How Do Users Like Their Tangibles? — An Exploration of Interaction Techniques for Data Transfer with Everyday Objects

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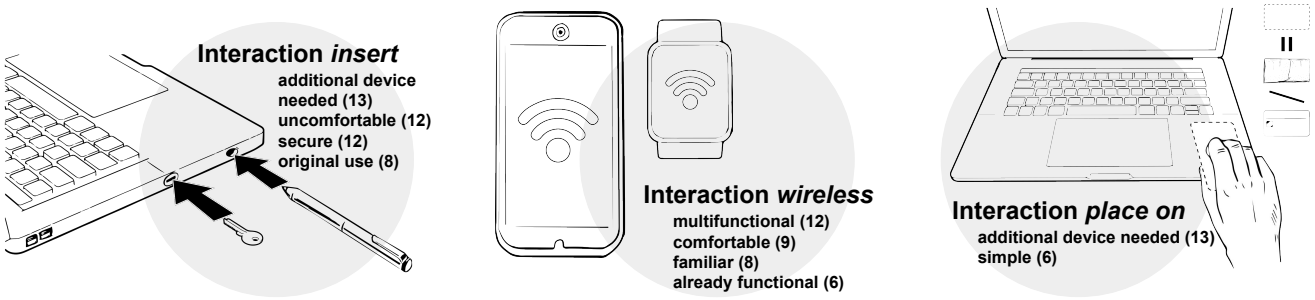

Figure 1: Depending on the type of objects, users prefer different interaction techniques for cross-device data transfer. We found that users tended to insert keys and pens into devices, use gestures indicating wireless transfer with phones and watches, and place flat objects, such as cards and tissues, 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 and infrastructural hardware every day. Oftentimes, they need to transfer data from one device to another. In many cases this process is still surprisingly cumbersome, requiring additional, non-intuitive steps, such as authentication, device pairing, or network setup. Tangible User Interfaces (TUIs) allow for quick and intuitive physical interaction with digital data. Therefore, they offer a promising design space towards more natural interaction techniques for cross-device data transfer. In a workshop and an elicitation study, we investigated different form factors and interaction techniques using six everyday objects in three different situations. We found that designing effective tangibles requires consideration of various factors which strongly depend on the target group and intended use case.

KEYWORDS

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

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1 INTRODUCTION

Data transfer has become an integral part of our daily life. From sending emails to sharing pictures and videos on social media, we transfer data in various forms across different platforms and devices. Cross-device interaction takes place in a variety of contexts. Depending on social, spatial and temporal factors, as well as the type and number of involved devices, there are widely different interaction techniques [5]. Previous research investigated and developed interaction techniques for finding nearby devices [14, 39], extending drag and drop [17, 33, 41], gesture [1, 7, 8, 16, 20, 27, 35], and gaze recognition [21, 40, 42], as well as using a smartphone [9, 13, 25] or its camera [3, 6, 38] to initiate data transfer.

Established forms of data transfer oftentimes require additional hardware, such as cables for a direct connection between the devices or hard drives. Wireless techniques for data transfer require a joint network and a multi-step connection process [37]. Other tools for data transfer, which claim to be simple and fast, are typically limited to a specific ecosystem or cloud-based, which require a complex authentication process and raise privacy concerns among users [10]. Thus, despite the variety of available methods, transferring data between devices remains a complex process for many users [5, 10]. This suggests that established interaction techniques for cross-device data transfer are not understood immediately and intuitively by users.

Tangible Interaction [18] could help address this issue by providing natural interaction techniques based on physical user interfaces [12, 19]. With a tangible user interface, digital information is controlled and displayed using physical space, surfaces, and objects [18]. Users interpret certain characteristics of physical artefacts by what they have learned in the past or through experience with analogous objects. These characteristics form the affordances of an artefact [4, 22, 28, 29]. Even though the clear affordances of tangible user interfaces could be used to make interaction more intuitive, there is little work combining tangibles with cross-device data transfer.

Pick-and-drop [32] uses a pen as a transmitter device 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. *Pick-and-drop* works for devices of several sizes [32]. *TDome* [36], a hemispherical input device, allows for triggering data transfer between displays with rotation gestures. *MediaBlocks* [43] can record notes on a whiteboard or videos and transfer them via small blocks. By inserting the block in another device, the recorded data is transferred [43].

As the physical form of tangibles indicates its function [34], they are often built specifically for one particular use case. Furthermore, they are rarely designed with users [26] or application scenarios [18] in mind. Consequently, there is a gap in research on user-centred design of TUIs for data transfer.

In this work, we explore which interaction techniques for cross-device data transfer are afforded by different tangible artefacts. To this end, we investigate users' needs considering various use cases and aim to provide an overview from scratch of what users want, guided by these research questions:

RQ_1 : "Which artefacts are suitable as TUIs for data transfer?"
RQ_2 : "How do users intuitively interact with the artefacts?"
RQ_3 : "Which factors influence interaction and artefact choice?"
RQ_4 : "Do users like the idea of using TUIs 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 transfer data in different situations. 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 a Wizard of Oz user 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 tangibles in data transfer.

2 METHOD

We employed qualitative research methods to investigate the field of data transfer. To answer our research questions, we firstly aimed to gain an understanding of user behaviour in data transfer and its influencing factors. Furthermore, in a task-based user study, we explored the reasonableness of tangibles in this field.

2.1 Preliminary Study

As we followed a user-centred approach to answer our research questions, our first step was to learn about users' experiences with

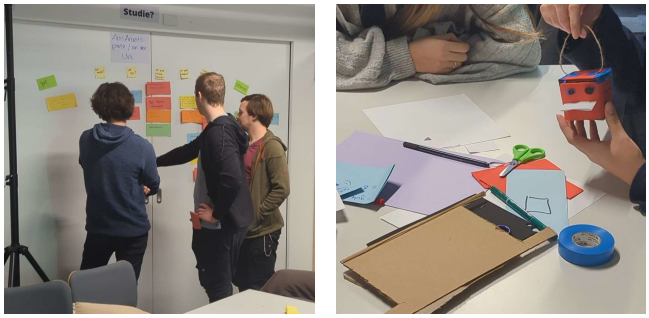

Figure 2: During our design thinking workshop, participants collected experiences with data transfer (left) and later built prototypes for tangibles (right).

data transfer in their everyday lives. As interactive workshops are an established first step to explore new design spaces [24], we conducted a workshop with 13 participants following a human-centred design thinking approach [30]. This workshop allowed us to understand potential use cases for tangible data transfer. Impressions of the workshop are depicted in Figure 2. First, participants shared particularly good and particularly bad experiences as well as typical use cases of data transfer. Then, we asked them to build and design tangibles with different contexts of use in mind. Afterwards, we collected benefits and criticism on tangible user interfaces for data transfer. Results 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. These characteristics are divided among different situations. To take all these factors for our user study into account, we combined them in three different situations (Figure 3):

- "take your thesis with you to print it at the Copyshop"
- "view your images on the TV"
- "share documents with your colleague in the Office"

As the workshop's results indicate that users do not want to take additional devices along, we decided to focus on everyday objects as tangible user interfaces for transferring data in the next study. To narrow down a set of suitable objects, we conducted an online survey where 100 participants each entered five everyday carries they always have at hand. Besides the three most mentioned (card, phone, key), we picked representatives of wearables (watch) and disposables (tissue). Furthermore, we decided to include a pen since it is a known input device [2, 15, 23, 31, 32]. Eventually, participants used each of these six artefacts as tangibles for data transfer.

2.2 User Study

We conducted a task-based user study to observe how participants intuitively interact with tangibles for data transfer. Using different artefacts and imagined situations, we asked participants to perform data transfer between two devices.

2.2.1 Study Design. For our task-based user study, we opted for a mix of elicitation study and Wizard of Oz experiment to observe participants' natural behaviour. Thus, we did not give instructions

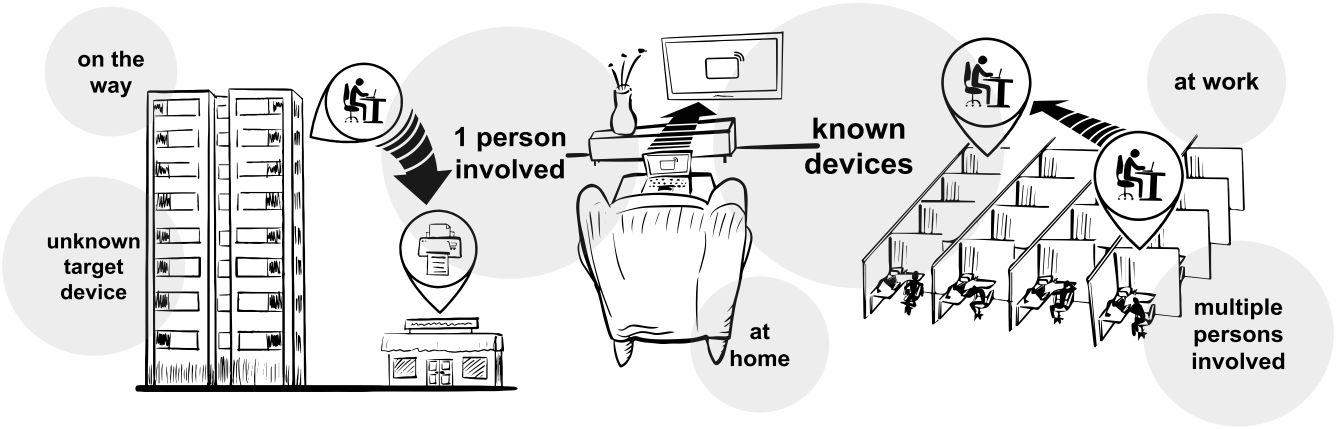

Figure 3: Situations in which participants transfer data during the user study from left to right: take your bachelor thesis to the Copyshop for printing, view your images on a TV, and share documents with your colleague in the Office. The study's supervisor represented the colleague in the Office condition.

on how to use any of the artefacts. We also pointed out that there are no technical restrictions, so participants could decide for themselves how the tangibles work and what features they have. 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 is successful.

Each participant has to intuitively perform a data transfer using six artefacts in three different situations. We chose these situations and artefacts based on a preliminary workshop and online survey. Therefore, our working definition of tangible artefacts is narrowed down to the six analogue or digital objects Key, Pen, Phone, Watch, Card, and Tissue.

2.2.2 Procedure. We invited participants separately to our lab. First, they were briefly introduced to tangible user interfaces in general, as well as the study's procedure. Then, they gave informed consent and filled in a demographic questionnaire. Afterwards, we asked them to imagine the three situations successively. For each situation, participants demonstrated their desired interaction for all six objects while thinking aloud. They also ranked the objects on a scale from *best* (1) to *worst* (6) according to their reasonableness in data transfer in the respective situation. 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 tangibles 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.

2.2.3 Participants. We recruited 30 participants (18 m, 11 f, 1 x) for our user study. They were aged 19 to 29 ($M = 24.33, SD = 2.52$). Their affinity for technology was between 2.33 and 5.56 ($M = 4.36, SD = 0.51$) on the ATI scale [11].

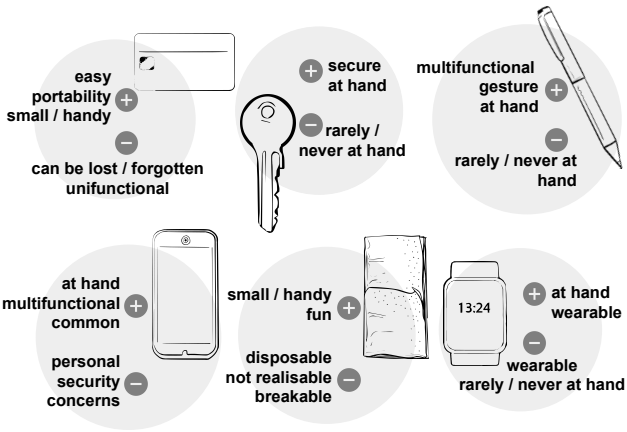

Figure 4: Objects we used in our user study: Card, Key, Pen, Phone, Tissue, and Watch. Participants associated different advantages and disadvantages with each object.

3 RESULTS

We annotated and coded all recordings and notes of our study. We combined similar codes to create broader categories for performed interactions, characteristics of artefacts and influencing factors following our research questions.

3.1 Which artefacts are suitable as TUIs for data transfer?

Overall, results of both our workshop and our user study indicate that everyday objects can serve as tangibles. To further investigate which objects are preferred, we analysed the rankings of objects overall, as well as for each situation. Over all situations, in rankings from 1 (best) to 6 (worst), Phone received the lowest mean score, and Tissue the highest. When comparing the situations, participants ranked the objects quite similarly in all of them. In the overall

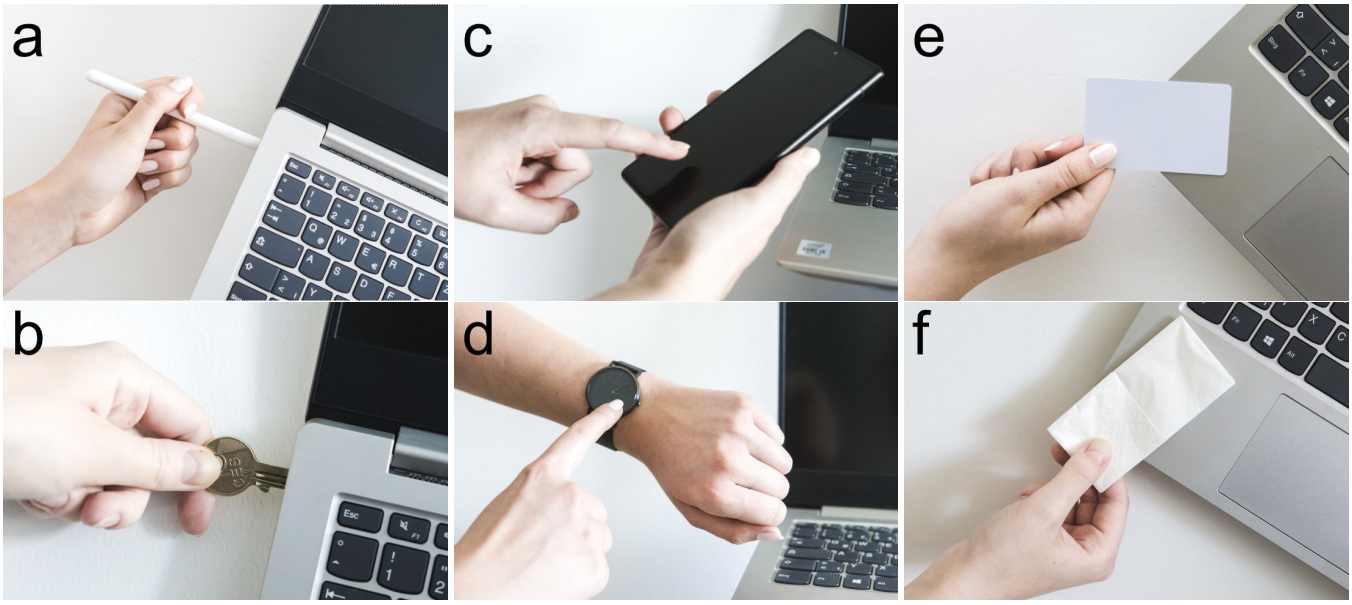

Figure 5: Most frequently performed interactions per artefact. Pen (a) and Key (b) were inserted, Phone (c) and Watch (d) were used via wireless connection, Card (e) and Tissue (f) were placed on.

ranking, most participants preferred Phone (20), followed by Card (10) and Watch (7). The less preferred objects were Key (6), Pen (4), and Tissue (1). To gain further insights into why participants ranked the objects the way they did, we analysed the mentioned advantages and disadvantages for each object and combined similar ones (Figure 4).

3.2 How do users intuitively interact with the artefacts?

Participants used a lower variety of interactions when using Card, Key, or Phone. In contrast, Watch, Pen, and Tissue showcased more variability in their interactions. This might indicate, that for example when interacting with the Tissue the affordance is less clear in comparison to the interaction with a Card. The number of different interaction is distributed as the following:

Card	11	Phone	14
Key	13	Tissue	21
Pen	18	Watch	16

Additionally, we investigated which interaction can be assigned to which object. To determine this, we analysed which interactions were most frequently performed with which objects. As illustrated in Figure 5, we observed that participants primarily utilised 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. Attributes associated with these interactions are listed in Figure 1. Additionally, Figure 6 illustrates unconventional interactions performed by some users. These are interesting because the affordance of the objects is reflected in the interaction performed.

3.3 Which factors influence interaction and artefact choice?

We inquired whether participants preferred using a single object for all situations or different objects for different use cases. Of 30 participants, 16 preferred using one object in all situations, while the remaining 14 preferred using specific objects in different situations. Main reasons for using dedicated objects in specific situations were to distinguish between public and private context (9), as well as privacy and security (5). For favourite 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. We also examined the factors that influenced participants in their choice of preferred object and interaction overall. We found that participants' choices were influenced by a combination of physical, psychological, social, and contextual factors which are illustrated in Table 1 (Appendix).

3.4 Do users like the idea of using TUIs for data transfer?

As a final step, we asked participants whether they like the idea of using tangible objects for data transfer. Almost all participants (25) indicated a willingness to use tangible objects 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 tangible 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). When asking about their general impression of tangibles in data transfer, the idea was found to be promising – under the condition that the aforementioned user concerns are addressed.

Figure 6: 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).

4 CONCLUSION

In this work, we explored interaction techniques for cross-device file transfer using tangible objects. To this end, we used qualitative methods to learn about affordances of different everyday objects in different situations. Firstly, by carrying out a workshop, we found that users transfer data at home, in a professional context, as well as on the way. The situations also differ in the number of people involved and the type of target device. Since users run the risk of forgetting something and do not want to carry an extra device, they appreciate the idea of using artefacts that are at hand anyway. To further investigate intuitive tangible data transfer, we conducted a user study. Participants transferred data in typical situations as they would intuitively do using six everyday objects as tangibles: Card, Key, Pen, Phone, Tissue, and Watch.

Our results show that numerous factors need to be considered when designing tangibles. In a private context without other people involved, users tend to prefer multifunctional devices. This contrasts with previous work, which usually designs a tangible only for a specific use case. Moreover, when designing tangibles, it is important to ask for users' associations with the object, regarding the interaction, as well as the objects' attributes. TUIs require physical interaction, which can be seen as both advantage and disadvantage. Thus, it is not possible to make a general statement about whether tangible user interfaces add value to data transfer. Users have found solutions to transfer data over time. Even if these solutions are not perfect, they will first and foremost fall back on what they already know. New tangibles should always be developed in comparison to existing systems to ensure that the new system offers enough added value so that users will embrace it. To sum up, it is important to know the intended target group and use case in detail. Our conclusions form a solid foundation for further research and provide many cues for designing tangible user interfaces.

5 LIMITATIONS AND FUTURE WORK

Even though we gained solid insights into users' needs in tangible data transfer, our results are only a first step towards understanding the use of tangible user interfaces for cross-device data transfer. As all of our participants can be considered digital natives, our results may not be generalisable to a manifold population. We cannot rule out that older people or children would have interacted differently. Nevertheless, the results of the ATI scale indicate a mixed affinity for technology among our participants. In our elicitation study, we used real objects participants were familiar with. Therefore, participants had previous experience in using those objects, which has certainly impacted their behaviour 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. Additionally, we focused on everyday carries as tangibles. But instead, it might be more reasonable to consider which objects are at hand in a particular situation. Although we asked participants to put themselves in the situation, an observational study in a real-world setting could help to gain even more information to examine intuitive interactions. Yet, through conducting a laboratory study, we were able to understand the motives of the participants through what was said at the think aloud.

Nevertheless, through our workshop and user study, we gained a quite promising dataset through qualitative data acquisition that includes interaction techniques for certain everyday objects and their attributes — in itself and for the respective interaction. We provided a first overview of our results, but this data still allows for much more detailed analysis by looking at references in a more nested way. In a next step, we aim to draw conclusions based on our results to form guidelines for the development of tangibles, overall and for data transfer. To this end, we will further evaluate our results.

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A APPENDIX

Table 1: Factors influencing choice of artefact and performed interaction. We could derive following mapping of factors and categories from our post-study interviews: physical, contextual, social, psychological, technical.

	physical	contextual	social	psychological	technical
material	×				
shape	×				
location	×				
location change	×	×			
presence		×			
situation		×			
hand over	×	×	×		
persons involved		×	×		
privacy			×		
comfort		×		×	
intuition				×	
usability				×	
familiarity				×	
affordance				×	
realisability					×
multifunctional					×
compatibility					×