All4One: A Moderated Sketching Tool for Supporting Idea-Generation with Remote Users

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Abstract

Despite the increased popularity of online tools for remote teamwork and meetings, moderated collaborative activities between multiple users in early conceptual design stages, such as brainstorming sessions, are yet not well supported. In this paper, we introduce *All4One*, a networked system that enables multiple remote users to participate in a moderated visual sketching session. Each participant can independently draw and share sketches using a tablet, and a moderator uses a set of tangible tools to arrange and manipulate sketches that are displayed in real-time on a whiteboard. We present our prototype in detail and the results from a workshop study simulating a brainstorming session with designers who tested the system in practice. Results show several usage patterns and the potential of *All4One* for use in early design stages, and the importance of the role of the moderator as the facilitator of the design process. The paper concludes by identifying weaknesses and strengths of the current system and possible directions for future work.

Keywords: moderated collaboration, sketching, remote, idea sharing, tangible.

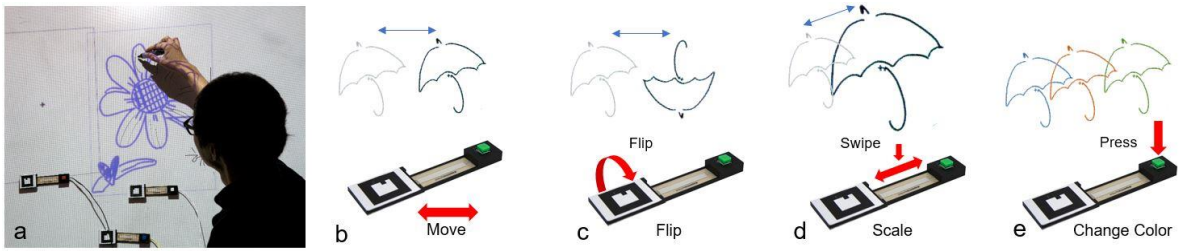

Figure 1: The *All4One* system in action during an idea-generation session (a). Tangible tools can be used to enable different direct manipulations of remote participants' sketches, such as moving (b), flipping (c), scaling (d), and rotating (e) images.

Remote teamwork and collaborative meetings using digital online tools are becoming commonplace. However, although remote telecommunication bridges the physical distance between team members, group activities involving discussions for generating creative content are not well supported and often require traditional offline, face-to-face meetings. Specifically, idea-generation group sessions, also known as brainstorming sessions, are still very difficult to conduct online. That is because good brainstorming is highly visual and physical (Kelly et al.,

2001), requiring a real-time synergetic effort of all the participants. Although several remote drawing tools have been developed and researched through the years to facilitate sharing of visual ideas and also a sense of presence among participants (e.g., Ishii & Kobayashi, 1992; Lee et al., 2014; Tang & Minneman, 1991; Junuzovic et al., 2012), these systems mainly focus on peer or 1-to-1 collaborations rather than moderated group discussions. However, in a series of controlled experiments, Chan et al. (2016) demonstrated that the active role of an expert moderator in the creative process increases the quantity and creativity of the workers' ideas compared to un-facilitated workers. Oxley et al. (1996) also reported similar results, indicating that teams facilitated by a moderator outperformed interactive groups with no supervision.

Therefore, to address the limitation of current unmoderated brainstorming systems, we propose a networked collaborative digital tool called *All4One* that enables designers to participate in a real-time online brainstorming session facilitated by an active moderator. The system supports individual contributions in the form of visual sketches from remote team participants, through a custom mobile application. On the moderator side, the system works by integrating both visual content with physical manipulations. Inspired by *CurationSpace* (Brudy et al., 2016), which uses a mixed-media toolkit that allows individuals or groups to create, edit, and share digital artifacts, *All4One* enables the moderator to directly manipulate the received sketches from remote participants using a set of tangible tools.

This paper contributes to prior work by describing an online system that supports collaborative visual brainstorming in the form of sketches generated by remote designers. The role of a moderator is emphasized by the unique setup of the system: the moderator is the only member of the team who can physically manipulate the sketches of all remote participants by using a set of tangible tools. We are interested in exploring how this specific setup can support online brainstorming sessions, and we want to understand whether the physical toolkit used by the moderator is sufficient for engaging the remote participants in an active real-time collaboration. In the paper, we present the system in detail, and provide a short evaluation through a moderated brainstorming session with designers. Based on the workshop results, we indicate how the system was used for drawing and sharing sketches, and possible future improvements.

Literature Review

Collaborative sketching tools

Numerous past researchers have focused on the development and testing of novel collaborative sketching tools for remote and co-located collaborations. Bly et al. (1988, 1990) published a pioneering work investigating the usage of shared drawing surfaces as communication tools for co-presence and remote collaborations. Following this research, several remote collaborative drawing platforms, mostly in the form of whiteboards or large tabletop surfaces, were developed in order to enable eye-contact between remote collaborators (Ishii & Kobayashi, 1992) and to share gestures through projected overlays (Junuzovic et al., 2012) or shadows of hands (Tang & Minneman, 1991). In parallel to these systems based on large displays, tablet-based collaborative

drawing tools were also widely studied. *Pass the iPad* (Yuill et al., 2013) is a collaborative, playful drawing tool designed to support meetings of co-located participants, and it works by using a single tablet device that is passed around as a shared canvas among participants. Finally, *skWiki* (Zhao et al., 2014) is a web application that saves revisions of text, content editing, hand-drawn sketches, and photographs for collaborative editing in digital multimedia projects. The main advantage of this system is that it works for both remote and co-located users, and, by borrowing the concept of revisions and branches from distributed version-control systems, it allows users to both synthetize ideas and explore alternatives using branching paths.

Tangible tools in multi-user collaboration and digital drawing

The increased popularity of tablet devices and digital drawing tools has fueled the research into both multi-touch input surfaces and Tangible User Interfaces (TUIs) that make collaborative drawing easier and more expressive. Leon et al. (2014) demonstrated that tangible interfaces, when used in combination with more traditional multi-touch tabletops, contribute to engaging users resulting in participation that is more active during the conceptual design process. Brudy et al. (2016) introduced *CurationSpace*, a cross-device system that provides interactive and expressive tools for curating digital content during ad hoc, co-located collaborations. The system allows users to collect, analyze, display, and share information using a large interactive surface for sharing content in combination with personal smart-watches as a tool for individual instrumental interaction.

In addition to that, there are several examples supporting individual digital drawing activity using tangible tools. *ToolStone* (Rekimoto, 2000) is a companion device for the non-dominant hand that can be physically manipulated for rapid tool selection or view control. Zhen et al. (2013) developed a system that can identify different tangible drawing tools (e.g., ruler, protractor, set square) on a capacitive multi-touch tablet. *AnnoScape* (Lee et al., 2014) is a system that enables users to navigate shared 3D virtual workspaces by using tangible handles, whereas Schkolne et al. (2001) presented a system for drawing directly on any surface and then manipulating the results through tangible tools. Finally, tangible tools are also used for drawing on unusual materials or surfaces, such as the *Graffiti Fur* system (Sugiura et al., 2014), which allows to draw on carpets using a physical device that modifies the direction of the carpet fibers.

All4One

All4One (Figure 2) is a networked system that supports moderated sketching sessions for collaborative idea generation with multiple remote users and a designated expert facilitator or moderator. While the remote users independently draw on their tablet devices following the moderator's suggestions and requests, their sketches are shared in real-time with the moderator and displayed on a whiteboard. Using a set of tangible tools, the moderator can then manage, modify, and selectively share these sketches with all of the other brainstorming participants, or save them for future use. Since the system works by projecting digital content created by the remote users onto a physical whiteboard, the moderator can also engage with both the digital

content, editable using a set of tangible tools designed ad hoc, and with any other analog content on the whiteboard. For example, the moderator can use a mix of digital and analog tools to annotate the sketches by drawing with a marker on the whiteboard or manipulating the remote participants' drawings with the system's tangible interface. Moreover, the system supports remote users' voice discussions via voice chat (Google Hangouts) with other users and the moderator, and it allows them to share snapshots of reference images using the tablets' cameras.

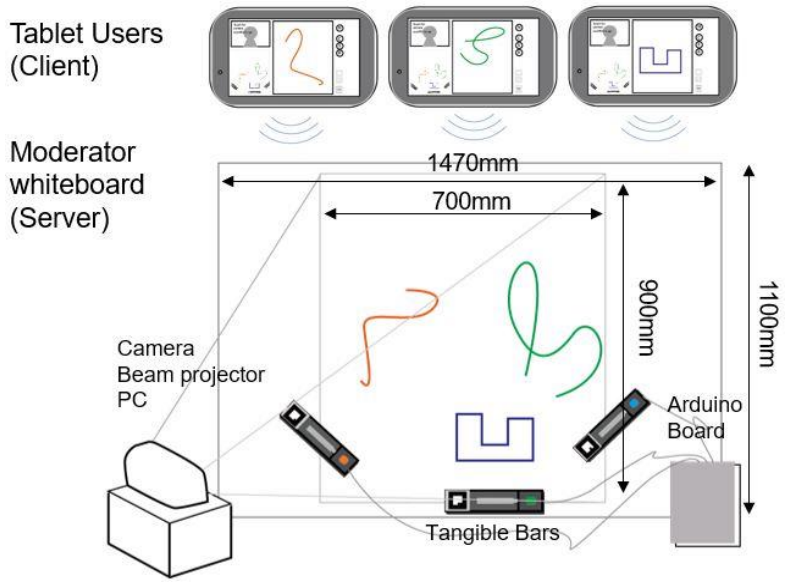

Figure 2: System architecture and components at a glance.

In the next sections, we describe the tablet sketching application for the remote users and the moderator's toolkit, composed of the whiteboard application for displaying the sketches and the tangible tool interface for manipulating them.

Mobile sketching application

The sketching application (Figure 3) was developed for Android tablets using Java and the Processing framework. The application acts as a client wirelessly connected to the moderator's whiteboard (the server) through the Open Sound Control (OSC) protocol. The graphical interface of the application consists of a main canvas where a user can draw lines, and of two windows displaying the live video streams of the moderator's whiteboard and of the built-in back camera. Several graphical toggle buttons are used to clean the canvas, connect/disconnect from the server, save the current drawing as an image on the tablet memory, and selectively synchronize the canvas content with the moderator's whiteboard. Finally, a user can take a snapshot with the built-in camera and optionally draw on it.

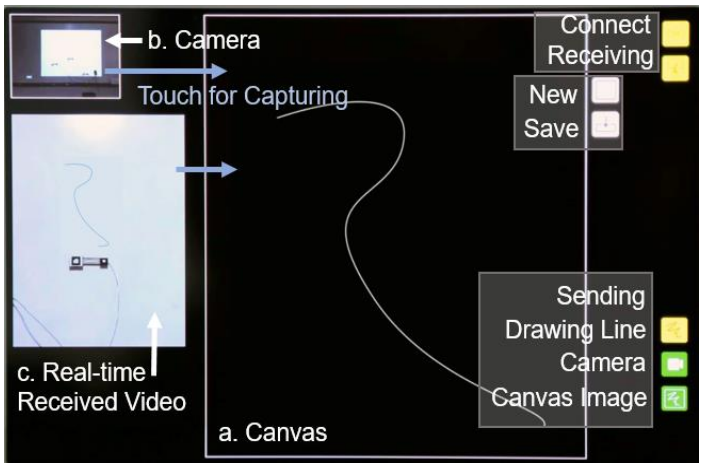

Figure 3: The graphical user interface of the sketching app.

Whiteboard system

The moderator's whiteboard system consists of the software and hardware setup for receiving, projecting, and manipulating the sketches drawn by remote users (Figure 4). A beam projector (NEC UM330W) and an HD webcam (Logitech C270) are mounted in front of a metal whiteboard (80 cm and 160 cm away, respectively). The projector displays the content of a computer application developed in Java showing a canvas with the remote users' sketches. The camera is used to track visual markers (NyARToolkit) named *MarkerTools*, which are placed on tangible handles. Each marker is associated with a unique ID and assigned to a user on a first-come-first-served basis. Users' sketches are displayed next to the associated markers and can be moved and modified with the corresponding *MarkerTools* (see next section). Finally, a specific area of the canvas (delimited by a 700 × 900 mm rectangle) can be used for broadcasting content to the remote users—if any drawing is displayed in such area, it is automatically shared with all participants. It is therefore up to the moderator to choose which sketch to share with other users.

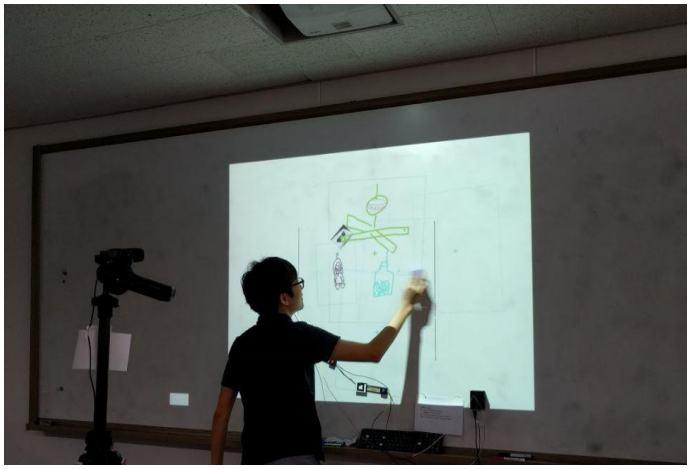

Figure 4: The system whiteboard in use.

Before using the system for the first time, the moderator is required to perform a calibration manually to align the camera and the projector views. Finally, a physical keyboard is placed next to the whiteboard and it is used for issuing commands that are not content-specific, such as enabling broadcasting to remote users, taking snapshots of the canvas content, and saving the canvas image in memory.

The tangible MarkerTools

The moderator can physically manipulate the drawings from the remote participants using tangible *MarkerTools* (Figure 5). Each *MarkerTool* is a 3D-printed, 130 × 25 mm flat handle bar and consists of a marker box, a 50 mm soft-membrane potentiometer, and a push button. The marker box is a 50 × 40 mm plastic support with two attached visual markers (on both the front and back sides) used for tracking *MarkerTools'* location and orientation, and identifying remote users. The marker box is attached to a bespoke bar using a small magnet. Each *MarkerTool* is wired to an Arduino UNO development board, which is connected to a controlling PC via USB. Finally, a magnetic strip is attached on the backside of the *MarkerTools* and to the Arduino box for easy attachment to a metallic whiteboard.

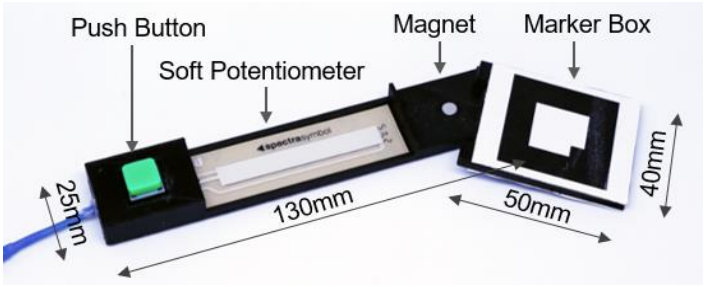

Figure 5: A tangible MarkerTool for manipulating the sketches from the remote users.

Using the *MarkerTool*, the moderator can directly manipulate each participant's sketch on the whiteboard (Figure 1): by moving and rotating the *MarkerTools*, the corresponding sketches follow the motion. The push button is used to change the colors of the sketches, the potentiometer is used for scaling the drawings, and the marker box can be flipped to vertically mirror the images.

Workshop

To understand how *All4One* could be used in practice, we organized a workshop study as a simulated brainstorming session with four design students (two graduate, two undergraduate) aged 21 to 32 years old (M: 24.7, SD: 4.7) from the industrial design department of KAIST. The goal of the experiment was to observe eventual patterns and collect feedback from users. The design of this workshop study was informed by a short pilot study with three participants that we conducted the week before.

After an ice-breaking session in which participants signed a consent form and were informed

about the objectives of the study, we introduced a short demo of the *All4One* system and its capabilities. We randomly assigned one participant as the brainstorming moderator. We then asked one other participant to stay in the room and sent the remaining two participants to two different remote locations (two different rooms in the same building in the university campus). While an assistant helped the two remote participants set up the mobile drawing application on three tablets (one LG V400 and two Samsung Galaxy Tab S2s), the moderator was familiarized with the marker tools and was debriefed about his role as moderator of the discussion. A voice-chat session was opened in the background of all systems to enable remote voice conversation.

The moderator randomly picked a theme for the brainstorming from a list of the following design concepts: a toy for 2-year-old children, a time-managing tool for older people and a robot for the home. The selected theme was the toy for children. The remote discussion then started and the moderator and participants freely talked and created sketches for approximately 30 minutes. The workshop concluded with a 10-minute face-to-face team interview in which we asked participants to elaborate on their experience using the *All4One* tool and to compare it with other tools they have used in the past. The workshop took about 1 hour and 30 minutes, and participants were compensated with 15 USD in local currency for their time.

Results

During the brainstorming session, the team generated three complete ideas for a toy (a car, a bear, and a crib mobile). Figure 6 is some example images from the workshop and illustrates how the moderator used the system. We could observe several usage patterns. For example, the moderator used *All4One* to (a) collect diverse ideas, (b) combine them in singles sketches, and (c, d) superimpose ideas from different participants. Communication with remote participants mainly happened using the voice chat, but remote participants used hand-written text as well. The moderator also used gestures (e.g., physically pointing at drawings) that were visible through the live-video stream in order to instruct participants or ask for clarifications. At the beginning of the drawing session, the moderator asked the tablet users to draw lines on the screen so that he could disambiguate participants and associate them with the corresponding *MarkerTool*.

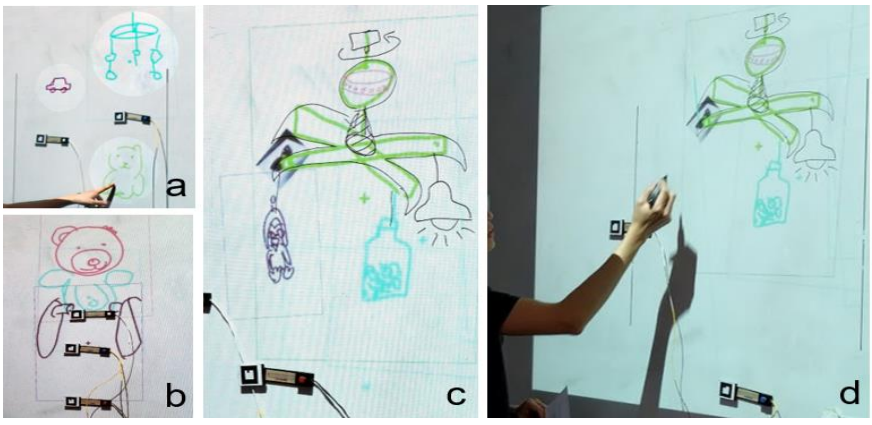

Figure 6: Possible usage of the system: collecting ideas (a); combining (b) and superimposing (c) sketches to form single images; annotating with a pen over digital sketches (d).

Encouraged by the moderator, each participant freely produced sketches for ideas under the same theme. Interestingly, the moderator also asked participants to redraw specific parts and assigned implicit roles to the participants. For example, when making a toy bear, the moderator suggested sketching the head, the body, and the legs separately among participants, before combining the individual images together. Another interesting behavior emerged from the remote participants. Some participants, instead of drawing directly on the tablet, preferred to sketch ideas on paper, and then took a picture of the resulting images with the tablet camera. Then, using the sketching application, they shared these images with the moderator, who seamlessly integrated them with the other participants' sketches. Some users also sent pictures of existing products as reference drawings, on top of which other participants were encouraged to elaborate. To summarize, we could identify four different ways in which the moderator used the *MarkerTools* (Figure 5): sketches were (a) collected in groups for quick comparison, (b) combined next to each other to compose large images, or (c) superimposed on each other to add details to existing sketches. Finally, we note that the moderator used a marker pen to draw over sketches or carbon copy reference images (d).

Overall, all participants reported having enjoyed using the *All4One* system and shared positive comments in the follow-up interviews. However, they also pointed out limitations and gave practical suggestions for how to improve the system. For example, they mentioned that the drawing application for the tablet does not provide enough control for expressive drawing: different brushes, color palettes, erasers, and ways to control the image resolution should be added to the drawing application designed for the tablets.

Discussion and opportunities for design

Generating diverse visual ideas and elaborating on them by combining and modifying sketches is the key to a successful brainstorming session (Kelly et al., 2001). While researchers in the past built systems that facilitate this process, supporting users with similar roles while using different digital sketching tools (e.g., Ishii & Kobayashi, 1992; Lee et al., 2014; Tang & Minneman, 1991; Zhao et al., 2014), this work focuses instead on how to support the role of the moderator of the brainstorming session. In fact, past researchers (Chan et al., 2016; Oxley et al., 1996) have demonstrated that the active role of expert moderators can strongly influence the quality and creativity of a brainstorming session. To support the role of the moderator we built a system that allows individual contributions in the form of sketches, and a set of tangible tools that only the moderator can use in order to selectively visualize, modify, and combine the participants' sketches. We conducted a simulated brainstorming session for product design in the form of a workshop and extracted two main findings.

During the workshop, the moderator was highly engaged in the creative process. Instead of assuming merely the role of an impartial supervisor who rarely contributes directly to the idea-generation, we observed the moderator taking the initiative and assuming the role of a leader, driving the conversation on specific topics, directing the remote users, suggesting timely

examples as in (Siangliulue et al., 2015), and even assigning them specific tasks. Although this finding is not surprising, since our physical setup was meant to give to the moderator a privileged position over the remote participants, it is interesting to see how in practice the moderator helped the team remain focused on the creative task. In some ways, the resulting brainstorming session resembled more a *brainsketching* session (Van Der Lugt, 2002) in which participants made incremental connections with earlier sketches "by more actively engaging in a constructive group reflection on the ideas generated". This result opens the opportunity for future longitudinal investigations in order to understand whether the creative quality and variety of the ideas generated with the proposed setup are superior to that of offline brainstorming or brainsketching sessions, and for which stage of the idea development *All4One* is more suitable (e.g., initial idea, refinement, polishing, etc.).

The second finding stems from the observation of how the system was used in practice by both the moderator and the remote participants. The moderator quickly became familiar with the tangible *MarkerTools* and, as a result, we could observe an increased engagement with the content and higher dexterity in the way he/she manipulated the physical tools mapped to the participants' sketches. While at first most of the input was single-handed and involved a single *MarkerTool* (hence, one sketch), the moderator easily shifted toward a bimanual interaction involving the simultaneous use of a pen and multiple tools (multi-sketch interaction). We believe that this increased dexterity is, as was observed before (Hinckley et al., 2014), a byproduct of the physical properties of the tangible tools used. The tangible tools were perceived as an intuitive way to manipulate sketches and fostered the moderator's ability to be creative when modifying and combining input from multiple users. The remote participants were also actively involved in the creative process. We could record several examples of non-verbal expressions between participants and the moderator, using both gestures and images streamed to the whiteboard.

Limitations, future work, and conclusions

Although most participants of the workshop were overall pleased by the experience with the *All4One* system, they also indicated limitations and future areas for improvement. Specifically, the limitations that were mentioned concerned the management of the working history during the idea-generation process, the expressiveness of the drawing tools, and the need for automatically identifying users and associating them with the content they produce.

The users said they would like more control over the revision history of the overall idea-generation process. Right now, our system implements a simple snapshot-saving functionality for generated sketches, but it is necessary to have diverse mechanisms for recording and importing images. Similar to previous work (Zhao et al., 2014), users with the system, should be able to record the diverse flow of thinking, share recordings, navigate through the history of changes, and finally arrange the sketches that are used for the result. Users also requested better tools for drawing on the tablets. Clearly, for the future it is important to improve the fidelity of the images by adding different types of brushes, color palettes, and other drawing tools, so as to assist users

with different drawing skills. Some users also demanded the ability to select an option for switching between synchronous and asynchronous collaboration modality.

Finally, during the workshop we observed the moderator asking each remote participant to identify herself/himself by drawing different shapes on their tablets at the beginning of the brainstorming session. We therefore think it would be necessary in the future to provide a mechanism to automatically identify users and to keep such identification available to the moderator during the entire duration of the brainstorming. We envision that we could use a tablet's front camera for capturing a remote user's face and that we could project it as a thumbnail image next to the corresponding drawing. We think that this simple improvement will help the remote communication and might be used to leverage non-verbal communication among users.

In conclusion, in this work we presented *All4One*, a networked system with tangible tools that allow remote users to participate in a moderated idea-generation session by sketching on tablets. Their ideas are projected in real-time on a whiteboard and directly manipulated (modified, re-arranged, annotated) by a moderator using physical tools. We organized a workshop as a simulated brainstorming session and were able to observe the usage of the system in practice, and identify interesting tendencies. Finally, we highlighted further possible research directions.

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