CloudBits: Supporting Conversations Through Augmented Zero-query Search Visualization

Florian Müller
mueller@tk.tu-darmstadt.de
TU Darmstadt, Germany

Sebastian Günther
guenther@tk.tu-darmstadt.de
TU Darmstadt, Germany

Azita Hosseini Nejad
nejad@tk.tu-darmstadt.de
TU Darmstadt, Germany

Niloofar Dezfuli
dezfuli@tk.tu-darmstadt.de
TU Darmstadt, Germany

Mohammadreza Khalilbeigi
khalilbeigi@tk.tu-darmstadt.de
TU Darmstadt, Germany

Max Mühlhäuser
max@informatik.tu-darmstadt.de
TU Darmstadt, Germany

Figure 1: CloudBits provides users with additional information based on the topics of their conversation, proactively retrieved through zero-query search. The information is visualized as augmented information bits falling from the *cloud*.

ABSTRACT

The retrieval of additional information from public (e.g., map data) or private (e.g., e-mail) information sources using personal smart devices is a common habit in today's co-located conversations. This behavior of users imposes challenges in two main areas: 1) cognitive focus switching and 2) information sharing.

In this paper, we explore a novel approach for conversation support through augmented information bits, allowing users to see and access information right in front of their eyes. To that end, we investigate the requirements for the design of a user interface to support conversations through proactive information retrieval in an exploratory study. Based on the results, we 2) present CloudBits: A set of visualization and interaction techniques to provide mutual awareness and enhance coupling in conversations through augmented zero-query search visualization along with its prototype implementation. Finally, we 3) report the findings of a qualitative evaluation and conclude with guidelines for the design of user interfaces for conversation support.

SUI '17, October 16–17, 2017, Brighton, United Kingdom

ACM ISBN 978-1-4503-5486-8/17/10…$15.00
https://doi.org/10.1145/3131277.3132173

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *Collaborative interaction*;

KEYWORDS

Human Factors; Design; HMD

ACM Reference format:
Florian Müller, Sebastian Günther, Azita Hosseini Nejad, Niloofar Dezfuli, Mohammadreza Khalilbeigi, and Max Mühlhäuser. 2017. CloudBits: Supporting Conversations Through Augmented Zero-query Search Visualization. In *Proceedings of SUI '17, Brighton, United Kingdom, October 16–17, 2017,* 9 pages.
https://doi.org/10.1145/3131277.3132173

1 INTRODUCTION

The retrieval of supplementary information using personal devices such as smartphones is a common habit in today's co-located conversations. However, the interaction with the smart device requires the user to shift the (visual) attention to the device and, thus, away from the conversation. This cognitive focus switching between conversation and smart device can hamper the flow of the conversation: Users can lose the connection to the conversation [24] or even favor the interaction with the smart device over the actual conversation; a phenomenon known as *phubbing* [5]. This can decrease mutual awareness of user's activities and result in losing coupling. Furthermore, sharing retrieved information with other participants of the conversation can be cumbersome: Users need to connect their device to a public display or pass round the device which imposes privacy issues [12].

Prior work proposed ambient voice search [25] as a first step towards supporting conversation scenarios through proactive information retrieval. Such systems automatically retrieve additional relevant information through voice recognition and topic extraction and present it on a shared (large-scale) public display to all users. This can help to diminish the need for individual information retrieval and, thus, help to mitigate the challenges as set out above. However, interaction with the presented information is limited to touch-based interaction on the public display itself. Furthermore, such a system cannot provide individual per-user output and, therefore, support private information.

We believe that the success of systems for conversation support through zero-query search greatly depends on the appropriate visualization and interaction techniques. In contrast to prior systems that represent supporting information on screens (including mobile phones and public displays), we argue that the representation of information in the periphery has a great potential to unobtrusively support conversation scenarios. Given recent advances in head-mounted displays (HMDs) and augmented reality, in this paper, we explore a novel approach to visualize and interact with related public and private information in the user's periphery to support conversations. Our system, called CloudBits, leverages the metaphor of *cloud* and *drops*, where retrieved information bits gracefully fall from the cloud above the users, visualizing the flow of the conversation (cf. Fig. 1).

In this paper, we 1) contribute the results of an exploratory study investigating the requirements for the design of a user interface to support conversations through proactive information retrieval. Based on the results of the study, we 2) present CloudBits: A set of visualization and interaction techniques to provide mutual awareness and enhance coupling in conversations through augmented zero-query search visualization along with its prototype implementation. Finally, we 3) report the findings of a qualitative evaluation of CloudBits compared to information retrieval on smartphones as a well-established practice and conclude with guidelines for the design of user interfaces for conversation support.

2 RELATED WORK

The problems emerging from information retrieval in conversation scenarios, as well as several approaches to overcome these problems, have been studied in the body of related work. In the following, we discuss these works with regards to the scope of our work.

2.1 Information Retrieval in Conversations

Many studies investigated on the influence of information retrieval using mobile devices on the quality of conversations. Su et al. [30] found that smartphones help to enhance conversations through additional information but can also cause disruptions to the ad-hoc and informal nature of conversations. Such devices "force people to isolate themselves rather than engage in their immediate surroundings". Continuing on this, Porcheron et al. [23] found that, while additional information retrieval may help to solve open discussions, the process of information retrieval also causes people to get distracted from the actual conversation. After the transient focus on the mobile device, people also showed problems to re-engage with the discussion. Brown et al. [3] found that information retrieval can be a vivid part of a conversation and "rather than search being solely about getting correct information, conversations around search may be just as important."

The perseverative interaction with mobile devices can lead to encapsulation in a mobile bubble, a phenomenon defined as *phubbing* [5]. Focusing on the influence on the quality of conversations, Przybylski et al. [24] found that the interaction with mobile devices reduces closeness and trust as well as interpersonal understanding and empathy between the participants. Regarding family meal situations, Moser et al. [20] found that "attitudes about mobile phone use at meals differ depending on the particular phone activity and on who at the meal is engaged in that activity, children versus adults." Continuing on this, Hiniker et al. [11] found that especially children find "rules that constrain technology use in certain contexts (e.g., no phone at the dinner table)" hard to live up to.

Regarding meeting scenarios, Böhmer et al. [2] found that phone usage interferes with and decreases productivity and collaboration. Individuals have the feeling that they make productive use of their smart devices but perceive the usage of others as unrelated.

2.2 Approaches for Conversation Support Systems

Various approaches have been presented to overcome the presented problems and to support information retrieval in conversations.

Lundgren et al. [17] proposed to use a tablet as a public display to provide awareness for the activity of persons working on their smartphones. Ferdous et al. [10] proposed to use personal devices as a combined shared display to support interactions and conversations at the family dinner table. To support conversations between strangers, Nguyen et al. [21] proposed to display potential conversation topics of mutual interest through HMDs.

Further approaches focus on managing the time users focus on their mobile device. Lopes-Tovar et al. [16] propose to assess the importance of notifications and whether the user needs to be interrupted. As another approach, Eddie et al. [9] present a solution that proactively interrupts users to discourage excessive mobile phone usage during conversations.

2.3 Zero-Query Search

To reduce the time needed to retrieve data, zero-query search has been proposed as a proactive mean to retrieve necessary information [26]. Such systems use contextual cues such as location, time or usage history to retrieve and proactively present information to the user. In recent years, zero-query search based systems such as Google Now or Microsoft Cortana were broadly implemented in consumer devices. This was accompanied by a stream of research focusing on how contextual cues can be used to derive search queries and when they should be presented to the user [28, 32].

Building on the concept of zero-query search, ambient voice search [25] supports users in a conversation scenario by providing relevant information to all participants of the conversation on a public display. This allows users to interact with the information through direct (touch) interaction on the display. Focusing on collaborative idea generation, Andolina et al. [1] presented a similar system to support users through displaying related keywords based on the topics of their conversation.

2.4 HMD Interfaces in Social Interaction

Head-mounted displays are a promising technology for immediate and direct interaction with information; interweaving augmented digital information with the physical reality. Despite all benefits, research showed that the use of such interfaces introduces problems in social interactions: The form factor of HMDs, as well as the private experience of the presented interfaces, can have a negative impact on attentiveness, concentration, and eye-contact, and, thus, lead to less natural conversations [8, 19].

While we believe that some of the problems will be solved through technological advances (e.g., better eye contact through less bulky devices), other problems are inherently connected to the use of HMDs. However, Koelle et al. [13] showed that, among others, the usage for specific tasks and the offering of awareness to "communicate the intention of use" help to build interfaces that overcome the presented drawbacks.

3 EXPLORATORY STUDY

We conducted an exploratory study to gain insights into the design of a user interface to support conversations. More specifically, we investigated the following research questions:

(1) How can a system effectively support information retrieval in co-located conversations?
(2) What are the requirements for the user interface of such a system?

We invited 7 participants (4 male, 3 female, 30 years in average) for individual semi-structured interview sessions. No compensation was provided.

3.1 Design and Procedure

We defined five different conversation scenarios (S1-S5) as starting points for the brainstorming sessions. Based on [7, 22], the five scenarios were designed to include a wide variety of circumstances of conversations in terms of (1) location, (2) objectives and (3) mood of the participants as well as (4) different relationships.

S1: Consultation A conversation between persons with different levels of information and understanding of a problem space, e.g., a medical consultation.

S2: Meeting A conversation between peers with the same level of information, e.g., a meeting between coworkers.

S3: Authority Gradient A conversation between persons with different levels of information and an authority gradient, e.g., an instructor teaching a trainee.

S4: Informal Talk A conversation between peers in an informal setting, e.g., friends at a bar.

S5: Different Intentions A conversation between persons with different intentions, e.g., a sales meeting with an estate agent.

Memorizing the positive and negative extremes of experiences is often more viable compared to usual incidents[27]. Therefore, we asked participants about their positive and negative memories on information retrieval in the respective scenarios, focusing on problems with the current systems. If participants did not have specific experiences in the respective scenario, we skipped this scenario. The study lasted around 2 hours per single-user session. For data gathering, we recorded the sessions.

3.2 Results

We analyzed the recorded sessions using an open coding approach and selected salient quotes for further analysis. In the following, we present the results of our study with respect to our research questions.

In general, all participants stated that they currently use mobile information retrieval in conversation scenarios. When asked about the kind of retrieved information, we found that participants primarily looked up unknown terms or abbreviations, factual information from public sources and personal information such as appointments or e-mails. From the participants comments, we identified three main requirements for the design of an user interface to support information retrieval in conversations.

R1: Unsolicited and Real-Time Service In the study, participants stated that the shame of nescience is one of the major reasons for information retrieval using personal devices in all of the discussed situations. This includes not only formal situations but also informal talk with friends. P4 said: "If I think that it's too easy or I don't listen to something, I won't ask anybody because it's embarrassing", P7 added: "I don't ask other people because of shyness". As another reason, we found that participants remembered multiple situations in which fast and immediate retrieval of relevant information was necessary for the continuation of the conversation. Participants stated that breaks during the conversation, caused by the necessity for information retrieval, were "really upsetting" (P4). Additionally, the interviews showed that information should stay available for immediate re-retrieval as the same information might be needed again within short time frames.

To support the presented situations, a system should provide direct and unsolicited service to all participants without the need to explicitly ask for information. The information should be available in a real-time (i.e., available at the right moment) and time-varying (i.e., available as long as needed) fashion.

R2: Supporting Fluid Transition and Re-Engagement We found that participants have the feeling that they spend a significant amount of time for information retrieval in conversations which "leads to missing other parts" (P2) of the conversation. This even led participants to refrain from searching (P2, P5) in multiple situations. Participants felt that the time spent on the mobile device caused them to "lose connection" (P3) to the actual conversation because their focus shifted towards the interaction with the device and the retrieved information. Participants named other instances (such as having to leave to room) that caused them to loose the connection to the topics of the conversation and, thus, forced an immediate re-engagement process after returning to the conversation.

Therefore, a system should provide means for a fast and easy transition between information retrieval and the actual conversation to prevent users from losing the connection. In case of inevitable disruptions, the system should support the user in the re-engagement process.

R3: Selective Sharing from the Public-Private Information Spectrum In the analysis, we found sharing of the retrieved information with other participants of the conversation to be cumbersome. The retrieved information is only available on the personal device of the retrieving user and, thus, shared through sharing the complete device by handing the mobile phone to someone. Participants felt "uncomfortable" (P3) doing this, not only in formal but also in more intimate situations. Besides privacy issues, participants recalled multiple situations (particular regarding S1 and S5) where this turned out to be frustrating for users because of the limited screen space.
Thus, a system should support 1) selective sharing of specific contents and 2) collaborative interaction with information in a large shared information space.

4 CLOUDBITS: CONCEPTS AND PROTOTYPE

Based on the findings from the exploratory study and the related work, we designed the CloudBits concepts and prototype implementation.

4.1 Augmented Zero-Query Information Bits for Unsolicited and Real-Time Service

We designed CloudBits as an augmented reality system for HMDs that supports users through small bits of information. To fulfill requirement R1, these information bits appear in real-time and time-varying to support the current context of the conversation and are visualized as drops, depicting a preview image, falling from the metaphorical *cloud* above the users (cf. Fig. 2 b). Information bits exist in a shared information space, i.e., position and movement of information bits is synchronized between the users. Thus, the information bits appear on the same real-world coordinates but rotated towards each user, allowing users to naturally refer to their positions (*Look, there!*, cf. Fig. 2 a). If interested, users can interact with the information bits or just let them drop slowly to the ground. Once an information bit hits the ground and, thus, it's lifespan is over, it disappear without further interaction from the user.

To that end, CloudBits unobtrusively transcribes conversations in the background through several microphones and a voice recognition system. Based on the transcribed text, the ambient voice search engine deduces topics of the conversation. CloudBits uses those topics as zero-query search terms to proactively retrieve information for the users from public (e.g., map data, websites) and private (e.g., e-mail, calendar) information sources. The individual spawn position of the information bits is calculated to be in the peripheral vision of the users in order to lessen the visual clutter and the imposed distraction [14].

4.2 Supporting Fluid Transition between Focus and Context

To support the fluid transition between the conversation and the process of information retrieval as is R3, we propose CloudBits as a focus+context [4] approach for interaction with information in a conversation setting.

While the conversation is the *focus* of the user, CloudBits provides *context* through small information bits visualizing the course of the conversation. Vice versa, when interacting with information, CloudBits becomes the *focus* of the user. In contrast to information retrieval using a mobile device, the augmented reality nature of CloudBits still allows visual participation in a conversation as *context* as the other persons of the conversation are still in the peripheral vision. The tight integration and synchronization of CloudBits with the conversation allows for a fast and easy transition of the focus between the actual conversation and the information retrieval.

The presented focus+context nature of CloudBits supports users in re-engaging with the content of the conversation through the always available context of the conversation. Furthermore, the important information bits are pinned in the information space and always accessible just through small looks.

4.3 Immediate Interaction with Information

We developed a set of interaction techniques that allow for easy and immediate interaction with the information. All interactions are shared between the users, i.e., if one user changes the position of an information bit or shows it's content, this is visualized for all users. This provides mutual awareness as users can understand (1) other user's interactions with the system and (2) the context of their interactions as they can also see the information they are interacting with.

We opted to use mid-air gestures for interacting with the system as such interfaces allow to avoid retrieving and focusing on secondary devices and provide natural and direct interaction with the content [31].

Grab & Move Users can grab (cf. Fig. 2, b) information bits and drag them from the stream of falling bits. Bits can be freely moved around in the real world.

Grab & Pin Interesting information bits can be kept for future access through pinning them to a real world position. Pinning is initiated by moving an information bit to the desired position and releasing the Grab & Move gesture. Users can unpin an information bit through tapping.

Grab & Throw When no longer needed, users can discard information bits by grabbing and throwing them away.

Grab & Show To access the content of an information bit, users can unfold it through dragging the information bit into the center of their vision and opening the hand with the palm facing upwards (cf. Fig. 2 b,c). Similar to the individual bits, the expanded information is presented at the same world coordinate but individually rotated towards each user. To close information bits, user's can perform the reversed gesture.

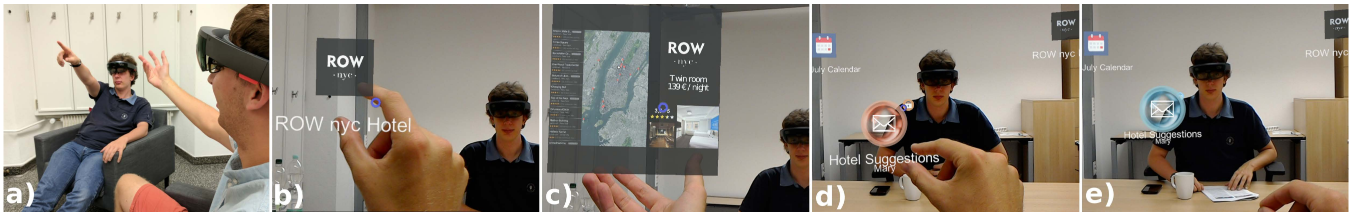

Figure 2: The interaction techniques of CloudBits: Users can (b) grab&move information bits freely in the space. To access information, users can grab an information bit and (c) open the hand with the palm facing upwards. Private information bits can (d,e) be shared with other users through grabbing and moving them towards another user. The color encodes if they are public or private.

4.4 Selective Information Sharing from the Public-Private Information Spectrum

To fulfill requirement R3 and to overcome the privacy issues of information sharing on personal smart devices [12] and in traditional ambient voice search systems, CloudBits supports private information that is only visualized for the respective user. Users can distinguish private and public information through a color coding (private orange, public blue, cf. Fig 2 d,e). Private information bits provide the same interaction techniques as outlined in the last section. Additionally, private information can be selectively shared with other users by grabbing the information bit and moving it towards another user, resembling the natural gesture of handing an object to another person.

4.5 Prototype Implementation

We built the CloudBits prototype upon the implementation of an ambient voice search engine presented in [25]. Our system implementation is based on two main components: (1) a centralized server and (2) a client visualization application for the HMDs.

The centralized server receives the topics from the ambient voice search engine. The server then orchestrates the spawn positions of information bits in world coordinates and distributes those to the client applications.

We implemented the client application for the Microsoft HoloLens using Unity3D. All interactions from users are synchronized with the centralized server in real-time (delay <0.2s, 20 fps) and, in the case of public information bits, broadcasted to the other connected clients.

5 EVALUATION

We conducted a controlled laboratory experiment to investigate how CloudBits supports co-located conversation scenarios. In particular, we focused on if and how

(1) people leverage the surrounding space for acquiring and interacting with information,
(2) CloudBits provides mutual awareness of activities and eases the (re)-engagement into the conversation and
(3) CloudBits enables selective sharing from the private-public information spectrum.

For this, we recruited 12 participants (P1-P12: seven female, aged between 25 and 35 years) in six groups of two persons each. The two person pairs knew each other before in order to simulate conversation and collaboration in real-life situations. We choose participant pairs with different relationships: work colleagues, close friends and spouses. None of them had prior experience with augmented reality glasses. We chose a within-subject design. No compensation was provided.

5.1 Design and Task

Inspired by the study design of [15], the overarching goal for the participants in the study was to collaboratively plan a vacation trip. We designed the scenario to require participants to search, explore, and share both private and public information with their partners.

We tested CloudBits and information retrieval via smartphones as two conditions. In both conditions, we gave the participants the destination name, the available budget and a list of tasks. We provided the participants with all tasks upfront and they where free to choose the order of processing. We asked the participants to note down their decisions on a provided paper. The four tasks were:

Task 1 required participants to agree on the departure date and length of the trip by reviewing their personal calendars and finding possible time slots.

Task 2 required participants to agree on a flight for their trip based on the selected dates and the price. Therefore, participants had to check the offers they personally received from their travel agencies via email.

Task 3 required participants to select a hotel based on their budget, the location of the hotel and online reviews. Furthermore, both participants received personal e-mails with suggestions from friends who traveled to the destination before.

Task 4 required participants to select a restaurant for the first evening based on location, reviews and the type of food they serve.

To understand if and how CloudBits supports (re)-engagement in the conversation, we imposed interruptions in both condition to interrupt the discussions and distract the participants from their current tasks. We realized the interruptions through faked technical problems. After five minutes, we pretended to have fixed the problems and asked participants to continue from where they left off.

Figure 3: The setting of the study. Participants were free to choose a spatial arrangement for both, the CloudBits (a) and the smartphone (b) condition.

5.2 Study Setup and Apparatus

We used the prototype application as presented in section 4.5 deployed to two Microsoft HoloLens devices. For the smartphone condition, we used two Google/LG Nexus 5X devices.

We opted for a Wizard-of-Oz [6] styled study to have full control on when and what the participants saw during the study and to eliminate system errors. Therefore, we implemented a wizard application that allowed us to prepare information bits upfront and to send them on demand to the individual participants.

Similarly, we prepared the smartphones used by the participants during the study with the content (such as e-mails and calendar entries) that they needed to complete the tasks.

We videotaped the sessions with an external camera and, for the CloudBits condition, recorded the individual views of the participants through the HoloLens "Mixed-Reality Capture". This allowed us to record the participants view into the real world together with the augmented information bits. We concluded the study with a semi-structured interview. We analyzed the data from the study using an open coding [29] approach.

5.3 Procedure

We counterbalanced the order of the two conditions by randomly assigning the starting condition to the participant pairs. We further changed the destination and date of the task to avoid learning effects between the conditions.

After welcoming, we introduced the participants to the setup of the study. We gave them 15 minutes to acclimatize to the HoloLens and it's general interaction and visualization techniques.

For the smartphone condition, we handed them the two prepared smartphones and informed them about their task. For the CloudBits condition, we observed the conversation of the two participants and sent them appropriate information bits during the study.

After both conditions, participants took a five-minute break. We concluded the experiment with a semi-structure interview focusing on their overall opinion about the CloudBits concept and the differences between the tested conditions. The experiment took 180 minutes per participant pair.

6 RESULTS

In the following section, we report on the results of the evaluation with respect to the research questions presented above.

6.1 Spatial Arrangement and Use of the 3D Space

The participants highly appreciated the general idea of in-situ conversation support through augmented information bits. Particularly, the possibility for an individual arrangement of information bits, visualized in a shared 3D space, was received enthusiastically. We found that most participants used the complete available (~ 30 square meter) space to sort the information and that they used all available dimensions (top/down, left/right and front/back). Nine participants expressed their satisfaction of using a wide space or even the whole room as an information space. P6 commented: "Comparing to the mobile scenario, where the information space is restricted to a very small screen, CloudBits big scene filled with information is extremely desired."

The human capabilities allow the creation of a cognitive map that contains relative positions and orientations of objects[18]. This so-called spatial memory allowed participants to place, arrange and relocate information bits naturally. P8 compared this to pervasive work practices for knowledge workers on desks: "It is like... I could arrange my documents on desktop and easily memorize where to find them. However, doing that in 3D is much more fun." P10 added: "I can easily categorize the retrieved information in space. Since the arrangement is personally customized, I can immediately remember where is what." The participants used this shared augmented information space to refer to information bits through natural gestures such as pointing and looking (cf. Fig. 3, c). P10 commented on this: "I just accidentally pointed at the information and said *Look there!*. It was amazing that my wife could also see the same information on the same place and understood what I meant."

Participants found that the smartphone condition required constant focus switches between different information sources on the smartphone and between the smartphone and the actual conversation and, thus, constant re-engagement. P3 commented: "When I need to search for information, using the mobile phone required me to constantly switch my focus from one application or piece of information to the other. So I will lose detail of one information when I switch to the next and need to repeatedly do the switching."

In comparison, CloudBits allowed the participants to "see more information at a glance" (P7) while still being able to focus on the actual conversation, supporting the *focus+context* nature CloudBits.

6.2 Working and Storage Zones

Participants used different spatial configurations to sort and categorize information bits. The spatial arrangements were created

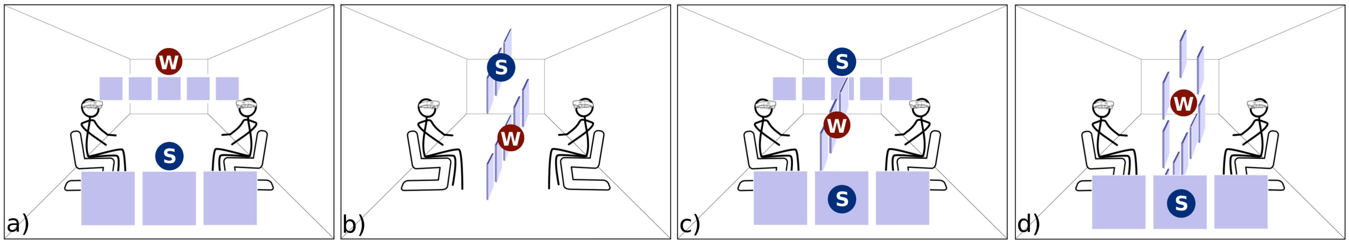

Figure 4: Spatial arrangement of shared information in the study. Participants divided the information bits into working (W) and storage (S) zones based on their current task.

collaboratively in an on-demand manner. While the participant groups created individual categories for categorization, we found that participants across all groups divided information bits into

Working Zones containing the information bits that participants were actively using for their current task.

Storage Zones containing the information bits not used at that time, but that participants kept for later use.

While the spatial layout of these zones differed over all participant groups (cf. Fig. 4), the usage of those zones was consistent over all participants.

The participants' tasks required them to make decisions and re-retrieve this information later on. Participants used the storage zones to pin relevant bits for later use while explicitly removing or letting fade out unused information bits. Five participants pointed out that they found CloudBits pin concept "very intuitive" (P2, P6) as ""when I pin my to-do post-it on the kitchen board"" (P2).

In the smartphone condition, participants reacted to the requirement to keep information for later access with different techniques: Participants wrote the information down on paper or created screen shots on the smartphones. P12 commented on the problems: "I need to browse and remember which snapshots are relevan as they look all similar and include a lot of text."

6.3 Awareness

We found that participants followed the actions of their partner through brief glances at their actions. In the following interview, all participants reported that they could gain insights about the current state of the work of their partner. P8 explained that "While using CloudBits, I was really happy that I could see what my partner is looking at and interacting with."

Our observations showed that the missing awareness in the smartphone condition caused a management overhead in the conversation. Participants were forced to give regular updates about their current actions and whether they were ready to continue the conversation with regard to the content. P3 described the problems: "We both wanted to search [...] each using our own mobile devices. [...] when I was still in the search process, she found her desired answer and started speaking about the next step we needed to do. But I was still engaged with the searching process of the last needed information piece and could not get what she was talking about."

6.4 Supporting (Re)-Engagement

During both conditions, we enforced a distraction through faked technical problems in the study setup. After five minutes, we told the participants to continue from where they left off.

From our observations and the participants' comments, we found that CloudBits provided them with means for easy and fast re-engagement. After the break, we observed that participants started the re-engagement process in the CloudBits condition by looking around the room and using the information bits to get back to the conversation. We found that participants used both, 1) the falling information bits (covering the latest topics of the conversation) as well as the pinned information bits in their working zones to re-engage with the conversation. During the interviews, seven participants explicitly appreciated that the necessary information to re-engage was directly available without the need to interact.

In contrast, our observations and comments from the participants clearly showed that the smartphone condition did not provide sufficient support for re-engagement. P4 said that "If I loose my attention to the topic of conversation, I need to concentrate for a while in order to be able to switch back to the topic, using my mobile phone does not help at all and might be even more distracting". P10 added "I usually have lots of open information tabs on my mobile device which needs to be browsed to skim them but I am not able to immediately remember where I have stopped."

6.5 Selective Sharing from the Public-Private Information Spectrum

All participants showed enthusiasm regarding the possibility to access both, public and private information, in a shared workspace at the same time. When asked for the reasons, participants reported that this enabled them to selectively share information without the need to share the complete device. P9 explained: "CloudBits let me share a part of the information which needs to become public [...]. I always have concerns about other persons having access to all my data while sharing information with others through my mobile phone." P10 further added: "I really did not want to share my personal device to my partner, but it was also kind of impolite to ask him to search for the same information himself. This meant I have no trust in you or I do not want to help you."

Participants did not mix public and private information in the same zones (cf. Fig. 5). In particular, participants chose spatial arrangements to keep private information bits far apart from the shared work zones. We observed two basic patterns for the spatial

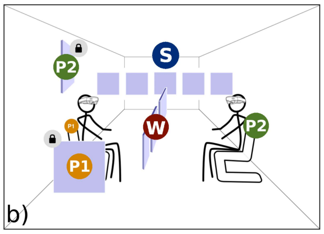

Figure 5: Spatial arrangement of public (W,S) and private (P1, P2) information in the study.

arrangement of private information: Half of the participants positioned private information bits close to themselves (cf. Fig. 5 P1), while the other half of the participants moved them to a unused space preferably far away (cf. Fig. 5 P2).

While we did not impose any restriction on the physical arrangement of the participants in the room, we found that participants chose different arrangements for the conditions to support the process of information sharing. In the CloudBits condition, all participants arranged themselves in a face-to-face setting (cf. Fig. 3 a). The interview revealed that this provided them with a comfortable position for the conversation and shared information access and, further, gave them the necessary space to perform mid-air gestures.

In the smartphone condition, we found two different approaches for the spatial arrangement to support information sharing: Three pairs constantly changed their position between face-to-face for individual work and side-by-side for sharing information through each other's smartphone screen (cf. Fig. 3 b). The other three pairs stayed in a face-to-face arrangement during the whole session and tried to exchange the found information orally.

Comparing both conditions, participants commented that information sharing felt more immediate and efficient in the CloudBits condition. P5 explained: "Similar to the real world, sharing information using CloudBits occurs by just naturally changing the virtual position of the information to where my partner is. This experience reminds me exactly to when I pass a physical object to someone to share it." P8 added that "CloudBits information sharing saves the effort currently is needed [...] to share [...]."

7 GUIDELINES AND LIMITATIONS

We strongly believe that our results help to answer fundamental questions related to the user interface design of conversation support systems. Therefore, we propose the following guidelines for the design of user interfaces for conversation support systems:

Leverage the Surrounding Physical Space for categorization of and interaction with the information.

Provide Means for Fluid Transition and Re-Engagement to support mutual awareness of activities and to ease the transition between information retrieval and the conversation.

Support Selective Sharing from the Public-Private Information Spectrum for privacy-preserving sharing of private information without the need to share the complete device.

Our current implementation and the results of our evaluation also impose some limitations and directions for further research:

Scope of the Study Due to the Wizard-Of-Oz style of the study, we had to closely confine the scope of the study in terms of scenario and relationship. Thus, a larger scale study in the wild could provide further insights into the problem domain.

Multi User Support The presented concepts focus on 1-on-1 collaboration scenarios. In the future, we plan to explore on how those concepts can be transferred to bigger groups.

Interaction in the 3D Space The main focus of the study was on the evaluation of CloudBits. During the study, we found multiple interesting starting points for further research on how people use a shared 3D information space to arrange themselves and information spatially.

8 CONCLUSION

We presented an exploratory user study investigating the problem space of zero-query based conversation support. Based on the findings, we designed CloudBits and it's prototype implementation. We evaluated our concepts in a qualitative lab study and presented guidelines for the design of user interfaces for conversation support.

ACKNOWLEDGMENTS

We thank Tobias Neidig, Maximilian Müller, Daniel Kauth and Alexander Hendrich for their valuable support. We also thank the anonymous reviewers for their helpful comments and suggestions. This work was supported by the German Federal Ministry of Education and Research (BMBF) SWC "NewViz" (01IS12054).

REFERENCES

[1] Salvatore Andolina, Khalil Klouche, Diogo Cabral, Tuukka Ruotsalo, and Giulio Jacucci. 2015. InspirationWall. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition - C&C '15*. ACM Press, New York, New York, USA, 103–106. https://doi.org/10.1145/2757226.2757252

[2] Matthias Böhmer, T. Scott Saponas, and Jaime Teevan. 2013. Smartphone use does not have to be rude. In *Proceedings of the 15th international conference on Human-computer interaction with mobile devices and services - MobileHCI '13*. ACM Press, New York, New York, USA, 342. https://doi.org/10.1145/2493190.2493237

[3] Barry Brown, Moira McGregor, and Donald McMillan. 2015. Searchable Objects. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. ACM Press, New York, New York, USA, 508–517. https://doi.org/10.1145/2675133.2675206

[4] S.K. Stuart K. Card, Jock D. Mackinlay, and Ben. Shneiderman. 1999. *Readings in information visualization: using vision to think*. Morgan Kaufmann Publishers. 686 pages. https://dl.acm.org/citation.cfm?id=300679

[5] M Coehoorn. 2014. *Phubbing? An absurd design intervention for redefining smartphone usage*. Ph.D. Dissertation. University of Technology, Delft. http://resolver.tudelft.nl/uuid:db9aa584-4167-48e7-be33-ec464301294e

[6] N Dahlbäck, A Jönsson, and L Ahrenberg. 1993. Wizard of Oz studies—why and how. *Knowledge-based systems* (1993). https://doi.org/10.1016/0950-7051(93)90017-N

[7] Hugh Dubberly and Paul Pangaro. 2009. What is conversation, and how can we design for it? *interactions* 16, 4 (jul 2009), 22. https://doi.org/10.1145/1551986.1551991

[8] BL Due. 2015. The social construction of a Glasshole: Google Glass and multiactivity in social interaction. *PsychNology Journal* 13, 2-3 (2015), 149—-178. http://www.psychnology.org/File/PNJ13(2-3)/PSYCHNOLOGY

[9] Thomas Eddie, Juan Ye, and Graeme Stevenson. 2015. Are our mobile phones driving us apart? Divert attention from mobile phones back to physical conversation!. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - MobileHCI '15*. ACM Press, New York, New York, USA, 1082–1087. https://doi.org/10.1145/2786567.2794331

[10] Hasan Shahid Ferdous, Bernd Ploderer, Hilary Davis, Frank Vetere, Kenton O'Hara, Geremy Farr-Wharton, and Rob Comber. 2016. TableTalk. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '16*. ACM Press, New York, New York, USA, 132–143. https://doi.org/10.1145/2971648.2971715

[11] Alexis Hiniker, Sarita Y. Schoenebeck, and Julie A Kientz. 2016. Not at the Dinner Table: Parents- and Children-s Perspectives on Family Technology Rules.

In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16*. ACM Press, New York, New York, USA, 1374–1387. https://doi.org/10.1145/2818048.2819940
[12] Amy K. Karlson, A.J. Bernheim Brush, and Stuart Schechter. 2009. Can i borrow your phone?. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*. ACM Press, New York, New York, USA, 1647. https://doi.org/10.1145/1518701.1518953
[13] Marion Koelle and Matthias Kranz. 2015. The mind behind the glass. In *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia - MUM '15*. ACM Press, New York, New York, USA, 445–449. https://doi.org/10.1145/2836041.2841225
[14] E Kruijff, JE Swan, and S Feiner. 2010. Perceptual issues in augmented reality revisited. *Mixed and Augmented Reality* (2010). https://doi.org/10.1109/ISMAR.2010.5643530
[15] Roman Lissermann, Jochen Huber, Martin Schmitz, Jürgen Steimle, and Max Mühlhäuser. 2014. Permulin. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*. ACM Press, New York, New York, USA, 3191–3200. https://doi.org/10.1145/2556288.2557405
[16] Hugo Lopez-Tovar, Andreas Charalambous, and John Dowell. 2015. Managing Smartphone Interruptions through Adaptive Modes and Modulation of Notifications. In *Proceedings of the 20th International Conference on Intelligent User Interfaces - IUI '15*. ACM Press, New York, New York, USA, 296–299. https://doi.org/10.1145/2678025.2701390
[17] Sus Lundgren and Olof Torgersson. 2013. Bursting the Bubble. In *First International Workshop on Designing Mobile Face-to-Face Group Interactions, European Conference on Computer Supported Cooperative Work, ECSCW*. Malin Carlgren. http://www.cse.chalmers.se/research/group/idc/ituniv/courses/13/mc/lundgren-mogi2013.pdf
[18] Joseph R Manns and Howard Eichenbaum. 2009. A cognitive map for object memory in the hippocampus. *Learning & memory (Cold Spring Harbor, N.Y.)* 16, 10 (oct 2009), 616–24. https://doi.org/10.1101/lm.1484509
[19] Gerard McAtamney and Caroline Parker. 2006. An examination of the effects of a wearable display on informal face-to-face communication. In *Proceedings of the SIGCHI conference on Human Factors in computing systems - CHI '06*. ACM Press, New York, New York, USA, 45. https://doi.org/10.1145/1124772.1124780
[20] Carol Moser, Sarita Y. Schoenebeck, and Katharina Reinecke. 2016. Technology at the Table. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. ACM Press, New York, New York, USA, 1881–1892. https://doi.org/10.1145/2858036.2858357
[21] Tien T. Nguyen, Duyen T. Nguyen, Shamsi T. Iqbal, and Eyal Ofek. 2015. The Known Stranger. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. ACM Press, New York, New York, USA, 555–564. https://doi.org/10.1145/2702123.2702411
[22] Gordon. Pask. 1976. *Conversation theory : applications in education and epistemology*. Elsevier. 402 pages.
[23] Martin Porcheron, Joel E. Fischer, and Sarah C. Sharples. 2016. Using Mobile Phones in Pub Talk. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16*. ACM Press, New York, New York, USA, 1647–1659. https://doi.org/10.1145/2818048.2820014
[24] A. K. Przybylski and N. Weinstein. 2013. Can you connect with me now? How the presence of mobile communication technology influences face-to-face conversation quality. *Journal of Social and Personal Relationships* 30, 3 (may 2013), 237–246. https://doi.org/10.1177/0265407512453827
[25] Stephan Radeck-Arneth, Chris Biemann, and Dirk Schnelle-Walka. 2014. Towards Ambient Search. In *Proceedings of the 16th LWA Workshops: KDML, IR and FGWM*. http://ceur-ws.org/Vol-1226/paper39.pdf
[26] B. J. Rhodes and P. Maes. 2000. Just-in-time information retrieval agents. *IBM Systems Journal* 39, 3.4 (2000), 685–704. https://doi.org/10.1147/sj.393.0685
[27] Helen. Sharp, Yvonne. Rogers, and Jenny Preece. 2007. *Interaction design : beyond human-computer interaction*. Wiley. 773 pages.
[28] Milad Shokouhi and Qi Guo. 2015. From Queries to Cards. In *Proceedings of the 38th International ACM SIGIR Conference on Research and Development in Information Retrieval - SIGIR '15*. ACM Press, New York, New York, USA, 695–704. https://doi.org/10.1145/2766462.2767705
[29] A Strauss and J Corbin. 2015. *Basics of qualitative research: Procedures and techniques for developing grounded theory* (fourth edi ed.). SAGE Publications.
[30] Norman Makoto Su and Lulu Wang. 2015. From Third to Surveilled Place. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. ACM Press, New York, New York, USA, 1659–1668. https://doi.org/10.1145/2702123.2702574
[31] Julie Wagner, Mathieu Nancel, Sean G. Gustafson, Stephane Huot, and Wendy E. Mackay. 2013. Body-centric design space for multi-surface interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13* (apr 2013), 1299. https://doi.org/10.1145/2470654.2466170
[32] Liu Yang, Qi Guo, Yang Song, Sha Meng, Milad Shokouhi, and Kieran Mcdonald. 2016. Modeling User Interests for Zero-query Ranking. In *Proceedings of the 38th European Conference on Information Retrieval Research 2016. ECIR 2016*. Springer International Publishing, 171–184. https://doi.org/10.1007/978-3-319-30671-1_13