TECHNOLOGY-SUPPORTED DESIGN RESEARCH

Thoring, Katja (1,2); Mueller, Roland M. (3); Badke-Schaub, Petra (1)
1: Delft University of Technology, The Netherlands; 2: Anhalt University of Applied Sciences, Germany; 3: Berlin School of Economics and Law, Germany

Abstract

This survey paper explores the opportunities and challenges of new technologies and social media for design research and design ethnography in particular, and summarizes the results in a framework. Understanding users' needs and observing their behavioral patterns becomes more and more important when designing innovative products or services. Traditional design ethnography mainly consists of in-depth interviews and field observations of individuals or groups in the social context to be investigated. Digital technologies might enable new possibilities in collecting, analyzing, and visualizing research data. Advanced hard- and software, the ubiquitous presence of smartphones, global accessibility of data, and new technological and social concepts, such as social media or crowdsourcing, allow for new approaches in design research. We suggest that technology nowadays is able to not only collect large numbers of data but also improve data quality by providing access to new approaches in design research as well as facilitating and assisting the researcher with coding and interpreting the collected data.

Keywords: Research methodologies and methods, Ethnography, Technology, Social Media, Survey Paper

Contact:
Katja Thoring
Anhalt University of Applied Sciences
Dessau Department of Design
Germany
katja@thoring.com

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1 INTRODUCTION

The Human-Computer-Interaction (HCI) research community has a long tradition in user research, and often makes use of ethnographic methods. Ethnography is an umbrella term for different research methods that target at observing and analysing a research subject in a given context. It is characterized by several aspects, such as fieldwork involving observations and interviews of individuals and groups in their respective environment, and results in empirical data (Hammersley and Atkinson, 2010). The main characteristic of ethnographic research is the aim to observe and analyse the research subject from various angles and perspectives. This so-called *triangulation* is supposed to reduce the possible bias of the researcher and achieve a holistic picture of the studied context. The combination of several research sources produces different perspectives, and the subsequent interpretation of the collected data will be based on the comparison of more than one view (Jick, 1979). Particular for *design* ethnography is the overall goal to transfer the resulting insights into new products, services, or systems (Crabtree et al., 2012). Design ethnography uses traditional ethnographic methods of observation, interviews, and field research to analyse and understand human behaviour. The research subjects are being studied, as well as their interactions and behaviour within their social group, and their actions and interactions within their environment (field) and with involved artefacts. The collected data then have to be analysed and interpreted by the researcher to understand the social meaning and culture—needs, wishes, and values—of the research subjects. This paper explores how technology can facilitate the process of data collection through ethnographic research methods, as well as the possibilities to evaluate, structure, and interpret the collected ethnographic data with the help of digital technologies, and specifically how such technology might be utilized to improve data quality. To the best of our knowledge, there is no survey article yet that presents an overview of different technological advancements (hardware, software, social media) and how these can be utilized for ethnographic design research, which is the aim of this article.

2 TECHNOLOGY-SUPPORTED DATA COLLECTION

The following section presents an overview of selected technological devices and software that can be used for the collection of qualitative and quantitative data. We distinguish between self-monitoring tools, externally controlled monitoring tools, crowdsourcing, and social media. This overview is not supposed to be exhaustive—the selection has been made to illustrate the state of the art in technology as of the present date by presenting examples from each category.

2.1 Self-Monitoring

Self-tracking movements—sometimes referred to as "lifelogging"—describe people's attempts to track and document particular aspects of their personal lives and environments, either through manual recording or by specific technologies, such as wearable computing. This movement is not new: already decades ago this was quite a common habit among professional athletes or people with certain medical conditions who wanted to track, for example, their heart rate, blood pressure, or food consumption over a period of time or during specific activities. However, today new technologies have made it easier to track oneself and one's environment, turning this movement into a kind of lifestyle activity. Lifeloggers try to capture large parts of their lives, or even their entire lives, by constantly documenting and photographing their environment and experiences, as well as their personal activities or bodily functions. Possible tools to support this behaviour include a) wearable photo, video, and audio recording equipment, b) Activity and bodily functions monitoring tools, and c) behaviour and activity tracking software.

Wearable photo, video, and audio recording devices: Photo and video cameras, as well as audio recording devices belong to the standard equipment of ethnographical research. Nowadays these devices are much smaller and wearable, and might include new useful features for ethnographic research or visualization techniques. The ubiquitous presence of smartphones among users would enable participants to easily collect photo, video, and audio data through one device and upload it to joint databases or researchers to track participants' movements in a certain environment via GPS data (Melles and Jakobs, 2012). Head-mounted cameras, such as GoPro (2002), allow for hands-free video recording of specific activities, which has become very popular among extreme sportspersons (e.g.,

free climbing and surfing). Autographer (2013) is a wearable camera that automatically takes pictures based on sensor measurements, such as movement, change of temperature, light, or sound, and captures metadata such as date, time, and GPS coordinates. The Narrative Clip (previously named Memoto) (2012) takes pictures on a regular basis (e.g., every 30 seconds) and presents a summary of the most interesting moments of each day, based on specific algorithms. Also audio recording devices have developed further: Kapture (2014) is a wristband that captures audio recordings. It is always in standby mode and can easily be activated through tapping. A 60-second buffer guarantees that no important conversation will be missed. Wearable Computers combine several features in one device. For example, Google Glass (2013) combines the features of wireless Internet connection and the display of information in a head-mounted display that video records the visibility field of the wearer. The interface can be accessed via natural spoken language or unobtrusive body movements.

Activity and bodily functions monitoring: There are several tools available that quantitatively measure people's health or fitness aspects. Among these tools are the Nike+ FuelBand (2012), FitBit (2007), Jawbone (2006), Apple Watch (2015), etc. They all offer similar functionalities, usually in the form of a wristband device, with features such as step count, measurement of calorie consumption, heart rate and blood pressure metering, monitoring of general body and sleeping activities, etc. More complex systems offer combinations of several tools, such as Withings (2008), which adds also scales, a body mat, etc. to the wristband. All such devices come with software applications to monitor, track, and display changes within these measurements.

Behaviour and activity tracking software: There exist numerous activity tracking software applications that focus mainly on measuring and improving work productivity or to overcome procrastination. Examples are RescueTime (2008), Toggle (n.d.), or Time Doctor (n.d.), which all are software applications that can be installed on a personal computer to log work activities. They display graphic charts of time spent working on different applications or surfing the web. Other types of software are connected to previously mentioned tracking devices that present a visual overview of the measured activities.

Opportunities of technology-supported self-monitoring: The features of wearable cameras could be useful during ethnographic research because participants would only have to wear the camera, without having to bother much about what to photograph or how to handle the device. Also, the cameras are quite small, which makes it likely that participants would soon forget about their presence. Automated audio recording based on sensor measurements or a time-delayed buffer allow capturing of data that would otherwise be missed. The combination of video recording and immediate display of information (such as provided by Google Glass) is of particular interest. Participants could record their environments and their own behaviour, and the researcher would be able to immediately react to these by sending questions or instructions right onto the display. Activity tracking devices would produce mainly quantitative data (biometrics about blood pressure, geo-tags, time stamps, etc.) that could be used for triangulation with other data. Activity tracking software can be utilized to identify tacit values and unexpressed needs of people, according to the time they spend on specific tasks. Combinations of various devices and applications allow for new research approaches and the development of completely new tools. The concept of digital cultural probes (Gaver et al., 1999; Mattelmäki, 2006) could be one example of such new research developments.

2.2 External Monitoring

In the 1970s, Palo Alto Research Center (Xerox PARC) was among the first design research centres to systematically integrate ethnographic methods into its product development. Through the use of video observations, it analysed users' interactions with copy machines to improve the usability of its products (Orr, 1996; Suchman, 2001). Another common ethnographic research method is Shadowing (McDonald, 2005), which describes the observation of people in their natural environment. It involves a researcher following the research subject closely, if possible without any disturbance or intervention. Although video observation and shadowing are still valuable methods for design research, new technologies today allow for more sophisticated approaches in observation.

GPS Tracking: Since many devices include GPS tracking possibilities (e.g. smartphones, digital cameras), these could be utilized to track and monitor movements of participants within space.

Indoor Positioning: More precise indoor positioning techniques offer possibilities to observe people's behaviour within buildings, even distinguishing between rooms and floor levels. Technologies for indoor positioning can be based on Bluetooth (e.g., iBeacon by Apple), RFID (radio frequency

identifier), NFC (near field communication), or Wi-Fi. The advantage of RFID-based devices is that RFID tags can be very small and cheap and could be handed to the participants without their having to install something on their smartphones. NFC is also based on RFID standards. Compared to Wi-Fi and Bluetooth, it needs less energy but has a smaller reception range. iBeacon is mainly used to transmit customized advertising onto people's cell phones according to their position within a store and their proximity to specific products. Other technologies can be utilized to identify movement paths of people within a location.

Motion-sensors: Motion-sensing input devices, such as Microsoft Kinect (2010) or Nintendo Wii (2006), have been developed to control games. In ethnographic research these technologies might be utilized to monitor specific movements of participants or to recognize gestures. Another example of computer-processed body language are facial expression recognition systems that allow automatic identification of emotional and cognitive states of individuals through video analysis. Examples of such technologies are iMotions (2005) and nViso (2009). Fasel and Luettin (2003) present an overview of automatic facial expression analysis methods.

Drones. Drones are unmanned, remote-controlled, and mainly aerial vehicles that can video record activities of people to observe and track movements or accumulations of people. This technology is mainly known from broadcasters that monitor sports events or other mass gatherings. In scientific research, drones are often utilized to investigate areas that cannot be accessed by people, such as in very remote or hostile environments (contaminated disaster areas, outer space, or deep sea). Drones are not yet utilized much for ethnographic research purposes, although this seems to be a promising opportunity for unobtrusive observation.

Opportunities of external monitoring devices: Indoor positioning technologies might be of particular interest in research settings that analyse, for example, waiting situations at airports or train stations, students' behaviour on their campus, patients' and relatives' behaviour within hospitals, or visitors' behaviour in museums or restaurants. The behaviour and movements of the observed people can later be displayed on a map. Additionally, customized instructions or research prompts might be sent to the participants via the respective devices, according to their current location (e.g. through iBeacon) or their behaviour. Facial recognition software is particularly relevant for interviews and observations. One of the main goals of design ethnographic research is to understand the users' tacit feelings and values that sometimes might not be verbalized explicitly. Facial expressions can reveal such underlying emotions. Through drones people can be observed without their noticing, which is technically interesting because the observations would be very unbiased and result in very real impressions. Of course, for all these external monitoring technologies, privacy of the observed people has to be guaranteed or consent has to be requested, especially in cases in which personal data are being gathered or when people are being filmed or audio recorded.

2.3 Social Media and Crowdsourcing

Although social media and crowdsourcing approaches are still based on human judgement and reporting, the interfaces and channels are based on digital media and technologies, which is why we discuss these phenomena as a form of technology-supported ethnography.

Social media: Social media, such as Twitter or Facebook, but also the Internet in general with its various blogs, message boards, and newsgroups are often used to collect quantitative data, such as through online surveys sent to specific target groups that can be identified through their group memberships or their expressed interests. However, qualitative data can also be retrieved through these channels (Boellstorff, 2012; Hine, 2000). This method is also referred to as 'netnography', a term coined by Kozinets (2010, 1998). Garcia et al. (2009) discuss online environments as a means to collect ethnographic data. However, Ruths and Pfeffer (2014) discussed several methodological problems using social media to study human behaviour. They mentioned population biases of platforms (e.g. specific demographics are over or under represented at Twitter or Instagram), platform specific filtering and ranking, difference of reported and actual behaviour, or shaping of behaviour through the platform, among others.

Social Network Analysis: Social Network Analysis (Scott and Carrington, 2011) can analyse network structures of social relationships in an organization or community. It can calculate metrics of the whole social community or for individuals, as well as visualize the data in a graph. Examples of Social Network Analysis software are Gephi (Bastian et al., 2009) and UCINET (Freeman, Lin et al., n.d.).

Crowdsourcing: Crowdsourcing describes the attempt to divide a bigger task into several smaller subtasks and to distribute these to a crowd of people via the Internet (Kittur et al., 2008). This is especially helpful to accomplish very time-consuming tasks. The motivation for the crowd to participate in theses tasks can be threefold: 1) People could be paid small amounts of money for completing the tasks. The trading of such tasks usually takes place on a crowdsourcing marketplace, such as Amazon Mechanical Turk (Kittur et al., 2008). Such platforms can be utilized to ask people to photograph or videotape specific aspects of their lives or environments. 2) People can be motivated through gamification strategies (Von Ahn, 2006). And 3) there could be a motivation through reputation building in specific social groups. People like to contribute something within their social group to gain reputation or endorsements. One example for this crowdsourcing strategy is frogmob (frog design, 2010), a social media site initiated by the design firm frogdesign, on which members of the respective community contribute pictures to specific topics, such as pictures showing the contents of their refrigerators. Mueller et al. (2010) present a taxonomy of crowdsourcing strategies.

Opportunities of social media and crowdsourcing for data collection: Through social media, it is possible to observe what people share voluntarily in their public profiles or in Blog entries. That way, they would not even have to be recruited as participants of the study because they would not notice that they were being studied. Moreover, such platforms offer possibilities for direct discussions with members of a specific target group—similar to an in-depth interview. Social media platforms such as ResearchGate or LinkedIn are often used for such research purposes. Crowdsourcing and social media make it possible to gather ethnographic insights from all over the world, without having to travel to various locations. However, the researcher must bear in mind that all of the previously mentioned channels incorporate a self-selection bias: usually only those people interested in the topic participate in these studies. It is difficult to select a sample of people for data collection via social media or crowdsourcing that is representative of a priori specified sociodemographic groups of society. However, in ethnographic research we might especially be interested in extreme users rather than in representative averages. Also, the quality of the returned data must be examined critically. This is especially true when people get paid for completing the tasks; they might not be interested so much in the quality of their data as much as in making money. Quality control, however, is also an aspect that can be achieved through crowdsourcing (Ipeirotis et al., 2010). People might play against each other in a game to act as verification, or the same task can be given to several people to measure the inter-rater agreement coefficient.

3 TECHNOLOGY-SUPPORTED DATA ANALYSIS

New technologies and software products can also help in the process of analysing and visualizing the collected data. The following section discusses possibilities for structuring and analysing ethnographic data through specific software tools as well as concepts that might help to interpret and understand collected ethnographic data, such as crowdsourcing or data mining. Furthermore, we discuss the importance for visualizing the data to identify patterns and to understand and interpret the collected data, and how this might be facilitated through new technologies.

3.1 QDA Software

Several applications exist to assist researchers with qualitative data analysis—so-called QDA software, also known as computer-assisted qualitative data analysis software (CAQDAS). Such applications can be used to structure, organize, reduce, code, and visualize qualitative data. On the one hand, it might help researchers save time, assist in coding, or provide insights by displaying emerging patterns. On the other hand, one should bear in mind that these tools also require some significant amount of time to learn. Miles and Huberman (1994, p. 44) define 14 criteria for a software to support qualitative studies: assistance in note-taking; writing or transcribing field notes; editing field notes; coding data (adding tags or keywords); storing data; search functionalities; linking of data (e.g., clustering); memoing (adding comments); content analysis (e.g., counting frequencies); displaying data for inspection; conclusion drawing and verification (aiding interpretation and testing); theory building; graphic mapping (creation of diagrams); and preparing reports. Available applications provide assistance with these tasks to various extents. The questions, which features should be given more emphasis and, hence, which application might be the right one highly depend on the particular requirements of the research project. Most applications offer a similar range of the most important

features (e.g., import of data sources; tagging and coding of text and audio files; visual display of coding sequences; and analysis tools that export diagrams, charts, and maps). There are several applications available, (e.g. nVivo (2012), Atlas.ti (2012), Dedoose (n.d.), QDAMiner (2004), MAXQDA (2014), etc.). Several issues must be considered, when choosing one specific application. Not all applications allow the direct import of pictures, and also video coding is not available in all applications. A detailed comparison would exceed the scope of this paper, but there have been numerous publications that compare QDA software tools or evaluate particular software packages in detail (e.g. Lewins and Silver (2009, 2007)).

Opportunities of QDA software for data analysis: Since the sole purpose of QDA software is to assist the researchers with analysing qualitative research data, we do not focus on explicitly listing these features. Some software packages include sophisticated data visualisation tools that are supporting the interpretation of the data (see. Section 3.4).

3.2 Crowdsourcing

Crowdsourcing can also be used to facilitate data analysis. People from all over the world can be asked to not only collect and contribute ethnographic data but also analyse, tag, code, or interpret any given data. Here, the same mechanisms apply as those for the data collection tasks (monetary, gamification, or reputation incentives), as described in Section 2.3. Google Image Labeler (von Ahn and Dabbish, 2004) is an example of a crowdsourcing game in which two randomly paired participants are asked to tag presented pictures with labels, and according to their accordance in labelling the images, they receive points as part of a game.

Opportunities of crowdsourcing for data analysis: Crowdsourcing can assist the researchers not only with collecting data from around the world, but also with analysing the data through outsourced coding and tagging. According to "the wisdom of the crowds" theory (Surowiecki, 2004) it might be considered that a crowd of independent people can better evaluate the data than a single researcher, because a crowd might be able compensate the possible bias of individuals, and because of the possibilities to cross-check the data. But still, also here the challenge is how to avoid misuses of the participants for monetary reasons (see Section 2.3).

3.3 Data Mining Technologies

Data mining is an umbrella term for various methods and technologies that are usually used to identify patterns within large numbers of quantitative data. Data mining distinguishes between supervised and unsupervised methods (Hand et al., 2001). The most important supervised method is classification. The researcher has to create a so-called training set in which specific classes are predefined. In design ethnographic contexts, this method might be utilized to classify different speakers in audio files (based on tone of voice, wording, etc.), classify the sentiment (mood) of a text paragraph, or categorize pictures into classes, such as "inside," "outside," "with people," or "without people," (based on shapes, colours, etc.). Crucial here is the predefined training set, which means that the researcher has to have some kind of assumption or theory beforehand that is then used to define the classes. A promising opportunity for ethnographic research would be semi-automatic methods in which the researcher would be presented with an automatically suggested tag, which would then be either accepted or changed by the researcher. Unsupervised methods—in contrast to supervised methods—do not use a predefined training set. Hence, the algorithm itself identifies patterns. This means that the pattern-finding process does not involve the manual creation of a training set and therefore is often less time consuming but also is less directed. Similar to a grounded theory approach (Glaser and Strauss, 1967), the researcher does not start with a hypothesis or theory but lets him- or herself be surprised by the suggestions and findings of the algorithm. This can be a positive aspect in that the researcher's bias is overruled and the algorithm might find patterns that have not occurred to the researcher. But it could also have negative aspects in that the patterns identified by the algorithm might be very obvious or arbitrary. Unsupervised methods include clustering, association analysis, sequence mining, and outlier analysis. In ethnographic research, clustering could be used to group together similar images, text paragraphs, or behaviour sequences. Association analysis identifies association rules in the form of "if A then B." This means that if A is observed, then very likely B also is observed. Sequence mining is similar to association analysis but results in additional information about the order of specific data points. Both association analysis and sequence mining techniques could be used in design ethnography to find related tags or tag sequences. Outlier analysis identifies

data points or objects that do not comply with the norm or the majority of all data objects—so-called outliers. These might be of interest in design ethnography to find extreme users and behaviour. All the previously mentioned data mining techniques can be applied to analyse not only data sources such as structured data (quantitative databases or tables) but also more qualitative data sources such as full text from transcribed interviews, pictures, video, audio, or web data extracted from social media.

Opportunities of Data Mining: All these data mining technologies might be helpful when coding the collected ethnographic data, which is usually a very time-consuming task. Here, the data mining algorithms can assist the coding process by automatically allocating persons in audio files, clustering pictures, etc. However, the suggested patterns always need to be checked and verified by the researcher (Boyd and Crawford, 2012), which also takes time. Moreover, training an algorithm needs a sufficient large amount of data. On the one hand, if the number of data objects is huge—as is probably the case with large bodies of text from several interviews or with thousands of pictures generated from lifelogging cameras—data mining methods might be a promising assistance to the researchers. On the other hand, data mining technologies can also facilitate pattern detection, which might result in completely new insights. The algorithm might be capable of identifying patterns that the researcher was not aware of and therefore didn't look for. Hence, data mining has the potential to not only assist the researcher with analysing the data but also create references and correlations that might otherwise remain undetected.

3.4 Data Visualization Tools

The visualization of the collected data is usually a crucial step in the analysis and interpretation phase of design research. Diagrams or other graphic representations help with structuring of data objects and often reveal patterns, voids, correlations, or other forms of connections that might otherwise be undetected. In design and innovation processes this step is usually called *synthesis* and aims for meaning making from the collected ethnographic data. See Kolko (2011) for numerous examples of how to interpret and understand ethnographic data through graphic structuring. Technology might be able to facilitate this process on several levels. Specific applications—the range goes from simple spread sheet tables to more advanced QDA software (see section 3.1)—allow the automated output of visualized data structures, such as diagrams and charts.

Opportunities of Data Visualization Tools: Visualizations of observed behavioural patterns can contribute significantly to the understanding of the data. For example, so-called heat maps that visualize accumulations of activities (e.g., eye-tracking paths, click paths on websites, movements of people within space, etc.) can provide insights into people's interests, values, motivations, and engagements. Some technologies mentioned earlier have such visualization capabilities already implemented; for example, Autographer cameras automatically produce maps based on GPS coordinates and display a pattern of locations for all taken pictures.

4 DISCUSSION

As shown previously, technologies can assist and facilitate design research in terms of data collection, data analysis, and data visualization. Table 1 summarizes the technologies discussed in a framework that highlights the benefits regarding the ethnographic approach. Thus, we ask in the following, in how far are these technologies able to assist and advance ethnographic design research:

1. ***Do technology-supported research approaches lead to more progress in design research?*** Technology might assist researchers in the process of data collection, data analysis, and data interpretation. More data can be captured with less effort because researchers do not have to follow the research subject personally but might utilize self-tracking, observation, or crowdsourcing for this task. Technology-supported design research allows for new research approaches and provides access to situations and contexts in which normal research methods could not be used, for example in private or remote situations. Also, the data analysis can be facilitated by data mining technologies or QDA software. Automated coding of large amounts of qualitative data can reduce the effort for the researcher significantly. However, data interpretation should always be guided by theoretical considerations and is never a goal in itself. The sense making and holistic understanding of the ethnographic data is still based on the reflective interpretation of a research. Data does not speak by itself.

2. ***Are technology-supported research approaches more objective?*** Nowadays, the researcher is able to collect data in large numbers—often also without knowing what exactly to do with the collected data. A large amount of numerical data usually conveys the feeling of trustworthiness and objectivity whereas the classical approaches such as interviews are regarded to be less objective data and more 'spoiled' by the human researcher who always brings his or her own perspective. There is an inherent assumption that technology has got no bias and does collect and analyse the data in a more objective way than a human researcher would. However, more data does not mean always better data. A big dataset that is biased because e.g. it is based on specific social media might be less useful than a small dataset that is representative for the desired population.
3. ***Are technology-supported research approaches more convincing in terms of theory development?*** Technologies can be used to complement the research data (triangulation), which can result in new or more precise insights. Automated data analysis tools—data mining in particular—might also provide researchers with new insights. Specific algorithms serve the researcher to detect patterns on different resolution levels and by this provide different views for successful data analysis. However, this might only be the starting point of a theoretical investigation and needs the critical reflection of a researcher. Also technologically gathered data needs similar interpretation as analogue ethnographic data.

Table 1: Framework of technology-supported design research

	Data Collection												Data Analysis							
	Type of Collection								Type of Data				Preparation					Visualization		
Technological Support	Open Observation	Participative Observation	Shadowing	Observe artefact interaction	Observe social interaction	Observe Environment	Interviews / Q&A	Self Research	Audio Data	Visual Data	Spatial Data	Quantitative Data	Coding / Tagging	Commenting	Clustering	Code Development	Filtering of Data	Diagrams / Charts	Sequences	Maps / Floor Plans
GoPro	●	●		●●	●	●●		●	●	●										
Autographer	●	●	●●	○	●	●		●●		●	●●	●	○				○		○	●
Narrative Clip	●	●	●●	○	●	●		●●		●			○	○	●		○		○	
Kapture							●	●	●●											
Google Glass	●	●	●	●	●	●	●	●	●	●		●								
Smartphones	●	●	○	○	○	○	●	●	●	●	●	●		○						
Withings												●					●	●		
Nike FuelBand												●						●		
Digital cultural probes							●	●●	○	●●	●	●	○	●	○				○	○
Video diary room							●	●●	●	●										
Rescue Timer								●				●●					●	●		
GPS Devices						●		●			●●								●	●
Indoor Positioning						●		●			●●								●	●
Motion Sensors	●			●	○	●				●	●	●				○			○	○
Eye-Tracking				●●		●				●		●				○			●	
Facial Expression Recognition				●●	●●					●●						○			●	
Drones	●		●●	○	○	●●				●	●●	○								●
QDA Software													●●	●	●●	●	●	●	●●	
Crowdsourcing	○	○	○	○	○	○	○	●●		●		●	●	●	●	●				
Social Media	○	○	○	○	○	○	○	●		●		●	○	●	○	○				
Social Network Analysis					○							○						●●		
Data Mining									●	●		●●	●		●	○		●		

●● Technology supports ethnographic task extensively
● Technology supports ethnographic task
○ Technology partially supports ethnographic task

Obviously, these new approaches will probably result in more accurate, more complete data, or in other words, better data. However, technologies might facilitate but not replace the interpretation and reflection of the human researcher. Hence, all these benefits should not be overvalued but should be critically questioned. The fact that a massive amount of data can be produced in a relatively short time and with relatively little resources also brings some drawbacks. The collected data have to be reviewed, analysed, and interpreted somehow, which significantly increases the amount of time and

required resources. As described in Section 3, technologies can also help with analysing the data, but still, the evaluation of the data being produced might be a challenge. We therefore suggest that a more directed and focused way of data collection would result in less but better data, which can be used not to identify statistical patterns but to identify users' needs and wishes as well as social and cultural values. Also, the combination of qualitative and quantitative data sources with a mixed-method approach seems promising (Creswell, 2013). Moreover, because these new technologies and tools make it easy to track and observe people by accessing their smartphones or by installing independent cameras, sensors, or other tracking devices, these possibilities raise many concerns about privacy and questions about ethical issues. As with any other form of research involving people, the permission of the participants has to be requested, and their privacy must be guaranteed. Just the fact that these technologies make it easier to intrude into people's lives doesn't mean that we, as researchers, are allowed to do so without asking permission. Still, the actual consequences of agreeing to being tracked through digital technologies or their own smartphones might not be evident to the participants. There is a difference in giving an interview, for instance, in which the participants can decide on the spot which information they are willing to share, whereas by granting someone access to one's cell phone or by wearing some kind of tracking device, the participants give away the control over their data. Participants should be made aware of this situation. Moreover, the small, wearable cameras will also record the environment of the participants along with their interactions with other people who have probably not been asked for their consent to be photographed or filmed. Covert audio recordings of conversations (e.g., through devices such as Kapture) might even be illegal. Hence, the researcher's responsibility to ensure people's privacy increases with the technological possibilities.

5 CONCLUSION

This paper presents an overview of current available technologies and practices that facilitate the collection and analysis of qualitative and quantitative data in the context of ethnographic research in design. The term "technology" summarizes a range of tools, concepts, or applications, which comprise hardware devices (tracking or monitoring equipment such as wearable cameras or sensors), software applications (such as activity-tracking or QDA software), and data mining technologies, as well as social phenomena (such as crowdsourcing, self-tracking movements, or social media), and investigate their potential to facilitate design research. The main contribution of this paper is a framework of new design research approaches, summarizing the discussed technologies and their contribution to the research setting. Furthermore, we critically discuss ethical problems that arise from the new possibilities of tracking and observing people through digital technologies. We also point out that despite the potential of technological support, a thoughtful data evaluation is crucial. An improvement in understanding is not dependant on the amount of data but on a careful implementation of the right method for the right research question. We believe that some of the described research procedures might help the researcher save time and resources and might even instigate new forms of research. Triangulating several traditional methods with the implementation of the new approaches results in better data quality and finally might reveal new insights.

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