I've Got the Data in My Pocket! Exploring Interaction Techniques with Everyday Objects for Cross-Device Data Transfer

Conference Paper · September 2024

DOI: 10.1145/3670653.3670778

Martina Emmert
Universität Regensburg

Nicole Schönwerth
Universität Regensburg

Andreas Schmid
Universität Regensburg

I’ve Got the Data in My Pocket! – Exploring Interaction Techniques with Everyday Objects for Cross-Device Data Transfer

Martina Emmert*
University of Regensburg
Regensburg, Germany
martina.emmert@student.ur.de

Nicole Schönwerth*
University of Regensburg
Regensburg, Germany
nicole.schoenwerth@student.ur.de

Andreas Schmid
University of Regensburg
Regensburg, Germany
andreas.schmid@ur.de

Christian Wolff
University of Regensburg
Regensburg, Germany
christian.wolff@ur.de

Raphael Wimmer
University of Regensburg
Regensburg, Germany
raphael.wimmer@ur.de

Figure 1: When users interact with everyday objects for cross-device data transfer, different objects afford different interaction techniques. We found that users tend to insert keys and pens into devices, use gestures indicating wireless transfer with phones and watches, and place flat objects, such as cards and tissues, on a device. Thus, the objects’ form factors and implied technical capabilities convey clear affordances which should be considered when designing interaction techniques involving such objects.

ABSTRACT

People interact with a multitude of personal digital devices every day. However, transferring data between devices is still surprisingly cumbersome due to technical barriers, such as authentication or device pairing. Due to their clear affordances, physical devices offer a promising design space as mediators for natural interaction techniques. In a workshop and an elicitation study ($n = 30$), we investigated different interaction techniques for cross-device data transfer using everyday objects. Our results suggest that depending on the use case, extending always-available physical objects might be more beneficial than developing new artifacts. Designing effective interaction techniques requires consideration of an artifact’s physical characteristics, affordances, and situational surroundings. Participants preferred multi-functional objects which are always at hand, such as their smartphone. However, they opted for more impersonal objects in unfamiliar situations. Interaction techniques associated with objects also influenced users’ actions. We provide an overview of factors influencing intuitive interactions and we derived guidelines for user-centered development of interaction techniques with physical objects as mediators for data transfer.

*Both authors contributed equally.

MuC ’24, September 01–04, 2024, Karlsruhe, Germany

ACM ISBN 979-8-4007-0998-2/24/09
https://doi.org/10.1145/3670653.3670778

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**; *User-centred design.*

KEYWORDS

Interaction Techniques, Tangible User Interface, Data Transfer, Cross-Device Interaction

ACM Reference Format:
Martina Emmert, Nicole Schönwerth, Andreas Schmid, Christian Wolff, and Raphael Wimmer. 2024. I’ve Got the Data in My Pocket! – Exploring Interaction Techniques with Everyday Objects for Cross-Device Data Transfer. In *Proceedings of Mensch und Computer 2024 (MuC ’24), September 01–04, 2024, Karlsruhe, Germany*. ACM, New York, NY, USA, 14 pages. https://doi.org/10.1145/3670653.3670778

1 INTRODUCTION

Managing and transferring data has become an integral part of our daily lives. From sending emails to sharing pictures and videos on social media, we transfer data in various forms across different platforms and devices. However, designing a data transfer infrastructure always goes along with technical restrictions [15, 61]. For example, transferring data mostly requires specific software running on the target and/or source device. Moreover, to initiate or accept data transfer, some kind of input device is needed. For wireless data transfer, a connection between devices has to be established, which often excludes devices that are not Wi-Fi- or Bluetooth-enabled. Instead, physical data transfer usually requires suitable ports for a cable or a storage medium.

Depending on the chosen way of transferring data, the interaction differs. This process requires either to establish a wired/wireless connection between the devices or physically moving a storage medium (e.g. a thumb drive) between source and target device. While wireless data transfer requires little physical setup from the user, it requires a shared network and a multi-step connection process [61, 64, 75]. Furthermore, additional information about the recipient is always a prerequisite, such as an IP address, a device name, or a user ID. When trying to simplify this connection process, other limitations arise. With cloud-based solutions, users need to create accounts and may have privacy concerns [11, 64]. Other tools for data transfer, which claim to be simple and fast, are often limited to a specific ecosystem. For example, Apple's *AirDrop* only works between Apple devices[1], while Google's *Quick Share* only works between Android devices[2]. *INFEX* [61] tries to solve this issue by providing a cross-platform framework for developing applications that cover a multitude of different devices.

Thus, despite the variety of devices, cloud services, and media available, transferring data between devices remains a complex process for many users [5, 11, 13]. While it is rather simple for users to specify their goal ('move this data from here to there'), actually reaching this goal requires several non-intuitive steps. Researchers have explored different approaches to effortlessly transfer data between devices. One such approach – which also dispenses with the need for traditional desktop and handheld computers – is to *physically* move data 'objects' from one device to another.

This is a key concept within the *tangible interaction* paradigm [28, 32] which encompasses natural interaction techniques based on physicalization of data [23, 33]. With a tangible user interface, digital information is controlled and displayed using physical space, surfaces, and objects [32]. When interacting with tangibles, users can build upon their existing knowledge of the physical world and of the characteristics of similar physical artifacts. These characteristics form the affordances of the artifact, i.e., the perceptible ways how it should be manipulated [4, 42, 53–55]. While physical objects have been used for data transfer in both research and practice, little attention has been paid to those objects' affordances [5, 32, 48, 85]. Re-purposing already-existing, everyday objects for cross-device data transfer might offer a both intuitive and always-available user interface.

In this paper, we extend a previous workshop article which presents first findings [17]. In addition to revisiting our approach and methodology, we further analyze and interpret our results to draw generalizable conclusions. In this paper, we first explore current limitations and issues in cross-device data transfer. To this end, we gained insights into the needs and preferences of users regarding data transfer in an initial workshop. In the workshop, we focused on understanding how users transfer data in different situations, which challenges they face in this process, and whether a physical device can support them. Our findings suggest that to enhance data transfer with the help of physical devices, we should extend already existing objects instead of designing custom tangibles. Thus, we aim to benefit from the advantages of physical devices without the need for additional artifacts and without ruling out the possibility of combining them with wireless technology or cloud-based solutions. Therefore, through an elicitation study, we explored which interaction techniques for cross-device data transfer are afforded by the following everyday objects: card, key, pen, phone, tissue, and watch. We also investigated whether intuitively performed interactions are influenced by use case and situation.

We found that preferred interaction techniques are highly dependent on the object used, as well as the situation. Based on our exemplary scenario of using everyday objects in the context of cross-device data transfer, we summarize our findings into design guidelines for interaction techniques for physical devices.

[1]https://support.apple.com/en-ae/HT204144
[2]https://support.google.com/files/answer/10514188?hl=en

2 RELATED WORK

Cross-device data transfer requires three components: a communication channel between devices, a service to find and connect to target devices, and a user interface for selecting data/target and initiating the transfer.

The **communication channel** is typically provided by a wired or wireless network or a point-to-point connection. For low-bandwidth transfers, infrared communication (e.g., IrDA), visible-light communication, or ultrasound may be used instead of radio communication. Desauw et al. [13] give a critical overview of current device-to-device (D2D) communication technologies, Chatzopoulos et al. [7] present empirical details on wireless cross-device connection availability.

Finding suitable target devices may be either done via a directory (e.g., a list of all devices registered to a user) or dynamically. In many cases, only nearby devices shall be found. This can be implemented by either using a range-limited communication channel or by tracking the absolute location of devices.

Short-range transmission systems such as Bluetooth [69, 81], RFID [78] and NFC [72, 73] can be used to find target devices in the immediate environment. Other approaches rely on ultrasonic signals for relative spatial tracking and short-range communication [8, 20, 26]. Li and Kobbelt [41] and Schmitz et al. [68] use smartphone cameras to track devices in close proximity and Dothraki [71] allows for tracking the absolute position of objects using built-in mouse sensors. However, all of these approaches require the devices to be equipped with suitable transmitters and sensors.

External tracking infrastructure allows for also determining the location and closeness of objects which do not have sensors built in. Such infrastructure may be on a building level (e.g., via Wi-Fi access points), on a room level (e.g, via cameras), or on a surface level (e.g., via capacitive touch screens). For example, interactive desks can track the position of devices placed on them and facilitate data transfer between them [1, 37, 62, 67].

Regardless of tracking technology, it is important to create awareness for available devices [45]. Once target devices have been located, a connection has to be established. Users can actively connect devices via QR-Codes [19], NFC, gestures [8], proxies [24], or physically connect to the target using cables, ports, or docks.

As the research presented in this paper pertains to interaction techniques for cross-device data transfer, we focus on interaction in the following. Depending on social, spatial, or temporal factors, as well as the type and number of involved devices, different interaction techniques are employed [5].

2.1 Interaction on the Device

A straightforward approach is to show a traditional GUI or use existing functions of an operating system. For example, the ultrasound-based system by Hazas et al. [26] displays detected devices in a window on a laptop into which files can be placed to be shared with others. Alternatively, existing GUI metaphors can be repurposed. *ScreenshotMatcher* [66] offers a fast and easy way to capture information on a computer screen and forward it to a smartphone by taking a photo with a special app [66]. With *Deep Shot* [6] it is even possible to further interact with the received information as the application state is forwarded from the desktop computer to the mobile device [6]. *Shoot&Copy* [3] makes use of a smartphone camera and a touch UI to paste selected files from a smartphone within the captured region [3]. In many cases, swiping or dragging gestures are used to pair adjacent devices or transfer files between them. Swipe gestures performed on portable devices allow data transfer towards either another portable device [35] or a larger display [9]. Instead of using the hand or a finger to perform a gesture on the device, the user's fingernails may also be used to pick up, store, and place data [82]. Since drag-and-drop is a common interaction technique, there is some work dealing with extending it for cross-device interaction [16, 31, 34, 59, 75–77].

2.2 Gestures with the Device

Data may be transferred between mobile devices by tilting one device towards another [46]. Also, tapping on the target area with a mobile phone recognized via NFC allows for data transfer [72, 73, 78]. Besides these, gestures like throwing [10] or chucking [25] can be used to transfer data to larger public displays. On an interactive tabletop, dragging images [14, 31], as well as touching devices against each other or knocking a device onto the tabletop may be used to initiate data transfer [67]. With *WatchConnect* [30], users can establish a connection between their watch and a display by touching the display with the hand that is wearing the watch. By waving back and forth, the watch sends and receives data [30].

2.3 Gestures around the Device

Cameras above a tabletop can detect gestures such as pointing, flicking, picking something up, or dragging. These can then trigger transfer actions between devices on the desk [1, 62]. A smartphone's camera and accelerometer can also track gestures to transfer data [83]. Touching or pointing at the source and target devices may also be used to trigger data transfer [50, 59].

Other research projects use proximity [22], gestures [8, 30, 62], and gaze [40, 52, 74] to interact with multiple devices. Gaze can also be used in combination with touch or mouse pointers for cross-device data transfer [70, 79]. In proxemic interaction in general, it is important to consider people's social understanding of personal space, provide information about available content as well as a range of possible interactions [45].

2.4 Tangible User Interfaces

Due to legacy bias, introducing new interaction techniques remains a challenge [5]. Therefore, it is essential to ensure that any interaction technique for cross-device data transfer is as intuitive as possible. Manipulating digital data feels more natural if the process is similar to interactions users would also perform with physical objects [23]. To give intangible data a physical presence, additional carrier objects – *tangibles* – can be used to transfer data between devices. *Pick-and-drop* [58] uses a pen to drag-and-drop data from one device to another. Users can select digital items, which they want to transfer, by tapping on them with a pen. Again, by tapping on the target device, the item is pasted. *TDome* [63], a hemispherical input device, allows for triggering data transfer between displays with rotation gestures. Additionally, the dome is extended with a display and camera, which allows various interactions to register and select nearby devices [63]. *MediaBlocks* [80] can record videos or notes on a whiteboard and transfer them via small blocks. By inserting the block into another device, the recorded data is transferred [80]. Similarly, *DroPicks* [29] allows for sharing content by placing a physical artifact in collaborative workspaces [29].

2.5 Summary

Over the past 25 years, a wealth of interaction techniques for cross-device data transfer has been explored. Compared to purely gesture-based interaction techniques, physical objects can have helpful affordances that provide feedback and control. For example, transferring data between devices raises privacy issues. Making that data tangible might reduce fears and usage errors. Further, it could also eliminate the need for a complex setup and authentication process.

However, as the physical form of interactive objects as tangible user interfaces should indicate their function [60], they are typically designed specifically for one particular use case. Existing research has focused on novel technologies and interaction techniques. Little attention has been paid to users' preferences [48] or application scenarios [32]. So even if new systems have been developed and evaluated, some uncertainties regarding users' needs remain. Is it possible to develop a universal tangible that fits any cross-device data transfer task, or do users prefer different physical devices for different situations instead? How do they intuitively interact with physical objects, and which factors impact them by doing so? Moreover, is there another approach to physicalizing data transfer besides traditional tangible user interfaces?

Thus, we should gain a more detailed understanding of users' needs and preferences before developing new devices. Without setting further boundaries, we investigate how a physical component can be integrated into the process of cross-device data transfer. We focus not only on what such a device might look like, but also on whether this differs between use cases and situational surroundings.

3 RESEARCH OBJECTIVES

In this work, we explore which interaction techniques for cross-device data transfer are afforded by different physical artifacts. To this end, we investigate users' needs considering various use cases, guided by the following research questions:

- RQ_1 : "Which artifacts are suitable as physical objects for data transfer?"
- RQ_2 : "How do users intuitively interact with the artifacts?"
- RQ_3 : "Which factors influence interaction and artifact choice?"
- RQ_4 : "Do users like the idea of using physical objects for data transfer?"

To answer those research questions, we proceeded iteratively, with each step building upon findings from the previous iteration. In a workshop, we investigated how people typically transfer data in different situations. Furthermore, we observed how they would design physical objects that could assist them in these situations. As this workshop has shown that users tend to reject adding additional objects to their everyday carry, we then used an online survey to find out which objects users normally have at hand in their everyday lives. We combined those findings in an elicitation study to examine which interaction techniques are used for file transfer depending on the situation and object at hand. Finally, we examined the factors that influence participants' decisions and overall impressions of physical everyday objects as mediators in data transfer. Based on our findings in those studies, we developed general design recommendations for interaction techniques involving physical objects in the context of data transfer.

4 WORKSHOP – USERS' EXPERIENCE IN DATA TRANSFER

To gain general insights into users' requirements concerning cross-device data transfer, as well as problems with current technology, we conducted a workshop following a human-centered design thinking approach [49, 56]. Interactive workshops are an established first step to exploring new design spaces [44]. Our objective for this first step of our research was to gain qualitative insights about:

- **situations** in which users transfer data between devices
- **technologies** used for cross-device data transfer and **problems encountered** when using those technologies
- **ideal interaction techniques** users envision for cross-device data transfer

First, we introduced participants to the workshop's topic and procedure. After giving informed consent and answering demographic questions, we assessed participants' affinity for technology using the *Affinity for Technology Interaction Scale* (ATI scale) [18]. As we assumed that different affinities for technology influence the perception and handling of digital data, we opted for a heterogeneous sample. We then asked participants to work in pairs to share and write down particularly good and particularly bad data transfer experiences. Afterward, in a silent brainstorming, participants wrote down general situations in which they transfer data based on the following pre-defined categories: *at home*, *on the way*, *at work/university*, and *other*. We clustered the resulting scenarios and use cases into categories: transfer *photos*, transfer *confidential data*, transfer *contact details (to strangers)*, and transfer *data in collaborative work* as well as *printing*.

We then asked participants how they would enhance data transfer. Based on the categories found, participants formed groups and designed a cardboard mock-up for an artifact suitable for the particular use case. Finally, each group presented their concept and discussed its benefits and limitations with other participants. Thus, we gained insights into participants' preferences and what arguments speak in favor or against using a physical device to assist in data transfer.

4.1 Participants

We recruited thirteen participants (6 men, 7 women, 0 diverse; aged 19 to 32; $M = 23.5, SD = 3.6$) to participate in our workshop via convenience sampling using our personal contacts, as well as a university mailing list. All but one participant were students in media informatics, law, business administration, and teaching. Participants ranked themselves between 2.55 and 5.66 ($M = 3.93, SD = 1.00, \alpha = 0.94$) on the ATI scale, which indicates a mixed affinity for technology. Media informatics students got a confirmation of attendance for study participation as required in their degree program.

4.2 Results

We digitized the artifacts crafted in the workshop and transcribed audio recordings. By coding and clustering them, we were able to gain first insights into users' requirements for cross-device data transfer, as well as their opinion on using physical objects as mediators.

4.2.1 Experiences with Data Transfer. When looking at particularly good experiences, participants mentioned sharing data via messengers, synchronized clouds, or networks. Others also use wireless connections such as Bluetooth and AirDrop, or even NFC and QR codes. On the other hand, particularly bad experiences involve bad connection between devices or non-paired devices. Further, interfering signals, problems with defective hardware, or compatibility problems were mentioned here.

4.2.2 Situations for Data Transfer. Together with our workshop's participants, we collected typical use cases for data transfer. These differ in terms of people involved: only oneself, other known people, and other unknown people. *At home*, participants exchange data (predominantly photos) with family and friends. Typically, messengers and cloud storage are used in this case. In addition, they often transfer data from one personal device to another. Participants mentioned using home servers, home networks, or external hard drives for transferring large amounts of data. To access data *on the way*, participants sometimes use analog media, such as printed documents. Participants also mentioned collecting data *on the way*, such as information about events, guides, menus, or advertisements. When exchanging contact details, unknown people are involved. *At work or university*, participants share data when collaborating with colleagues or fellow students. In this use case, as well as when lecturers provide material in courses, data is provided via cloud services and other online platforms.

4.2.3 Physical Artifacts for Data Transfer. During the prototyping phase of our workshop, participants crafted five cardboard mock-ups as mediators for data transfer in different situations (Figure 2). Participants built a cube-shaped camera to transfer *photos*. It is also able to send and print images in various sizes. For transferring *confidential data*, participants constructed a card-shaped device with an additional self-destruct button. A similar card-shaped form factor was chosen for transferring *contact details to strangers*. On the device, users can select which contact details to transfer and a corresponding code to scan is displayed. The physical object for transferring *data in collaborative work* was, again, shaped like a card. Collaborators can use this card by placing it on their computer to

Figure 2: In the workshop, participants collected typical use cases for data transfer and created physical objects for these afterward. From left to right: transferring *photos*, transferring *confidential data*, transferring *contact details to strangers*, and transferring *data in collaborative work* as well as *printing*.

authenticate and join a shared workspace. For *printing* participants also chose a card-shaped device, including a preview display for easy usage.

Following the prototyping phase, participants discussed each of the envisioned artifacts. In summary, participants liked the idea of using physical devices for data transfer. Yet, they highlighted the importance of handy dimensions of a physical device for data transfer – it needs to be easy to take with one. Being location-bound was mentioned as a disadvantage due to less flexibility on the one hand. On the other hand, participants assessed this aspect as more secure than without a physical device. In general, participants had fewer privacy concerns when using physical artifacts to transfer data in comparison to known non-physical alternatives. They found it promising to transfer data using their artifact instead of relying on a well-established internet connection or a third-party provider. Also, its physical form gave participants the feeling of deeper involvement during the interaction. Overall, participants preferred multi-functional devices and were not fond of adding an additional, highly specialized device to their everyday carry.

4.2.4 Summary. In the workshop, 13 participants shared their experiences with data transfer. They are used to non-physical ways of data transfer, for example cloud-based solutions or wireless services such as AirDrop. At the same time, however, they remarked negative experiences concerning privacy and compatibility issues, complex pairing processes, or an unstable connection when using these. Thus, in the second part of the workshop, participants appreciated the idea of physical devices in data transfer to overcome these difficulties. They perceived physical interaction as more secure and involving. Nevertheless, they criticized the need for an additional device and aimed for multi-functional everyday objects instead. During the workshop, participants repeatedly highlighted the importance of the device being easy to take along. This could be achieved with a handy form factor, e.g., a credit card shape, or by extending existing objects, so there is no need to carry an additional device. Overall, there was a noticeable positive interest in using physical objects for data transfer.

5 USER STUDY – ELICITING INTERACTION TECHNIQUES

From our workshop, we gained insight into use cases, issues, and possible enhancements of cross-device data transfer. Results suggest the extension of physical objects which are at hand. However, we did not yet know how users would interact with these artifacts and whether the artifacts themselves or the situation influence the performed interaction.

5.1 Study Design

We conducted a task-based user study in which participants intuitively perform data transfer with different artifacts in different situations. We opted for a mix of *elicitation study* [84] and *Wizard of Oz experiment* [36] as this allows us to observe participants' naturally occurring behavior. This type of study is a well-established method for developing novel interaction techniques in HCI, including the field of cross-device interaction [21, 38, 39, 51, 75]. Furthermore, as Morris et al. [51] have found, gestures designed by end-users were understood better by other users than gestures designed by HCI researchers.

In a controlled laboratory environment, participants were asked to imagine particular situations and then interact with different artifacts to transfer data from one device to another. Participants were free to assign any functionality they wanted to the artifact. Accordingly, we did not specify where and how data was stored and how data transmission works – every interaction participants imagined was considered possible. Like in a Wizard of Oz scenario, we animated the data transfer to give participants the feeling that their performed interaction was successful. At the end, we concluded with a post-study interview to gain participants' overall impressions of physical everyday objects in data transfer.

We opted for a within-subjects design, so we could ask participants for advantages and disadvantages of the different objects in each situation and for their favorite overall object.

5.2 Selection of Objects

Findings from the workshop suggest that users prefer using objects they already have at hand instead of carrying additional objects for data transfer. Thus, we chose everyday objects as physical artifacts for the user study. To select objects for our elicitation study, we conducted an online survey. Participants (n = 100; 48 men, 52 women, 0 diverse; aged 15—61, $M = 24.70, SD = 7.98$) entered five objects which they always have at hand. Based on this survey's results, as well as findings from our workshop and related literature, we selected six objects for our user study. Card, phone and key were among the most mentioned objects in our survey. Additionally, we included a pen, as this is a common input device which is often used for interaction in HCI research projects [2, 27, 43, 57, 58]. Finally, we decided to add a wearable (watch) as well as a disposable (tissue) object to our selection.

5.3 Conditions

The results of the workshop show that typical data transfer differs in the number of people involved, as well as the type of source and target device. People transfer data at home, in professional settings, such as work or university, and on the way. *On the way* describes any scenario or environment outside one's home or work/university, whether indoors or outdoors. These situations loosely reflect the three layers of *access to devices* defined by Scharf et al. [65]: *private access* involves a single user with multiple devices, *shared access* involves multiple users with one device, and *public access* involves a device controlled by one user but observed by multiple people. To take all these factors into account, we combined them in three different situations (see Figure 3):

Copyshop - "Imagine you just finished your bachelor's thesis and now want to print it out in a copyshop. You leave your laptop at home and take the thesis on your everyday carry with you." *(public access)*

TV - "Imagine you are at home, sitting on your couch and your notebook is right next to you. You want to view the photos of your last vacation on your TV instead of the notebook, as the display is way larger." *(private access)*

Office - "Imagine you are at work, sitting in your office. A colleague of yours, whose office is down the hall, needs a work-related file on their computer." *(shared access)*

The copyshop situation includes one person on the way and an unknown target device. For the TV situation, data transfer takes place in a private surrounding with known target devices and also only the user involved. In the office situation, several persons are involved in a professional/public place and known target devices.

In summary, we narrowed down the most popular items from the online survey, related literature, and our workshop's results to the following six objects: Card, Key, Pen, Phone, Tissue, and Watch. In our task-based user study, these objects should be used for cross-device data transfer in three situations: Copyshop, TV, and Office.

5.4 Procedure

We invited participants separately to our lab. First, they were briefly introduced to the study's procedure. Then, they gave informed consent and filled in a demographic questionnaire. Participants also ranked themselves on the ATI scale [18], since we assumed that different affinities for technology may lead to different interactions performed and objects preferred. Afterward, we asked them to imagine the three situations successively. For each situation, participants demonstrated their desired interaction for all six objects while thinking aloud. We asked them to perform the data transfer interaction starting with selecting the file on the source device until finally pasting it on the target device, as well as any interaction in between. For example, one could place Card on their computer and later hand it to a colleague, who initiates the data transfer by placing it on their device again.

After each situation, participants ranked the objects according to their reasonableness in data transfer in the respective situation. The scale ranged from *best* (1) to *worst* (6) and the same rank could be assigned to multiple objects. After going through this process for all three situations, we conducted a post-study interview on advantages and disadvantages of the objects, participants' preference for objects, as well as factors influencing them in interacting. Finally, we asked about general impressions of everyday physical objects in data transfer and problems regarding those. We filmed the performed interactions and audio-recorded participants' think aloud. Also, we took notes regarding interactions, answers, and explanations.

5.5 Participants

The total of 30 participants (18 men, 11 women, 1 diverse) were aged from 19 to 29 ($M = 24.33, SD = 2.52$). 17 studied media informatics, and the remaining 13 had various professions or studied other subjects. Again, we used convenience sampling within our personal contacts and the university mailing list. For media informatics students, we have confirmed the participation required for their course of study. On the ATI scale, the affinity for technology is between 2.33 and 5.56 ($M = 4.36, SD = 0.51, \alpha = 0.87$). This way, we could ensure a mixed affinity for technology, and thus a broad range of different perspectives on the topic.

6 RESULTS

As we found in both workshop and the preliminary online survey, participants preferred to transfer data with an object they have at hand. We therefore conducted a user study using six everyday objects, see subsection 5.2. In the following we describe the evaluation and results of the study.

For the evaluation of our results, we used MAXQDA[3]. In a first step, two annotators individually annotated notes and transcriptions of the study. To avoid disagreements, we specified annotation guidelines before and held consensus meetings to discuss still arising disagreements. This way, we were able to gain a uniform code set. Following the inductive coding method for qualitative content analysis by Mayring and Fenzl [47], we iteratively combined similar codes into broader categories.

In total, we analyzed 753 performed interactions. After coding, 27 different interaction categories emerged. Besides performed interactions, we divided the results into features concerning the object and interaction, as well as social and spatial factors influencing the interaction. We then examined the relations between these categories, exploring how they intersected and overlapped. Thus, to answer our research questions, descriptive analysis allows us to identify key patterns and trends. In the following, the number in parentheses represents the count of a certain code.

To enable other researchers to comprehend our results as well as to conduct further investigation, we will make our data set publicly available. It contains the performed interactions with the objects in different situations, as well as rationales and properties of them.

[3]https://www.maxqda.com/

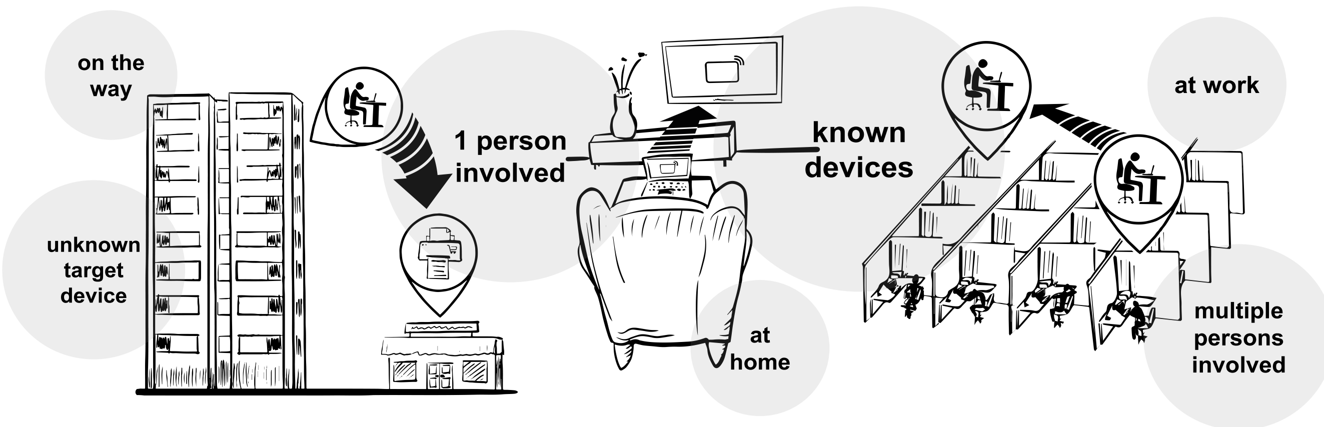


Figure 3: Situations in which participants transfer data during the user study from left to right: take your bachelor's thesis to the Copyshop for printing, view your images on a TV, and share documents with your colleague in the Office. The study's supervisor represented the colleague in the Office condition. The situations differ in various factors regarding involved persons, location, and devices.

6.1 Objects

The first step of our analysis regards the objects used for interaction. For each object, we consider advantages and disadvantages mentioned by participants, as well as the overall ranking.

6.1.1 Object Rankings. For each situation, participants ranked objects from 1 (best) to 6 (worst). In general, participants ranked objects similarly across situations. Overall, Phone was given the highest rank and Tissue the lowest (Table 1).

Table 1: Mean (top) and mode (bottom) of object rankings on a scale from 1 (best) to 6 (worst) for each situation. Overall rankings result from combining the situational rankings. Tied ranks were averaged.

	card	key	pen	phone	tissue	watch
copyshop	2.98	4.27	3.95	1.38	5.80	2.58
	2	5	5	1	6	2
TV	3.92	4.90	2.78	1.90	4.73	2.70
	5	5	3	1	6	2
office	3.92	4.90	2.78	1.90	4.73	2.70
	1	5	4	1	6	2
overall	3.29	4.34	3.33	2.03	5.03	2.94
	3	5	3	1	6	2

In addition to the situation-specific ranking, we asked participants for their overall favorite objects after the last condition. Participants most frequently mentioned Phone (20), followed by Card (10) and Watch (7). The less preferred objects were Key (6), Pen (4), and Tissue (1).

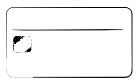
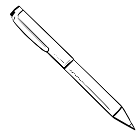
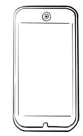
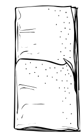
We also inquired whether participants preferred using a single object for all situations or different objects for different use cases. Almost half of the participants (16 out of 30) preferred using the same object for any situation. They liked Phone (10) due to its *multi-functionality* (5), while the remaining six participants named Card (2), Pen (2), Key (1), and Watch (1) as their preferred object for any use case. The remaining 14 preferred using different objects for different situations. Among those, nine participants based their usage preferences on *public/work* and *private* situations, while the other five named *daily use* and *sensitive data* as factors. For favorite objects in *public/work* situations, participants preferred Card (6), followed by Pen (2) and Watch (1). For *private* situations, participants liked Phone (5) and Watch (6) exclusively.

6.1.2 Objects' Advantages and Disadvantages. To gain further insights into why participants ranked the objects the way they did, we analyzed the advantages and disadvantages mentioned for each object and combined similar ones. These are listed in Table 2. Interestingly, Tissue is the only object for which participants indicated more disadvantages than advantages. For all other objects, participants mentioned clearly more advantages than disadvantages when using those objects as mediators for cross-device data transfer. The most frequently stated reasons deal with *functionality*, *security*, and *shape*, as well as if the object is a *personal* one and *at hand.*

6.1.3 Outliers in the Rankings. Some participants ranked objects clearly differently from the general consensus. As those controversial rankings could indicate interesting implications regarding the interaction, we closely investigated our qualitative data for those outliers. In the Copyshop situation, most participants preferred using the Phone with *wireless* transfer and ranked this interaction best or second best. However, two participants ranked Phone clearly worse. They used a *cable* for transferring data because it was a *known* but *impractical* and *uncomfortable* interaction which requires *extra steps.* Additionally, three participants who did not like the Phone in other situations gave it the highest rank in the Copyshop. They used *hold to* and *place on* and assessed their interaction as *comfortable* and again *known.*

Most participants *inserted* the Key in all situations. It received a low ranking in most cases. Interestingly, those participants who

Table 2: Most frequently mentioned advantages (+) and disadvantages (-) of each object when used for data transfer. The sum sign indicates the overall count of the mentioned advantages and disadvantages for the particular object.

												
+	easy portability	15	always at hand	16	multifunctional	16	at hand	29	small / handy	11	at hand	27
	small / handy	14	secure	11	gesture	11	multifunctional	20	fun	9	wearable	18
					at hand	11	common	17				
	Σ	91	Σ	66	Σ	82	Σ	95	Σ	40	Σ	96
−	being lost / forgotten	5	low compatibility	8	rarely / never at hand	12	personal	9	disposable	11	rarely / never at hand	15
	unifunctional	4	personal	6			security concerns	6	not realizable	11	wearable	13
									breakable	9		
	Σ	37	Σ	44	Σ	39	Σ	42	Σ	83	Σ	61

ranked Key highly, preferred other gestures such as *hold to*, *swipe*, or *touch*.

Some participants ranked Tissue differently in the Copyshop situation. Although the majority used the *place on* interaction, some used *grab*, *insert*, *wipe*, and *writing*, which they perceived as *impractical* and with *no added benefit or value*. Despite these drawbacks, one participant described the interaction as *intuitive*.

6.1.4 Summary. Over all situations, Phone was the most popular object among participants. Almost half preferred specific objects for different situations, while the other half preferred different objects for different situations. Factors that influenced participants' choice of objects include *public/work* and *private* situations, *daily use*, and *sensitive data*.

6.2 Interactions

During the user study, participants performed a broad variety of interactions. We put them into relation with their used object and interaction attributes.

6.2.1 Performed Interactions with Objects. We counted the number of distinct interactions for each device. Participants used a lower variety of different interactions when using Card (11), Key (13), or Phone (14). In contrast, a more heterogeneous set of interactions was used with Watch (16), Pen (18), and Tissue (21).

Additionally, we investigated which interaction can be assigned to which object. We observed that participants primarily utilized Card and Tissue by *placing* them *on* the source or target device. On the other hand, participants predominantly used Key and Pen via *insertion*. Participants frequently operated Phone and Watch through a *wireless* connection. Those interactions are illustrated in Figure 1. Table 3 provides a detailed overview of object-interaction pairs. Further, Figure 4 illustrates unconventional interactions performed by some users. We consider those as especially interesting as these interactions reflect the objects' affordances.

Furthermore, we observed how participants interacted with their surroundings during interaction, see Table 4. Gestures such as *hold*

Table 3: Distribution of performed interactions per object. Results portray totals of all situations. Eleven distinct interactions were aggregated in the category *other*.

	card	key	pen	phone	tissue	watch
additional setting	0	0	0	1	0	0
cable	0	0	1	19	0	1
drag through	7	0	0	1	0	0
encircle	0	0	2	0	0	0
grab	0	1	0	0	1	0
hold to	21	6	9	10	16	28
imprint	0	0	0	0	7	0
insert	26	58	37	0	6	4
magnetic	0	0	9	0	0	0
other	0	6	3	0	1	1
photo	0	0	0	9	0	0
place next	1	2	1	0	2	0
place on	37	17	1	13	29	8
pointing	1	0	26	1	3	0
project	0	0	1	0	0	1
scan	6	0	1	2	4	3
shake	0	0	0	0	1	0
swipe	3	1	13	5	2	11
tap on object	0	1	17	0	4	5
throw	0	0	0	0	2	1
touch	2	2	9	1	4	3
turn	0	12	0	0	0	2
unfolded	0	0	0	0	8	0
voice	0	1	0	0	2	3
wipe	0	0	1	0	10	1
wireless	4	3	13	77	7	54
writing	0	0	10	0	7	0
total	**108**	**110**	**154**	**139**	**116**	**126**

Table 4: Differences in spatial and social interaction in data transfer, as well as the whereabouts of the object after the data transfer. Participants proceeded differently – they did or did not: a) change their location during the interaction, b) hand over the object if other persons are involved, or c) take the object back after data transfer. Listed interactions are the most frequently performed ones. Depending on the whereabouts, users most frequently perceived the process of transferring data as either comfortable, simple, or uncomfortable.

	change of location		hand over		take back	
	yes	no	yes	no	yes	no
hold to	28	9	13	12	19	5
insert	47	4	32	7	20	29
place on	28	7	17	3	13	13
pointing	3	9	2	3	2	0
swipe	2	17	1	6	0	0
wireless	16	51	7	32	8	2
total	124	97	72	63	62	49

to, *insert*, and *place on* caused participants to change location. Contrary, they remained stationary for *pointing*, *swipe*, and *wireless* interactions. Change of location was generally described as *uncomfortable*.

A similar distinction can be made for gestures that involve handing over objects. Participants frequently handed over objects during *insert* and *place on* while for *swipe* and *wireless* they kept the object. The disposable Tissue was thrown away nine times after using it for data transfer.

6.2.2 Perception of Performed Interactions. Participants provided feedback on how they perceived different interactions. Among the most frequent interactions, *place on* was commonly described as *simple* (6), while both *insert* (13) and *place on* (13) *required an additional device*. Participants also mentioned that interactions using *insert* felt *uncomfortable* (12) but *secure* (12). They liked that it feels like the object's *original use* (8). In contrast, for *wireless* interactions, participants generally appreciated *comfort* (9), *familiarity* (8), and *multi-functionality* (12). However, considering *wireless* interaction, participants noted that this type of interaction is often *already functional* (6).

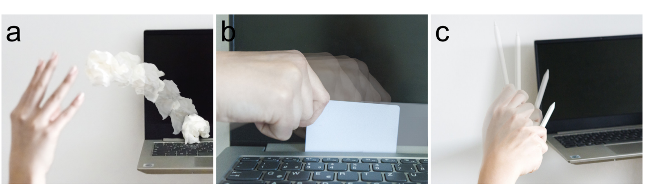


Figure 4: Some participants came up with unconventional interaction techniques for transferring data: throwing a crumpled tissue (a), pulling a card through a slit (b), or waving a pen like a magic wand (c). Objects' affordances seem to determine the interactions.

6.2.3 Influence of the Situation on Interaction. We observed that different situations have a large influence on participants' preference regarding the interaction technique. Participants utilized a *cable* for data transfer more commonly in the Copyshop situation than in other situations. Furthermore, participants *imprinted* and *wrote* for the Copyshop, performing the *original use* of the object. In the other two situations, participants used *write* with *verification*. Conversely, participants did rarely perform *touch* interactions in the Copyshop even though it was considered *fast* and *known* in other situations.

Participants found *pointing* to be *comfortable* and *fast*, but only used it in the TV situation. They most frequently used *swiping* in the TV situation and described it as *known*, *comfortable*, and *requiring an additional device*. However, in the Office situation, participants performed less *swiping*. In the Copyshop, they did not use it at all. Although participants used Phone and Watch for *wireless* data transfer in all situations, it was notably more frequent in the TV situation.

We also observed that the *place on* interaction is the most used in the Copyshop situation, followed by TV and then Office. As this interaction involves standing up, we explored that participants preferred to stand up in the TV situation rather than in the Office. In the Office situation, participants utilized a messenger (*wireless*) more frequently.

6.2.4 Summary. Different objects afford different interactions. Card and Tissue were mostly *placed on*, which participants perceived as *simple* interaction. Key and Pen are *inserted*, which seems to be *secure*, whereas using Phone and Watch with a *wireless connection* is *comfortable*. However, these interactions as well as the corresponding perception might be influenced by situation. Depending on the performed interaction, participants integrated their surrounding differently.

6.3 Influencing Factors

In addition to attributes, advantages, and disadvantages of the objects, the study also examined factors that influenced participants in their choice of preferred object and interaction. The most frequently mentioned factor was the *material* (10) of the object, followed by *familiarity* (9) with the object's *shape* (9) and *situation* (7) in which it is used. *Presence* (7) of the object, the *interaction* (5) with it and *comfort* (4) were also important factors. Participants also named *compatibility* (4), *security* (3), *affordance* (3), and *realizability* (3). Participants stated the *object's appearance* (3), as well as whether *another person* (3) is involved, has an impact on their choice. Some participants also perceived whether the object is a *personal* (2) one as an important factor. Other factors mentioned include *intuition* (2), *speed* (2), *multi-functionality* (2), *usability* (2), and *location* (2). Overall, the study found that participants' choices were influenced by a combination of physical, psychological, and contextual factors.

6.4 Participants' opinion on everyday objects for data transfer

As a final step, we asked participants whether they like the idea of using everyday objects for data transfer. Almost all participants (25) indicated a willingness to use them for data transfer, while three participants stated they would not like to use them. Two were indecisive.

Still, there were a few concerns regarding the use of everyday objects. The main problems that participants identified include *security* (11), the possibility of *losing or forgetting* (5) the object, and the perception of *no added value* (5). Some participants also question the realizability (4) and note that using physical objects requires *extra steps* (4). They may not be *compatible* (3) with any device or *breakable* (2). Additionally, a few participants expressed that the use of additional objects could lead to an *excess* (1) of them and be *impractical* (1), *expensive* (1), or *uncomfortable* (1). Participants also fear issues of the object being a *personal* or *non-personal* (1) device. Furthermore, they mentioned *location* (1) and *situation* (1) based issues, as well as the inconceivability of *storage capacities* (1). Finally, participants questioned the *affordances* (1) of objects that are originally used for other purposes.

Further remarks by participants include that physical objects might be a suitable form of interaction for a *different target group or purpose* (3), like smart homes or for people with less technological affinity. Finally, aspects such as *multi-functionality* (2), *intuition* (2), *usability* (2), as well as *comfort* (3) were valued by participants.

7 DISCUSSION

We investigated how physical everyday objects can be used as mediators for data transfer. As suggested by Brudy et al. [5], we examined various factors, namely object types, situations, and external influencing factors. In the following, we discuss how these are interrelated based on our research questions.

7.1 Which artifacts are suitable as physical objects for data transfer?

In our workshop, we found that users do not want to carry an additional device dedicated to data transfer, but rather use one they cannot lose or forget and that is multi-functional. Based on these findings, we chose everyday carries for our study. Conventional tangible user interfaces are often designed for a specific use case [60], which is in direct conflict with our findings. In contrast, extending everyday objects for data transfer offers the opportunity for multi-functional physical devices.

In an elicitation study, we examined which everyday objects are suitable mediators for data transfer. It is worth noting that our intention was not to look into information behavior concerning the interaction with actual physical storage devices used for device to device data transfer. The multitude of form factors of current storage gadgets using mimicry and skeuomorphism[4] (quite similar to our selection of physical objects, storage devices can be found in the form of keys, cards, pens, bracelets et cetera) is an additional, if indirect, indicator for the user preferences for physical objects we found in this study.

Our findings suggest that users like the idea of interacting with everyday objects, as well as objects that are already at hand in a particular situation. In our study, some participants valued wireless interactions, but others liked the idea of being independent of connections. Personal objects seem to be preferred when no other users are involved. Even though some participants remarked that they would prefer not to use a personal device when interacting with others, using a phone still achieved the highest ranking among our selection of objects.

Our results also indicate that for objects that are already capable of transferring data, it has to be considered whether adding a new interaction technique adds any value. In particular, most participants preferred using wireless data transfer when interacting with the phone. As users seem to prefer using the phone and the watch in a way that is already possible, and based on user feedback, the card can be seen as a suitable all-rounder for novel forms of data transfer.

7.2 How do users intuitively interact with the artifacts?

In some cases, we could observe that objects' form factors strongly influence how participants interact with them. For example, the interaction "place on" was used for both, card and tissue. However, while the card seems to clearly afford the "place on" gesture, participants found a large variety of interaction techniques with the tissue. This can be explained with users' prior associations and mental models regarding technical possibilities and the resulting interaction space of those objects. Even though both, card and tissue, have a similar shape and size, participants have experience using cards to interact with computer systems in their daily lives. On the other hand, assigning technical capabilites to a tissue seemed alien to participants. Therefore, we conclude that besides an object's form factor, users' mental models play a significant role shaping affordances for interaction. This can be an important insight when designing new forms of interaction that involve physical objects.

Corresponding to Haller et al. [23] interaction techniques for digital systems feel more natural to users if there is a physical equivalent. Our findings confirm this assumption, as for the objects pen, tissue, and key, participants performed gestures similar to those objects' originally intended use. Because of their strong affordances, interaction with those objects remains intuitive even in a completely different usage context. For example, the key was frequently inserted and even turned to initiate the data transfer. Therefore, it is crucial to take the object's affordances from a user's perspective into account when designing interaction involving physical everyday objects. However, our results show that there is no overall ideal interaction for cross-device data transfer. Nevertheless, some objects seem to offer stronger affordances towards particular interaction techniques.

7.3 Which factors influence interaction and artifact choice?

Concerning the choice of interaction and artifact, prior knowledge and experiences with the objects are important to consider. We found that users prefer to interact with objects in a way they already know. Furthermore, the familiarity of the interaction with the device also plays an important role. This goes in line with Israel et al. [33], as deep familiarity with physical objects can reduce mental load in interaction.

Social factors, such as location and people involved, also influence the choice of object. For example, in private environments and

[4]Illustrative material can be found on the websites of companies that market promotional products (e.g. https://www.everyusb.com).

familiar locations, multi-functional objects are preferred. In unfamiliar situations, users tend to avoid handing over their device to others and thus try to stay in control over the data transfer process. Marquardt et al. [46] found a similar behavior when investigating cross-device information transfer in different settings: users tend to be more restrictive in less familiar situations.

Overall, users value security highly in their device choice. However, even though security issues were oftentimes mentioned as disadvantages of phones, participants still ranked them highly in all situations. This suggests that familiarity with the device is an even more decisive factor than security and concerns regarding privacy and possession. On the other hand, users struggled to find suitable interaction techniques with the tissue. According to Brudy et al.'s literature review on cross-device interaction [5], it is important to avoid the trade-off between matching users' intuition and the efficiency of interaction by finding an object which supports both. Our results confirm this guideline for the context of cross-device data transfer. All of those aspects support the assumption that users' mental models for how the transfer process should work have to be taken into consideration.

7.4 Do users like the idea of using physical objects for data transfer? And why (not)?

Users still perceive security concerns as a major problem when using physical devices for interaction. This issue has also been stated by previous research [11, 12]. Furthermore, users face the risk of losing or forgetting the object and perceive no added value by carrying additional objects. Again, this finding goes in line with previous comparisons of tangible user interfaces and smartphone apps [12]. Surprisingly, joy of use was only a minor concern for our participants, with one exception: several times, interacting with the tissue was described as enjoyable and funny.

In general, the target group, use case and purpose need to be considered. Nonetheless, the idea of everyday objects in data transfer was found to be promising, under the condition that the aforementioned concerns are addressed.

7.5 Design Guidelines

Our results allowed us to establish some guidelines for using physical objects as mediators for interaction. We assume that these guidelines also apply to the development of tangible user interfaces and the design of new interaction techniques for them.

- When designing an artifact which is meant to be used in a private environment without other people involved, multi-functionality should be considered. In more exposed situations, users may prefer uni-functional objects that are adapted to a particular use case.
- Users' mental model has to be taken into account. Artifacts and interaction techniques should not counteract users' expectations, but echo them in their design. For example, in data transfer, a user could be confused if using a key is not secure. Instead, they might intuitively prefer a key over other objects when they have to transfer sensitive data.
- Previous research on tangibles is mostly focused on engineering, but nowadays with promising wireless and cloud-based solutions, it is all the more important to think about in which use cases an additional physical object is indeed beneficial. For example, as our results suggest, using physical objects especially adds value in data transfer when the target device is unknown, a wireless connection cannot be established, unknown people are involved, or a change of location must take place anyway.
- Users tend to prefer known devices and interactions, even if there are objectively better options. Thus, to enhance user experience in situations where there is already a working approach, one should focus on improving the status quo. Radically new approaches should only be considered if they are significantly better in several aspects or when facing problems for which there is no solution yet.
- When re-designing existing objects for a more extensive usage, it might be helpful to choose an interaction technique which is already associated with that object. To introduce new interaction techniques, it might be advisable to resort to a form factor without previous associations by users. However, an object's affordances should always be taken into consideration.

8 LIMITATIONS & CONCLUSION

In this paper, we document users' preferences when interacting with physical objects for cross-device data transfer. Through a design workshop, we identified three usage contexts – at home, in a professional context, and on the way. The situations differ in the number of people involved and the types of target devices. Since users run the risk of forgetting something and do not want to carry an extra device, they appreciate the idea of using artifacts that are already available. In an elicitation study, participants transferred data in typical situations as they would intuitively do by employing six everyday objects: card, key, pen, phone, tissue, and watch.

In previous work, common tangibles were custom-designed only for a specific use case. However, we found that users actually tend to prefer multi-functional devices in a private context without other people involved. Moreover, when designing physical interactive devices, users' mental models regarding interaction and the objects' attributes have to be considered. Physical objects and interaction techniques come with their own advantages and disadvantages. Thus, it is not possible to make a general statement about whether the extension of everyday objects adds value to data transfer. As most users already have an idiosyncratic way to transfer data between devices, they will oftentimes default to this method. Therefore, new interactive systems should always be developed with existing systems in mind to ensure that the new system adds enough value for adoption.

Despite a wide spread of technical affinity, all of our participants were proficient with current digital devices. Therefore, our results may not be generalizable to an even more diverse population. Thus, specific user groups such as elderly people or children might have interacted differently. As we used everyday objects in our elicitation study, participants had previous experience in using them. Therefore, existing mental models could certainly have impacted their behavior during the study. By repeating the study with neutral proxies, those factors could be excluded and effects caused by the objects' form factors could emerge. Furthermore, an observational study in a real-world setting could help to gain insights with higher external validity. Yet, through conducting a laboratory study, we were able to understand participants' objectives through the think-aloud method and post-study interviews.

Interactive artifacts created based on our design guidelines should be specifically evaluated for usability and intuitiveness using validated methods in future work. With the limitations of current ways for cross-device data transfer in mind, comparative studies should investigate whether using physical objects as mediators can increase task performance and usability. Lastly, current societal and technological factors impact user needs, as well as their mental models regarding interaction, significantly. Therefore, our findings only represent the current status quo and should be revisited with respect to possible future paradigm shifts.

REFERENCES

[1] Thomas Bader, Astrid Heck, and Jürgen Beyerer. 2010. Lift-and-drop: crossing boundaries in a multi-display environment by Airlift. In *Proceedings of the International Conference on Advanced Visual Interfaces - AVI '10*. ACM Press, Roma, Italy, 139. https://doi.org/10.1145/1842993.1843019

[2] Patrick Baudisch, Edward Cutrell, Mary Czerwinski, Daniel Robbins, Peter Tandler, Ben Bederson, and A. Zierlinger. 2003. *Drag-and-Pop and Drag-and-Pick: Techniques for Accessing Remote Screen Content on Touch- and Pen-Operated Systems.*

[3] Sebastian Boring, Manuela Altendorfer, Gregor Broll, Otmar Hilliges, and Andreas Butz. 2007. Shoot & copy: phonecam-based information transfer from public displays onto mobile phones. In *Proceedings of the 4th international conference on mobile technology, applications, and systems and the 1st international symposium on Computer human interaction in mobile technology (Mobility '07)*. Association for Computing Machinery, New York, NY, USA, 24–31. https://doi.org/10.1145/1378063.1378068

[4] David C. Brown and Lucienne Blessing. 2008. The Relationship Between Function and Affordance. American Society of Mechanical Engineers Digital Collection, 155–160. https://doi.org/10.1115/DETC2005-85017

[5] Frederik Brudy, Christian Holz, Roman Rädle, Chi-Jui Wu, Steven Houben, Clemens Nylandsted Klokmose, and Nicolai Marquardt. 2019. Cross-Device Taxonomy: Survey, Opportunities and Challenges of Interactions Spanning Across Multiple Devices. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–28. https://doi.org/10.1145/3290605.3300792

[6] Tsung-Hsiang Chang and Yang Li. 2011. Deep shot: a framework for migrating tasks across devices using mobile phone cameras. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. Association for Computing Machinery, New York, NY, USA, 2163–2172. https://doi.org/10.1145/1978942.1979257

[7] Dimitris Chatzopoulos, Carlos Bermejo, Ehsan ul Haq, Yong Li, and Pan Hui. 2019. D2D Task Offloading: A Dataset-Based Q&A. *IEEE Communications Magazine* 57, 2 (2019), 102–107. https://doi.org/10.1109/MCOM.2018.1700873

[8] Ke-Yu Chen, Daniel Ashbrook, Mayank Goel, Sung-Hyuck Lee, and Shwetak Patel. 2014. AirLink: sharing files between multiple devices using in-air gestures. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, Seattle Washington, 565–569. https://doi.org/10.1145/2632048.2632090

[9] Haeyong Chung, Chris North, Jessica Zeitz Self, Sharon Chu, and Francis Quek. 2014. VisPorter: facilitating information sharing for collaborative sensemaking on multiple displays. *Personal and Ubiquitous Computing* 18, 5 (June 2014), 1169–1186. https://doi.org/10.1007/s00779-013-0727-2

[10] Raimund Dachselt and Robert Buchholz. 2009. Natural throw and tilt interaction between mobile phones and distant displays. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems*. ACM, Boston MA USA, 3253–3258. https://doi.org/10.1145/1520340.1520467

[11] David Dearman and Jeffery S. Pierce. 2008. It's on my other computer! computing with multiple devices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. Association for Computing Machinery, New York, NY, USA, 767–776. https://doi.org/10.1145/1357054.1357177

[12] Sarah Delgado Rodriguez, Sarah Prange, Christina Vergara Ossenberg, Markus Henkel, Florian Alt, and Karola Marky. 2022. PriKey – Investigating Tangible Privacy Control for Smart Home Inhabitants and Visitors. In *Nordic Human-Computer Interaction Conference*. ACM, Aarhus Denmark, 1–13. https://doi.org/10.1145/3546155.3546640

[13] Lauric Desauw, Adrien Luxey-Bitri, Rémy Raes, Romain Rouvoy, Olivier Ruas, and Walter Rudametkin. 2023. A critical review of mobile device-to-device communication. *arXiv preprint arXiv:2309.11871* (2023).

[14] Andreas Dippon, Norbert Wiedermann, and Gudrun Klinker. 2012. Seamless integration of mobile devices into interactive surface environments. In *Proceedings of the 2012 ACM international conference on Interactive tabletops and surfaces (ITS '12)*. Association for Computing Machinery, New York, NY, USA, 331–334. https://doi.org/10.1145/2396636.2396693

[15] W. Keith Edwards, Mark W. Newman, and Erika Shehan Poole. 2010. The infrastructure problem in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1753326.1753390

[16] Martina Emmert, Andreas Schmid, Raphael Wimmer, and Niels Henze. 2023. CoShare: a Multi-Pointer Collaborative Screen Sharing Tool. In *Proceedings of Mensch und Computer 2023 (MuC '23)*. Association for Computing Machinery, New York, NY, USA, 325–329. https://doi.org/10.1145/3603555.3608524

[17] Martina Emmert, Nicole Schönwerth, Andreas Schmid, Anton Alešik, and Raphael Wimmer. 2023. How Do Users Like Their Tangibles? — An Exploration of Interaction Techniques for Data Transfer with Everyday Objects. Gesellschaft für Informatik, Rapperswil (SG), Switzerland. https://doi.org/10.18420/muc2023-mci-ws09-407

[18] Thomas Franke, Christiane Attig, and Daniel Wessel. 2019. A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. *International Journal of Human–Computer Interaction* 35, 6 (April 2019), 456–467. https://doi.org/10.1080/10447318.2018.1456150

[19] Luca Frosini, Marco Manca, and Fabio Paternò. 2013. A framework for the development of distributed interactive applications. In *Proceedings of the 5th ACM SIGCHI symposium on Engineering interactive computing systems (EICS '13)*. Association for Computing Machinery, New York, NY, USA, 249–254. https://doi.org/10.1145/2494603.2480328

[20] Hans Gellersen, Carl Fischer, Dominique Guinard, Roswitha Gostner, Gerd Kortuem, Christian Kray, Enrico Rukzio, and Sara Streng. 2009. Supporting device discovery and spontaneous interaction with spatial references. *Personal and Ubiquitous Computing* 13, 4 (May 2009), 255–264. https://doi.org/10.1007/s00779-008-0206-3

[21] Weilun Gong, Stephanie Santosa, Tovi Grossman, Michael Glueck, Daniel Clarke, and Frances Lai. 2023. Affordance-Based and User-Defined Gestures for Spatial Tangible Interaction. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (Pittsburgh, PA, USA) *(DIS '23)*. Association for Computing Machinery, New York, NY, USA, 1500–1514. https://doi.org/10.1145/3563657.3596032

[22] Saul Greenberg, Nicolai Marquardt, Till Ballendat, Rob Diaz-Marino, and Miaosen Wang. 2011. Proxemic interactions: the new ubicomp? *Interactions* 18, 1 (Jan. 2011), 42–50. https://doi.org/10.1145/1897239.1897250

[23] Michael Haller, Peter Brandl, Daniel Leithinger, Jakob Leitner, Thomas Seifried, and Mark Billinghurst. 2006. Shared Design Space: Sketching Ideas Using Digital Pens and a Large Augmented Tabletop Setup. In *Advances in Artificial Reality and Tele-Existence*, Zhigeng Pan, Adrian Cheok, Michael Haller, Rynson W. H. Lau, Hideo Saito, and Ronghua Liang (Eds.). Vol. 4282. Springer Berlin Heidelberg, Berlin, Heidelberg, 185–196. https://doi.org/10.1007/11941354_20 Series Title: Lecture Notes in Computer Science.

[24] Peter Hamilton and Daniel J. Wigdor. 2014. Conductor: enabling and understanding cross-device interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. Association for Computing Machinery, New York, NY, USA, 2773–2782. https://doi.org/10.1145/2556288.2557170

[25] Nabeel Hassan, Md. Mahfuzur Rahman, Pourang Irani, and Peter Graham. 2009. Chucking: A One-Handed Document Sharing Technique. In *Human-Computer Interaction – INTERACT 2009*, Tom Gross, Jan Gulliksen, Paula Kotzé, Lars Oestreicher, Philippe Palanque, Raquel Oliveira Prates, and Marco Winckler (Eds.). Vol. 5727. Springer Berlin Heidelberg, Berlin, Heidelberg, 264–278. https://doi.org/10.1007/978-3-642-03658-3_33 Series Title: Lecture Notes in Computer Science.

[26] Mike Hazas, Christian Kray, Hans Gellersen, Henoc Agbota, Gerd Kortuem, and Albert Krohn. 2005. A relative positioning system for co-located mobile devices. In *Proceedings of the 3rd international conference on Mobile systems, applications, and services - MobiSys '05*. ACM Press, Seattle, Washington, 177. https://doi.org/10.1145/1067170.1067190

[27] Ken Hinckley, Gonzalo Ramos, Francois Guimbretiere, Patrick Baudisch, and Marc Smith. 2004. Stitching: pen gestures that span multiple displays. In *Proceedings of the working conference on Advanced visual interfaces (AVI '04)*. Association for Computing Machinery, New York, NY, USA, 23–31. https://doi.org/10.1145/989863.989866

[28] Eva Hornecker and Jacob Buur. 2006. Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction. (2006), 10.

[29] Simo Hosio, Fahim Kawsar, Jukka Riekki, and Tatsuo Nakajima. 2007. DroPicks – A Tool for Collaborative Content Sharing Exploiting Everyday Artefacts. In *Ubiquitous Computing Systems*, Haruhisa Ichikawa, We-Duke Cho, Ichiro Satoh, and Hee Yong Youn (Eds.). Springer, Berlin, Heidelberg, 258–265. https://doi.

org/10.1007/978-3-540-76772-5_20
[30] Steven Houben and Nicolai Marquardt. 2015. WatchConnect: A Toolkit for Prototyping Smartwatch-Centric Cross-Device Applications. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 1247–1256. https://doi.org/10.1145/2702123.2702215
[31] Steven Houben, Paolo Tell, and Jakob E. Bardram. 2014. ActivitySpace: Managing Device Ecologies in an Activity-Centric Configuration Space. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces - ITS '14*. ACM Press, Dresden, Germany, 119–128. https://doi.org/10.1145/2669485.2669493
[32] Hiroshi Ishii and Brygg Ullmer. 1997. Tangible Bits: Towards Seamless Interfaces Between People, Bits and Atoms. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI '97)*. ACM Press, Atlanta, Georgia, United States, 234–241. https://doi.org/10.1145/258549.258715 ZSCC: 0004869.
[33] Johann H. Israel, Jorn Hurtienne, Anna E. Pohlmeyer, Carsten Mohs, Martin Kindsmuller, and Anja Naumann. 2009. On intuitive use, physicality and tangible user interfaces. *International Journal of Arts and Technology* (Nov. 2009). https://www.inderscienceonline.com/doi/10.1504/IJART.2009.02924 Publisher: Inderscience Publishers.
[34] Shahram Izadi, Harry Brignull, Tom Rodden, Yvonne Rogers, and Mia Underwood. 2003. Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In *Proceedings of the 16th annual ACM symposium on User interface software and technology (UIST '03)*. Association for Computing Machinery, New York, NY, USA, 159–168. https://doi.org/10.1145/964696.964714
[35] Haojian Jin, Christian Holz, and Kasper Hornbæk. 2015. Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*. ACM, Charlotte NC USA, 147–156. https://doi.org/10.1145/2807442.2807475
[36] J. F. Kelley. 1984. An iterative design methodology for user-friendly natural language office information applications. *ACM Transactions on Information Systems* 2, 1 (Jan. 1984), 26–41. https://doi.org/10.1145/357417.357420
[37] Clemens Nylandsted Klokmose, Janus Bager Kristensen, Rolf Bagge, and Kim Halskov. 2014. BullsEye: High-Precision Fiducial Tracking for Table-based Tangible Interaction. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces (ITS '14)*. Association for Computing Machinery, New York, NY, USA, 269–278. https://doi.org/10.1145/2669485.2669503
[38] Christian Kray, Daniel Nesbitt, John Dawson, and Michael Rohs. 2010. User-defined gestures for connecting mobile phones, public displays, and tabletops. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services*. ACM, Lisbon Portugal, 239–248. https://doi.org/10.1145/1851600.1851640
[39] Ekaterina Kurdyukova, Matthias Redlin, and Elisabeth André. 2012. Studying user-defined iPad gestures for interaction in multi-display environment. In *Proceedings of the 2012 ACM international conference on Intelligent User Interfaces (IUI '12)*. Association for Computing Machinery, New York, NY, USA, 93–96. https://doi.org/10.1145/2166966.2166984
[40] Christian Lander, Sven Gehring, Antonio Krüger, Sebastian Boring, and Andreas Bulling. 2015. GazeProjector: Accurate Gaze Estimation and Seamless Gaze Interaction Across Multiple Displays. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15)*. Association for Computing Machinery, New York, NY, USA, 395–404. https://doi.org/10.1145/2807442.2807479
[41] Ming Li and Leif Kobbelt. 2012. Dynamic tiling display: building an interactive display surface using multiple mobile devices. In *Proceedings of the 11th International Conference on Mobile and Ubiquitous Multimedia (MUM '12)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/2406367.2406397
[42] Jonathan R. A. Maier and Georges M. Fadel. 2008. Affordance-Based Methods for Design. American Society of Mechanical Engineers Digital Collection, 785–794. https://doi.org/10.1115/DETC2003/DTM-48673
[43] Vitus Maierhöfer, Andreas Schmid, and Raphael Wimmer. 2022. Demonstration of an Infrared Pen as an Input Device for Projected Augmented Reality Tabletops. In *Mensch und Computer 2022*. ACM, Darmstadt Germany, 584–586. https://doi.org/10.1145/3543758.3547519
[44] Robert B. Markum, Sara Wolf, Michael Hoefer, and Franzisca Maas. 2023. Designing Tangible Interactive Artifacts for Religious and Spiritual Purposes. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference (DIS '23 Companion)*. Association for Computing Machinery, New York, NY, USA, 117–120. https://doi.org/10.1145/3563703.3591463
[45] Nicolai Marquardt, Till Ballendat, Sebastian Boring, Saul Greenberg, and Ken Hinckley. 2012. Gradual engagement: facilitating information exchange between digital devices as a function of proximity. In *Proceedings of the 2012 ACM international conference on Interactive tabletops and surfaces (ITS '12)*. Association for Computing Machinery, New York, NY, USA, 31–40. https://doi.org/10.1145/2396636.2396642
[46] Nicolai Marquardt, Ken Hinckley, and Saul Greenberg. 2012. Cross-device interaction via micro-mobility and f-formations. In *Proceedings of the 25th annual ACM symposium on User interface software and technology*. ACM, Cambridge Massachusetts USA, 13–22. https://doi.org/10.1145/2380116.2380121
[47] Philipp Mayring and Thomas Fenzl. 2019. Qualitative Inhaltsanalyse. In *Handbuch Methoden der empirischen Sozialforschung*, Nina Baur and Jörg Blasius (Eds.). Springer Fachmedien, Wiesbaden, 633–648. https://doi.org/10.1007/978-3-658-21308-4_42
[48] Ali Mazalek and Elise van den Hoven. 2009. Framing tangible interaction frameworks. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 23, 3 (Aug. 2009), 225–235. https://doi.org/10.1017/S0890060409000201
[49] Christoph Meinel, Larry Leifer, and Hasso Plattner. 2011. *Design Thinking: Understand – Improve – Apply*. https://doi.org/10.1007/978-3-642-13757-0
[50] Pranav Mistry, Suranga Nanayakkara, and Pattie Maes. 2011. SPARSH: passing data using the body as a medium. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work (CSCW '11)*. Association for Computing Machinery, New York, NY, USA, 689–692. https://doi.org/10.1145/1958824.1958946
[51] Meredith Ringel Morris, Jacob O Wobbrock, and Andrew D Wilson. 2010. Understanding users' preferences for surface gestures. (2010).
[52] Ville Mäkelä, Mohamed Khamis, Lukas Mecke, Jobin James, Markku Turunen, and Florian Alt. 2018. Pocket Transfers: Interaction Techniques for Transferring Content from Situated Displays to Mobile Devices. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–13. https://doi.org/10.1145/3173574.3173709
[53] Donald A. Norman. 1988. *The psychology of everyday things*. Basic Books, New York, NY, US. Pages: xi, 257.
[54] Donald A. Norman. 1999. Affordance, conventions, and design. *Interactions* 6, 3 (May 1999), 38–43. https://doi.org/10.1145/301153.301168
[55] Dominic Potts, Martynas Dabravalskis, and Steven Houben. 2022. TangibleTouch: A Toolkit for Designing Surface-based Gestures for Tangible Interfaces. In *Proceedings of the Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 39, 14 pages. https://doi.org/10.1145/3490149.3502263
[56] Leonard Przybilla, Kai Klinker, Michael Lang, Maximilian Schreieck, Manuel Wiesche, and Helmut Krcmar. 2020. Design thinking in digital innovation projects—Exploring the effects of intangibility. *IEEE Transactions on Engineering Management* 69, 4 (2020), 1635–1649.
[57] Adrian Reetz, Carl Gutwin, Tadeusz Stach, Miguel Nacenta, and Sriram Subramanian. 2006. *Superflick: A natural and efficient technique for long-distance object placement on digital tables*. Vol. 2006. https://doi.org/10.1145/1143079.1143106
[58] Jun Rekimoto. 1997. Pick-and-drop: a direct manipulation technique for multiple computer environments. In *Proceedings of the 10th annual ACM symposium on User interface software and technology - UIST '97*. ACM Press, Banff, Alberta, Canada, 31–39. https://doi.org/10.1145/263407.263505
[59] Jun Rekimoto and Masanori Saitoh. 1999. Augmented surfaces: a spatially continuous work space for hybrid computing environments. In *Proceedings of the SIGCHI conference on Human factors in computing systems the CHI is the limit - CHI '99*. ACM Press, Pittsburgh, Pennsylvania, United States, 378–385. https://doi.org/10.1145/302979.303113
[60] Jun Rekimoto, Brygg Ullmer, and Haruo Oba. 2001. DataTiles: a modular platform for mixed physical and graphical interactions. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '01*. ACM Press, Seattle, Washington, United States, 269–276. https://doi.org/10.1145/365024.365115
[61] Reinout Roels, Arno De Witte, and Beat Signer. 2018. INFEX: A Unifying Framework for Cross-Device Information Exploration and Exchange. *Proceedings of the ACM on Human-Computer Interaction* 2, EICS (June 2018), 1–26. https://doi.org/10.1145/3179427
[62] Roman Rädle, Hans-Christian Jetter, Nicolai Marquardt, Harald Reiterer, and Yvonne Rogers. 2014. HuddleLamp: Spatially-Aware Mobile Displays for Ad-hoc Around-the-Table Collaboration. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces - ITS '14*. ACM Press, Dresden, Germany, 45–54. https://doi.org/10.1145/2669485.2669500
[63] Houssem Saidi, Marcos Serrano, Pourang Irani, and Emmanuel Dubois. 2017. TDome: A Touch-Enabled 6DOF Interactive Device for Multi-Display Environments. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 5892–5904. https://doi.org/10.1145/3025453.3025661
[64] Stephanie Santosa and Daniel Wigdor. 2013. A field study of multi-device workflows in distributed workspaces. In *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. ACM, Zurich Switzerland, 63–72. https://doi.org/10.1145/2493432.2493476
[65] Florian Scharf, Christian Wolters, Michael Herczeg, and Jörg Cassens. 2013. Cross-Device Interaction: Definition, Taxonomy and Applications. (2013).
[66] Andreas Schmid, Thomas Fischer, Alexander Weichart, Alexander Hartmann, and Raphael Wimmer. 2021. ScreenshotMatcher: Taking Smartphone Photos to Capture Screenshots. In *Proceedings of Mensch und Computer 2021 (MuC '21)*. Association for Computing Machinery, New York, NY, USA, 44–48. https://doi.org/10.1145/3473856.3474014

[67] Dominik Schmidt, Julian Seifert, Enrico Rukzio, and Hans Gellersen. 2012. A cross-device interaction style for mobiles and surfaces. In *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. ACM Press, Newcastle Upon Tyne, United Kingdom, 318. https://doi.org/10.1145/2317956.2318005

[68] Arne Schmitz, Ming Li, Volker Schönefeld, and Leif Kobbelt. 2010. Ad-Hoc Multi-Displays for Mobile Interactive Applications. (2010).

[69] Mario Schreiner, Roman Rädle, Hans-Christian Jetter, and Harald Reiterer. 2015. Connichiwa: A Framework for Cross-Device Web Applications. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*. Association for Computing Machinery, New York, NY, USA, 2163–2168. https://doi.org/10.1145/2702613.2732909

[70] Robin Schweigert, Valentin Schwind, and Sven Mayer. 2019. EyePointing: A Gaze-Based Selection Technique. In *Proceedings of Mensch und Computer 2019 (MuC '19)*. Association for Computing Machinery, New York, NY, USA, 719–723. https://doi.org/10.1145/3340764.3344897

[71] Dennis Schüsselbauer, Andreas Schmid, and Raphael Wimmer. 2021. Dothraki: Tracking Tangibles Atop Tabletops Through De-Bruijn Tori. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Salzburg Austria, 1–10. https://doi.org/10.1145/3430524.3440656

[72] Khoovirajsingh Seewoonauth, Enrico Rukzio, Robert Hardy, and Paul Holleis. 2009. Touch & connect and touch & select: interacting with a computer by touching it with a mobile phone. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '09)*. Association for Computing Machinery, New York, NY, USA, 1–9. https://doi.org/10.1145/1613858.1613905

[73] Khoovirajsingh Seewoonauth, Enrico Rukzio, Robert Hardy, and Paul Holleis. 2009. Two NFC interaction techniques for quickly exchanging pictures between a mobile phone and a computer. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '09)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/1613858.1613909

[74] Marcos Serrano, Barrett Ens, Xing-Dong Yang, and Pourang Irani. 2015. Gluey: Developing a Head-Worn Display Interface to Unify the Interaction Experience in Distributed Display Environments. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '15)*. Association for Computing Machinery, New York, NY, USA, 161–171. https://doi.org/10.1145/2785830.2785838

[75] Adalberto Simeone, Ming Chong, Corina Sas, and Hans Gellersen. 2015. Select & Apply: understanding how users act upon objects across devices. *Personal and Ubiquitous Computing* 19 (Feb. 2015). https://doi.org/10.1007/s00779-015-0836-1

[76] Adalberto L. Simeone, Julian Seifert, Dominik Schmidt, Paul Holleis, Enrico Rukzio, and Hans Gellersen. 2013. A cross-device drag-and-drop technique. In *Proceedings of the 12th International Conference on Mobile and Ubiquitous Multimedia - MUM '13*. ACM Press, Luleå, Sweden, 1–4. https://doi.org/10.1145/2541831.2541848

[77] Adalberto L. Simeone, Julian Seifert, Dominik Schmidt, Paul Holleis, Enrico Rukzio, and Hans Gellersen. 2013. Technical framework supporting a cross-device drag-and-drop technique. In *Proceedings of the 12th International Conference on Mobile and Ubiquitous Multimedia*. ACM, Luleå Sweden, 1–3. https://doi.org/10.1145/2541831.2541879

[78] Iván Sánchez, Jukka Riekki, Jarkko Rousu, and Susanna Pirttikangas. 2008. Touch & Share: RFID based ubiquitous file containers. In *Proceedings of the 7th International Conference on Mobile and Ubiquitous Multimedia (MUM '08)*. Association for Computing Machinery, New York, NY, USA, 57–63. https://doi.org/10.1145/1543137.1543148

[79] Jayson Turner, Andreas Bulling, Jason Alexander, and Hans Gellersen. 2014. Cross-device gaze-supported point-to-point content transfer. In *Proceedings of the Symposium on Eye Tracking Research and Applications (ETRA '14)*. Association for Computing Machinery, New York, NY, USA, 19–26. https://doi.org/10.1145/2578153.2578155

[80] Brygg Ullmer, Hiroshi Ishii, and Dylan Glas. 1998. mediaBlocks: physical containers, transports, and controls for online media. In *Proceedings of the 25th annual conference on Computer graphics and interactive techniques - SIGGRAPH '98*. ACM Press, Not Known, 379–386. https://doi.org/10.1145/280814.280940

[81] Andrew D. Wilson and Raman Sarin. 2007. BlueTable: connecting wireless mobile devices on interactive surfaces using vision-based handshaking. In *Proceedings of Graphics Interface 2007 on - GI '07*. ACM Press, Montreal, Canada, 119. https://doi.org/10.1145/1268517.1268539 ISSN: 07135424.

[82] Raphael Wimmer and Florian Echtler. 2013. Exploring the benefits of fingernail displays. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13)*. Association for Computing Machinery, New York, NY, USA, 937–942. https://doi.org/10.1145/2468356.2468524

[83] Christian Winkler, Markus Löchtefeld, David Dobbelstein, Antonio Krüger, and Enrico Rukzio. 2014. SurfacePhone: a mobile projection device for single- and multiuser everywhere tabletop interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 3513–3522. https://doi.org/10.1145/2556288.2557075

[84] Jacob O. Wobbrock, Meredith Ringel Morris, and Andrew D. Wilson. 2009. User-defined gestures for surface computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*. Association for Computing Machinery, New York, NY, USA, 1083–1092. https://doi.org/10.1145/1518701.1518866

[85] Johannes Zagermann, Ulrike Pfeil, Carmela Acevedo, and Harald Reiterer. 2017. Studying the benefits and challenges of spatial distribution and physical affordances in a multi-device workspace. In *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia*. ACM, Stuttgart Germany, 249–259. https://doi.org/10.1145/3152832.3152855