Peak Moments of Physical Mobile Interaction Techniques

Completed Research Paper

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ABSTRACT

Users are able to connect their mobile phones to nearby objects using four common physical mobile interaction techniques: pointing, touching, scanning, and typing manual input. A set of prior user studies has compared these techniques, but none of the comparison studies have included a more recent form of the pointing technique: image recognition. We investigate users' peak-moment experiences while using physical mobile interaction techniques, including image recognition, by applying the critical incident technique (CIT). As a result, we present a comprehensive categorization for sources of user perceptions, describe the differences between the techniques, and position image recognition among other techniques. Our study adds a source category – achievement – that prior comparison studies have not covered. Also, we discovered that control is a crucial issue for users, even though it is often understated in prior comparison studies.

Keywords

Physical mobile interaction, user study, user experience, evaluation, critical incident technique

INTRODUCTION

Users commonly employ their mobile devices to interact with their surroundings. Through such interactions, users are able to, for example, acquire digital information about physical objects, share and create content related to one's surroundings, or perform other interactions such as ticket purchases. According to an established classification of physical mobile interaction techniques, users can point objects, touch objects, scan their surroundings, or manually type input directly into their mobile phones to interact with smart or everyday objects (Rukzio, Broll, Leichtenstern and Schmidt, 2007; Rukzio, Leichtenstern, Callaghan, Holleis, Schmidt and Chin, 2006). Pointing is typically associated with capturing visual tags or using laser pointers, while touching is connected with NFC and RFID tags. Scanning may use Bluetooth or Wi-Fi to form a list of objects from which the user can select and connect to an object.[1] Technically, these techniques have been developed and tested for years, yet we still lack comprehensive knowledge about user perceptions on comparing the different techniques.

With physical mobile interaction techniques, there are two phases: connection and subsequent interaction. Some researchers have compared different techniques in the subsequent interaction phase (e.g., Baldauf, Fröhlich, Buchta and Stürmer, 2013), but this phase is out of the focus of our study. We concentrate on the initial phase, where the user forms a connection between a mobile phone and an object. For related work, there is a limited set of prior studies that investigate the connection phase from the users' perspective (Broll, Siorpaes, Rukzio, Paolucci, Hamard, Wagner and Schmidt, 2007; Mäkelä, Belt, Greenblatt and Häkkilä, 2007; O'Neill, Thompson, Garzonis and Warr, 2007; Rukzio et al., 2006, 2007; Von Reischach, Michahelles, Guinard, Adelmann, Fleisch and Schmidt, 2009; Välkkynen, Niemelä and Tuomisto, 2006). However, none of these studies include *image recognition* as a pointing technique in their selection of the compared techniques. Image recognition is a more recent interaction concept in which an object of interest is identified through the camera of the mobile device by applying sophisticated algorithms. The finding that different pointing methods lead to different user perceptions (Rukzio et al., 2007) further supports the need to investigate image recognition as a pointing technique, since it notably differs from visual codes and laser pointers that have already been studied in a variety of contexts. We study a topical context – interactive public displays – in which the connection and subsequent interaction phases are clearly distinguishable.

[1] More detailed descriptions and examples of each physical mobile interaction technique can be found in the work by Rukzio (2007).

To address these issues, we present a comprehensive categorization for sources of users' positive and negative perceptions. With the help of this categorization, we describe the differences between physical mobile interaction techniques and position the recent pointing technique, image recognition, among other techniques (Figure 1). As a methodological contribution, this study demonstrates how the critical incident technique (CIT) can be used in laboratory studies. The research questions are:

- What are the sources of particularly positive and negative moments in the connection phase of physical mobile interaction?
- How and why do these sources appear?
- How is image recognition, as a pointing method, perceived compared to other techniques?

Figure 1. Illustration of physical mobile interaction techniques. From left to right: pointing (image recognition), pointing (QR codes), touching (NFC), scanning (Bluetooth), manual input (text typing)

USER PERCEPTIONS OF PHYSICAL MOBILE INTERACTION TECHNIQUES

As information systems have become more commonplace, ubiquitous, and targeted for end-users, the focus on measuring utilitarian and pragmatic perspectives has shifted into understanding more holistic user perceptions that include hedonic aspects (Hassenzahl and Tractinsky, 2006; Van der Heijden, 2004). Utilitarian aspects relate typically to instrumentality, quality, usefulness, ease of use, and social utility, while hedonic aspects relate to enjoyment, fun, aesthetics, and affection (Hassenzahl and Tractinsky, 2006; Holbrook, 1998). Both Holbrook (1998) and Hassenzahl and Tractinsky (2006) confirm that utilitarian and hedonic aspects may appear simultaneously, and this has also been found to be true in physical mobile interaction (Salo, Olsson, Makkonen, Hautamäki and Frank, 2012). Utilitarian and hedonic aspects of different physical mobile interaction techniques have been considered in prior comparison studies as follows.

Utilitarian Aspects

The main utilitarian advantages of the touching technique compared to other techniques are its speed, simplicity, easiness, cognitive effortlessness, naturalness, and reliability (Broll et al., 2007; Mäkelä et al., 2007; Rukzio et al., 2007; Von Reischach et al., 2009). Even though users have preferred touching specifically over pointing (Broll et al., 2007; Mäkelä et al., 2007), pointing might outweigh touching in some properties such as lower physical effort (Rukzio et al., 2007). The lack of needed physical effort is also an advantage for scanning, but the other properties of scanning are considered rather mediocre (Rukzio et al., 2007). Not surprisingly, the manual input technique is considered slower and more difficult to use compared to touching and pointing (Rukzio et al., 2007; Von Reischach et al., 2009). Though unexpected, in some cases, users have preferred manual input because of its quickness or familiarity (Broll et al., 2007; O'Neill et al., 2007).

Issues of social acceptance, which are mostly utilitarian but may also reflect hedonic aspects, affect user perceptions, especially in public places (O'Neill et al., 2007; Riekki et al., 2006). In the field, users have reported feeling embarrassed or awkward when touching tags in public places because it might draw some unwanted attention (O'Neill et al., 2007; Riekki et al., 2007). In contrast, pointing is sometimes suggested as a more unnoticeable and socially acceptable way to connect with objects in public places until touching becomes more common (Välkkynen et al., 2006). Indeed, a study shows that some users see pointing as a more familiar and socially acceptable way to interact with objects than touching (Mäkelä et al., 2006). Scanning and manual input techniques are typically used in a similar way with other common features of a mobile phone, so with those techniques, there are presumably less issues regarding social acceptance.

In addition to these main properties, there are other less-studied utilitarian issues: users have control, security, and privacy concerns about physical mobile interactions in public places (Mäkelä et al., 2007; O'Neill et al., 2007; Riekki et al., 2006; Välkkynen et al., 2006). Users of tagging systems reportedly worry about movement monitoring and misuse of personal information (Günther and Spiekermann, 2005). Users have expressed that visual or RFID tags can be hacked, changed, or modified, whereupon users may receive harmful content (Mäkelä et al., 2007). Some users are even afraid of unintentionally receiving harmful content just by walking by tags (Mäkelä et al., 2007; O'Neill et al., 2007). As a consequence of such

thoughts, Riekki et al. (2006) found that their test users wanted to know the identity of their interaction counterpart. Also, there is a practical risk of mobile phone theft in public places (O'Neill et al., 2007). These issues of control, security, and privacy are assumedly more crucial in cases where mobile phones contain a large amount of important personal data.

Hedonic Aspects

For fun and innovative- related properties, Rukzio et al. (2007) rate touching, pointing, and scanning high, while only manual input is rated low. Broll et al. (2007) confirm these extremes by showing that users perceive touching as an enjoyable technique while they perceive manual input as neither enjoyable nor innovative. With touching and pointing, the naturalness of the technique may promote not only utility, but also enjoyment. Mäkelä et al. (2007) have reported user comments about the visual appeal of 2D codes, but other graphically aesthetical aspects of interaction techniques seem to remain unreported in previous comparison studies.

METHOD

The aim of the empirical part of our study is to thoroughly understand users' perceptions on utilitarian and hedonic aspects. Thus, we conducted a qualitative content analytic user study in laboratory settings. We decided to tap into users' perceptions by examining their single positive and negative moments with each physical mobile interaction technique.

Critical Incident Technique (CIT)

The main idea of CIT, originated by Flanagan (1954), is to ask respondents to describe their crucial incidents within a certain situation. Typically, users describe a single outstandingly positive or negative experience from their past orally or in writing. CIT has been used widely in service research to assess customer evaluations of service (Gremler, 2004). To summarize, CIT involves *"a set of procedures"* (Flanagan, 1954) *"to collect, content analyze, and classify observations of human behavior"* (Gremler, 2004). The strengths and the weaknesses of CIT are reflected in Figure 2.

Strengths

1. Researchers are able to gain a thorough understanding of relatively new phenomena, such as physical mobile interaction (Gremler, 2004; Meuter, Ostrom, Roundtree and Bitner, 2000).

2. Respondents only report the aspects that are particularly relevant and important for them, since they already have processed each response cognitively. For example, the traditional qualitative interview would often be more time consuming or constricting: the researcher has to either limit the interview themes or spend long hours afterwards defining what is relevant and important.

3. CIT enables researchers to find issues that might be missed with other techniques (Serenko and Stach, 2009), since the technique does not force responses into any predefined perspective or framework.

Weaknesses (Gremler, 2004)

1. CIT only captures the extremes of positive and negative moments without paying attention to what is between them. However, in this study, we want to focus on such extreme moments, since related studies have conducted more typical evaluations.

2. Recall bias, a typical risk for CIT studies, does not have much of relevance in our study because of the study's narrow time frame.

3. The analysis of qualitative data is always subjective, but we decrease the level of subjectivity by measuring interrater reliability.

Figure 2. Addressing the strengths and the weaknesses of CIT

IS researchers have used a rich variety of methods in user studies to support product or service evaluation. Yet, the use of CIT has been very scarce, even though it is considered a proper technique for end-user review and judgement in laboratory settings (Hartson, Andre and Williges, 2001). Only a few recent laboratory or field studies seem to include similar aspects with CIT; for example, right after the experiment, users were asked to describe three particularly positive or negative aspects (Hassenzahl and Ullrich, 2007) or to specify single meaningful situations (Knobel, Hassenzahl, Lamara, Sattler, Schumann, Eckoldt and Butz, 2012). Consequently, there seems to be much more room for using CIT in laboratory or field studies.

Study Design, Data Collection and Participants

Study setting. In the laboratory, we developed and setup prototypes of the following five physical mobile interaction connection techniques for public display: image recognition, QR codes, NFC, Bluetooth scanning, and manual text input (Figure 1). All of the prototypes were fully operational, except for Bluetooth scanning, which was simulated. From a

technical point of view, we standardized all techniques to seamless functionality and designed them to match current state-of-the-art specifications in terms of, for example, speed. All of the techniques employed similar user interface principles. With image recognition, markerless image recognition was enabled by detecting salient image regions, the description of features, and corresponding matching algorithms to compare a newly taken photo with a reference target from a set of known images. More detailed descriptions of the prototypes can be obtained from the authors. We had two parallel TV displays as public displays within a 3-meter distance from each other. Even though our focus was on the connection phase, we wanted to design realistic context and post-connection activity. Thus, one display showed a public opinion poll and the other offered a travel agency quiz. The NFC tags and QR codes located in front of the displays. We positioned display names and IDs for scanning and manual input in the right corners of the displays, as suggested by Rashid, Terrenghi, and Quigley (2010). Before the actual user study, we conducted two full pre-tests with smartphone owners to refine the interview questionnaire and to finalize practical and technical issues.

Participants. In order to focus on current physical mobile interaction issues, we carefully selected a specific sample group of 33 persons, the demographics (age and sex) of which reflect the population of smartphone owners in Austria. The group consisted of 20 males and 13 females, and 16 of them were between the ages of 18 and 29, 10 between 30-49, and 7 over 50. All but two owned a smartphone, and most agreed rather highly with statements regarding technology use, mobile skills, and personal innovativeness. We offered each participant a gift card as compensation for the 2.5 hour test.

Test. At the beginning of each individual user test, the participant was briefed about all of the techniques with accompanying illustrative photos. By a systemically alternated order of techniques, every participant underwent a training and a test phase for each technique. In the training phase, participants trialed the said technique until they thought it was familiar enough. During the actual test, participants connected with the displays and switched the display at least four times at their own pace.

CIT interviews. By following Bitner, Booms, and Tetreault (1990), Flanagan (1954), and Meuter et al. (2000), each respondent was asked immediately after each technique to *"think of a moment [in the previous session] that was particularly positive or negative"* and to *"feel free to take some time and try to come up with the most positive or negative moment."* After coming up with such a moment, the respondent described what happened and what specifically caused the positivity or negativity. To address the specific cause and their reasoning in more detail, the interviewer asked a series of *"why"* and *"why is that important for you"* questions, similar to the laddering interview technique (Reynolds and Gutman, 1988). Finally, the interviewer asked the participant to describe his/her feelings and emotions during the moment as well as to rate the moment on a 5-point scale from neutral (1) to extremely positive/negative (5). Through this procedure, we aimed to tap into users' peak moments during a service process, as illustrated in Figure 3. The interview was supplemented with observation notes by the interviewer, and the tests were videotaped with user permission.

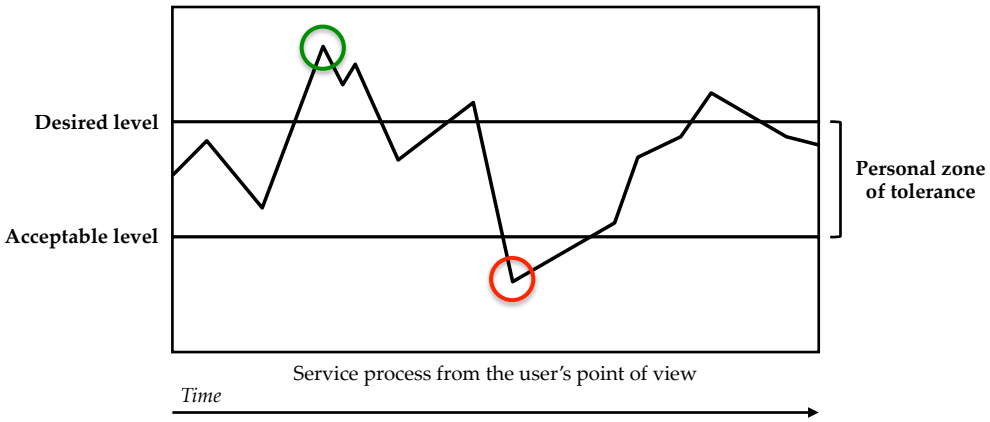

Figure 3. An example illustration of peak moments during a service process, inspired by Johnston (1995), Odekerken-Schröder, Van Birgelen, Lemmink, De Ruyter, and Wetzels (2000), and Zeithaml and Bitner (2003)

Content Analysis

As researchers should define criteria for inclusion and exclusion of critical incidents (Bitner et al., 1990; Gremler, 2004), we analyzed only the descriptions that reflected a single moment; the participants had described in sufficient detail; and ranked particularly positive/negative (from 3 to 5). From the 427 collected incidents, 226 met these criteria and were included as units of analysis. The content analysis followed the main guidelines set by Gremler (2004) and Srnka and Koeszegi (2007) (Table 1).

Step 1	
Reading data, screening prior research	One author read and reread the data, wrote notes, and identified keywords as suggestions for categories. Simultaneously, the author screened prior studies of physical mobile interaction techniques in order to find similarities within the data.
Step 2	
Forming a categorization scheme (Appendix)	The author then adopted initial categories from prior comparison studies, modified them to match the data, and developed one new category on the grounds of the data. These categories were discussed and refined with other authors.
Step 3	
Coding moments into categories	One author coded each moment description into one or more categories. The codings for borderline cases were discussed and decided together.
Step 4	
Measuring interrater reliability	Two independent coders, blind to others' codings, analyzed 50 positive and 50 negative moments. The consensus estimates for the codings, after the number of categories per moment was given, were 97.5% and 93.8%.

Table 1. The steps of our content analysis

RESULTS

Of all of the 226 described moments, 142 (62.8%) were positive and 84 (37.2%) were negative. On a 5-point-scale (1=neutral, 5=extremely positive/negative), the average rating of all positive moments was 4.2 and 3.8 for all negative moments. The distribution of the moments into categories is illustrated in Figure 4.

Utilitarian Aspects

Simplicity

In our data, simplicity reflects a great share of the moments. More positive moments were related to image recognition than to other techniques, but still, each technique received praise from the users. The users describe image recognition as having *"smooth uncomplicated functionality*" and an *"easy"* technique to use and learn *"without any effort."* Often times, the user is surprised about the simplicity of image recognition. As NFC and QR techniques are also straightforward and uncomplicated, the older techniques – scanning and manual input – have their strengths in familiarity and similarity to well-known ways to use mobile phones.

For negative moments, only one moment of image recognition reflects simplicity, and it actually originates from the user's habit of using the camera in landscape mode. A few users commented that NFC tags and QR codes might require more learning and effort, since the user is required to *"get close to connect."* However, scanning and manual input are complex. With scanning, users mentioned effort *("laborious"),* misconnections due to the complex list *("I would have been connected to a different [display]")*, and a more-than-one-step process *("I need to make a detour here").* Correspondingly, manual input is related with physical effort *("I definitely have to come nearer to the [display]")* as well as typing effort and mistakes *("mistype, clean, type again")*.

Speed

In the positive descriptions, users tend to see speed as a strong advantage of image recognition because the point of connection is very quick and sometimes described as even *"faster than me."* Some moments of NFC and QR codes are associated with speed and instant responsiveness *"with no waste of time*,*"* but only a few users mentioned speed as an advantage of scanning or manual input.

The negative moments in this category primarily relate to scanning and a few with QR codes, while there are almost no negative moments associated with image recognition, NFC, or manual input. Scanning is considered slow and unresponsive by several users because it sometimes keeps the user *"waiting for the list to build up*,*"* after which the user still has to *"scroll," "find,"* and confirm the wanted object. With QR codes, sometimes targeting the code just *"took longer."*

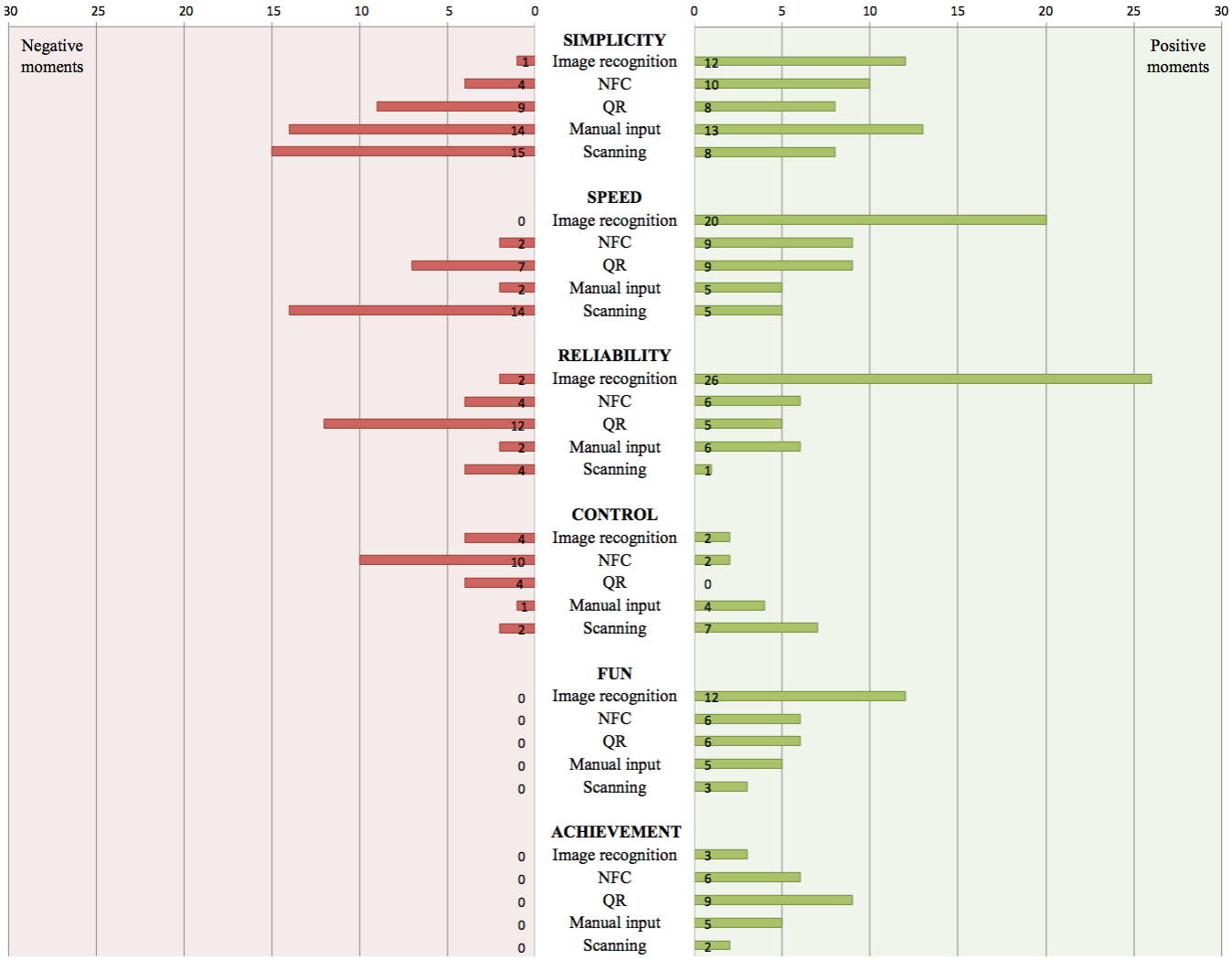

Figure 4. Distribution of peak moments regarding techniques and categories

Reliability

Many users had positive moments with image recognition, especially due to reliability and accuracy issues, such as distance *("it's working from distance")*, angles *("special angle wasn't required")*, and partial recognition *("only a small part has to be aimed")*. At times, NFC, QR codes, and manual input are also considered stable and reliable techniques. For example, touching the NFC tag may *"fulfill reliable [one's] expectations – like locking a door."*

The associated negative moments were mostly about QR codes, which generate some distrust *("I've done it like I'm used to and normally there is no problem with [targeting]")*, and suspicious questions about the functionality *("How to use it? How can I make it* so *the [targeting] works?")*. A few users mentioned similar doubts about scanning *("Will [the object] even appear [in the list], is there something broken?")*. Also, some users had moments when they had to accurately place the mobile to NFC tag to make it work.

Control

Most of the positive moments in this category relate with the more traditional techniques – scanning and manual input. These techniques are able to *"give the feeling of control,"* since users can decide and use their own actions to steer the process. Practically, such moments reflect freedom of location.

In contrast, users had negative moments with image recognition, NFC, and QR codes. During such moments, users felt they were *"at the mercy of [the technique]"*: bound, restricted, forced, and limited. In particular, image recognition was described to make the connection too quick without any confirmation requests. Control aspects often include issues of security and

safety *("losing the handbag in the crowd when I'm distracted because of the mobile")* as well as privacy *("feels like everybody can see what I'm doing on my private device")*. With NFC, a few users also had concerns related to hygiene and scratches.

Hedonic Aspects

Fun

Within this category, users had active play-and-fun moments and described passive appreciation for beauty and aesthetics. Sometimes, the effort and challenge made a moment highly active and thus *"playful,"* even though there were no special game elements. Beauty, in particular with image recognition and NFC, is associated with enjoyment and such words as *"cool," "wow," "exciting,"* and *"astonishing."* With image recognition, one user even had the illusion of *"a self-teaching machine."* However, all of the techniques were associated with moments of fun; for example, one user had a playful moment with the scanning technique after searching for the wanted object from the list.

None of the negative moments in our data were caused by issues related to fun.

Achievement

Some of the peak moments are associated with enjoyment of self-growth and the success of achieving something. Some of the strongest expressions include *"outsmarting"* and *"triumph[ing]"* over the technique. Particularly, the techniques that require effort can be stimulating and generate a sense of achievement, as the following example of QR codes describes: *"Hey, it works! I was close enough and it started. Success, [a] small sense of achievement."*

None of the negative moments in our data were caused by issues related to achievement.

DISCUSSION

This study contributes to the literature on physical mobile interactions by presenting a comprehensive categorization for sources of user perceptions with detailed descriptions. Since the prior comparison studies have mainly focused on rankings of predefined categories, our content analytic approach helped us identify a previously uncovered category, *achievement*. Some users enjoyed this sense of success, especially when a technique required some effort, was challenging, or unfamiliar. For example, a few users had to puzzle over QR codes for some time, which eventually led to triumphing over the technique. We also found that *control* seems to be a crucial issue for users, even though it is often understated in prior comparison studies. Users had a variety of control-related concerns, ranging from feeling restricted to lost privacy and fear of accidents. Despite these negative issues, control may also promote positive perceptions by feeling free and independent from a technique. Such positive effects are especially related with the more traditional techniques: scanning and manual input.

Importantly, with the categorization, we found out that hedonic aspects only affected positive moments, but not negative ones. Further on, some of the users considered some techniques more interesting than others because of hedonic aspects, especially *fun*. This could mean that such fun aspects may be success factors when users evaluate and select their favorite among many alternatives for physical mobile interaction.

In practice, our comparison makes it is easier to distinguish between the typical strengths and the weaknesses of a certain technique. Some of the findings are in line with previous studies (cf. our review section), but it seems the properties of the techniques are not as unequivocal as thought due to their multidimensionality and users' subjectivity. For example, some users perceive the scanning technique as slow because of the connection process' overall duration, while some users find the same technique fast because each event in the process progresses quickly. Additionally, our detailed investigation revealed new insights about several detailed issues affecting user perceptions, such as touching-related hygiene and scratches as well as the illusion of a self-teaching machine.

As one of the research tasks was to compare image recognition with already established techniques, the distribution of the moments reveals that users associate it with numerous positive moments and very few negative moments. The positive moments reflect both utilitarian and hedonic aspects: users perceive image recognition as simple, fast, accurate, and capable of creating playful moments without any actual gaming elements. These are all aspects of which application developers should take advantage. With negative issues, there are some concerns regarding control and security with image recognition. Issues caused by the too-immediate connection could be overcome by implementing a confirmation gesture or button.

Methodological Contribution

Overall, we found CIT suitable for user studies in laboratory settings. With the technique, researchers can reach information that other techniques do not necessarily cover. Based on our experience, we advise researchers to pay attention to the following issues: First, there are differences between users. Some users provide rich and detailed moment descriptions while others have difficulty identifying or describing peak moments. In our case, the rather short test and interview cycles might have affected users in that they simply did not have much to say. Second, CIT highlights the role of the interviewer and thus requires the ability to react and guide the discussion. For example, some users found it easy to describe moments when the questions were presented with the exact words, but with others, the interviewer had to use variations of wordings. Third, some users described contradictory moments that included both negative and positive aspects. However, researchers can beat most of these difficulties through careful planning and training, conducting preliminary interviews, and applying detailed criteria for incidents to be included in the study.

Limitations and Future Research Topics

First, the main limitation is that the study does not cover social issues because it was conducted in a laboratory setting. Still, this paper focuses on the connection technique itself and succeeds in providing new knowledge on the issue. In the future, a replication study could be conducted in field settings to investigate possible social issues. Second, the size of the sample group is relatively small. In qualitative research, it is important to seek a deeper understanding of the phenomenon, so our main aim did not lay in producing generalizable results. Third, perception of what constitutes *"a moment"* slightly differs among respondents. We do not see this as a serious problem, since the data enable moment-based evaluation of the techniques as we planned. In the future, researchers could extend the analysis by building hierarchical value maps that link product attributes with consequences and personal values, as presented by Reynolds and Gutman (1988).

ACKNOWLEDGMENTS

We thank Rosa Nisula, Janne Pirttiniemi, FFG and A1 for funding the PRIAMUS-project and the COMET-program, the Nokia Foundation, the Research and Training Foundation of TeliaSonera Finland Oyj, and the HPY Research Foundation.

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Appendix: Categorization Scheme

Utilitarian Aspects

Simplicity

A service is easy, simple, straightforward, effortless, or convenient (or difficult, complicated, effortful, laborious, or inconvenient) to use and learn.

+ Example: *I could make a connection in a smooth and simple manner with minimal effort.*
- Example: *It was laborious and took some learning.*

Speed

A service is quick, timely, or responsive (or slow, time-demanding, or unresponsive) in use.

+ Example: *It connected quickly without waiting.*
- Example: *It was slow so I had to wait.*

Reliability

A service is reliable, accurate, exact, precise, or trustworthy (or unreliable, inaccurate, inexact, imprecise, or untrustworthy) in its performance. These issues are often related with targeting, recognizing, and making the connection.

+ Example: *It performed more accurately than I thought, even with distractions.*
- Example: *I had doubts about whether the service even worked.*

Control

A service provides feelings of control, freedom, privacy, security, and safety (or being restricted, limited, forced, bound, insecure, unsafe, and lacking privacy).

+ Example: *I could decide and confirm the action I wanted to happen.*
- Example: *The machine was in charge of making the connection – I was restricted.*

Hedonic Aspects

Fun

A service is fun, playful, exciting, astonishing, cool, wow, or otherwise aesthetic.

+ Example: *It was amazing how well it performed, wow!*

Achievement

A service provides enjoyment based on feelings of self-growth, a sense of achievement, and success.

+ Example: *I enjoyed the sense of achievement because I managed to do it.*