalness, ease of learning and use. The evaluation was conducted with 9 participants, mostly international students who had previously participated in the probes study and co-design sessions. The participants varied in gender (8 male, 1 female), age (between 22 and 47), and background (6 technical, 3 non-technical). The evaluations were conducted in 3 groups of 3 participants. All sessions were recorded on video.

## 5.1 Tasks

In the first part of the study (30 min.), we briefly explained the *MindMap* prototype and its interaction techniques. We then allowed them to freely explore the available functionality and get acquainted with the application. In the second part of the study (30 min.), all 3 participants collaboratively created a mind map containing at least 10 notes on any topic that they would agree on. In the final part of the study (30 min.), we had semi-structured interviews in which we asked participants to walk us through some of their experiences while creating the mind map. Finally, we asked participants to fill-out an AttrakDiff [3] questionnaire to quantitatively measure the hedonic and pragmatic aspects of the prototype.

## 5.2 Quantitative Results

Regarding the ratings on the standardized AttrakDiff questionnaire (Figure 3), the prototype was rated as "fairly self-oriented". It was rated high on the hedonic quality (HQ), namely because it "stimulates users, awakes curiosity and motivates them" and "the overall impression of the product is very attractive." On the pragmatic quality (PQ), the results show "there is room for improvement in terms of usability." The confidence rectangle shows the level of agreement between users.

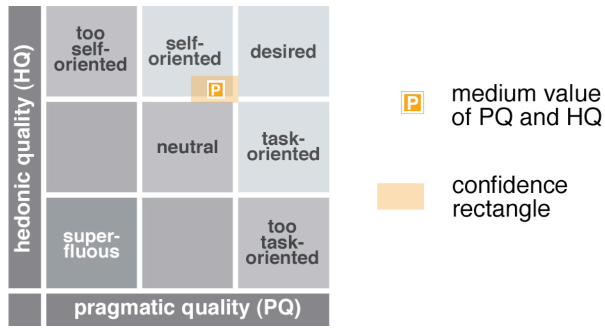


**Figure 3. Averages and values of the dimensions PQ and HQ and the confidence rectangle for the *MindMap* prototype.**

## 5.3 Qualitative Results

Regarding our qualitative results, two researchers made affinity notes as they watched the videos from the sessions independently, and later built an affinity diagram for the analysis [6].

### *5.3.1 Participants Positive on the Prototype*

In general, participants were positive on the *MindMap* prototype. Almost all participants (8/9) felt the prototype was innovative and that it supported teamwork:

*"(This application) is interesting, something new. It's like teamwork."* [P4]

*"I didn't think people were thinking of creating something like this. I'm quite impressed."* [P2]

### *5.3.2 Supporting Different Strategies*

The prototype provides good support for mind-map creation. The application was flexible enough to allow different kinds of strategies and work practices to be used when creating mind maps. We observed that in the first session each participant had a specific role (i.e. P1: create and type notes, P2: provide content and define layout, and P3: follow the discussion and make high-level decisions on content), while in the second and third sessions participants shifted these roles more freely throughout the session.

### *5.3.3 Collaboration*

All participants (9/9) said the application supported collaboration between them. The interaction between people and with the devices really created a common working space for participants. They could see what others were doing with the notes and it also established discussion between the participants:

*"It's collaborative, it gets more things out of everybody. It's good at discussing things, you get new ideas with these trees."* [P5]

*"For teamwork, this is the best idea."* [P4]

However, the current implementation of the application only allows one note to be edited at the same time. Especially in the second session where all participants contributed actively to entering new notes, it could not be done fast enough because they had to wait for a user to finish note editing before a new note could be entered. For this reason, they had to take turns in editing notes, which made the interaction sequential and slightly reduced the collaborative feeling of the application.

### 5.3.4 Interaction Techniques

Participants thought the joint interactions required to build a mind map were new and stimulating. All participants (9/9) were able to create, edit, connect and delete notes after our brief explanation of the interaction techniques.

Regarding the pinch gesture using the touchscreen to combine different devices, we observed that in all three sessions participants used this feature to enlarge the viewable work area, both for note creation and to arrange notes. However, this option to combine devices was not used permanently for a couple of reasons. First, as we have mentioned earlier, in the first session, participants had separate roles, thus it was more natural for them to work and discuss with the rest of the group while holding one device each. And second, once the devices were combined, some participants would use their dominant hand to interact with the devices and use the non-dominant hand to hold them together into place as they were not physically attached. As a result, the non-dominant hand would sometimes block the view of the screen for other participants. With such small devices, this can have a dramatic influence on collaboration.

Most participants (6/9) had initial difficulties with positioning the notes on the map. Instead of moving the note in the intended direction, the application was built so that you would drag the table behind the note. Although all participants were able to recover from this problem, most of them said that at first it felt confusing and caused lots of movements in the wrong direction:

*"It's another way of thinking. It's more user-friendly to move the note, moving the table is not the normal way."* [P2]

*"It was a bit confusing."* [P3]

Both the 1:1 scale view of the workspace and the overview were actively used in all three sessions. The majority of the participants (8/9) mentioned that both views are necessary to collaboratively build a mind map. In all three sessions the participants felt that, as the number of notes increases, the notes are getting too small in the overview mode. The application scaled down the size of the notes in the overview as new notes were added, but quite soon the notes became so small that their legibility suffered and it was impossible to find a note or read its content.

Participants were positive about the use of hand gestures (e.g. picking up the device to get the overview or flipping the device upside down to delete a note) and most of them (7/9) explicitly requested other similar gestures to support different actions. Participants commented on the intuitiveness of the interaction and the usefulness of the feedback for deleting a note:

*"Deletion was a totally new thing, it was really good."* [P5]

*"The trash sound is useful for me. You are not seeing the display, you hear the sound and then it's done."* [P2]

*"There could have been more hand gestures, like throwing my data to another phone."* [P3]

## 6. CONCLUSIONS

We have built and evaluated the *MindMap* prototype, a support tool for brainstorming sessions. The prototype encourages people to engage in shared co-located interactions with their mobile phones. We have evaluated the prototype in a user study to assess hedonic and pragmatic aspects of the tool. The results of the study showed that participants thought the prototype was innovative and that it supported teamwork. The prototype allowed for different strategies and work practices in mind-map creation.

We were able to overcome the limitation of not being able to automatically detect when two devices are next to each other by introducing a simultaneous pinch gesture using the touchscreen of the devices. This simple gesture allows users to connect devices in different orientations (at 90-degree intervals) and positions (displacements are also possible) and thus dynamically tile different views of the workspace.

In the future, we plan to further explore the spatial aspects of the interaction by adding position-tracking sensors to the devices used in the prototype. Once we are able to determine the positions of the devices in relation to each other, we can research new interaction techniques based on device proximity and orientation.

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