Mass Survey for Demand Analysis

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Abstract In the ongoing digitalization of society new technical systems and technologies are increasingly penetrating people's everyday lives. In order to be able to analyze the resulting complex interactions and forms of networking, a participative approach is needed to identify the needs of these user groups. Empirical studies, e.g., mass studies, are important because it may be required that many stakeholders have to be questioned in a short period. In this article, various methodological approaches are presented using best practice examples to show the strengths and weaknesses of these methods.

1 Introduction

Technical systems and new technologies permeate our everyday lives more and more and are a fundamental part of our environment. The sustainable development of appropriate systems and products for the integration into the respective socio-technical systems requires a participatory approach. Through this practice both the needs and desires but also the fears and obstacles of potential future can be considered. This topic is of particular importance due to the increasing complexity of interaction and networking of people with technical components. It may be necessary to involve and question a large number of stakeholders in a short period to create user profiles, e.g., to generalize or validate results from empirical studies of smaller samples in the laboratory or field. In order to support an usage that is independent of a specific discipline and possible application-contexts different methodological approaches and systematics of this topic will be briefly explained below, according to their use in the human-centered development cycle DIN EN ISO 9241-210. Concrete best practice experiences for different implementation variants will also be presented, which consider the strengths and weaknesses of the respective methods.

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1.1 Theoretical Background

Since the emergence of empirical research, different paradigms have maintained the focus on social development from different perspectives. Together, they aim to collect a massive range of data in order to be able to make statements on their specific subject area [Vis14]. It must be carefully considered which design can best cover or answer a specific question, because different research designs can lead to different results [Zha17]. In this context, mass surveys represent a large part of empirical research. They are able to anticipate social trends in a broad group and make them measurable by means of statistical methods [Sch49]. Also, they are able to verify or falsify hypotheses and to generalize statements about the relevant population. Mass surveys are necessary for participatory requirements analysis, as a large number of different actors have to be questioned about new developments in a short period of time in order to identify possible needs for action and to develop target group specific design recommendations. The procedures described below can be used to ensure that the results obtained in the studies have a certain degree of generalizability and that other research groups with a similar background can take up these results.

1.2 Mass Surveys as Part of a Human-Centered Development Process

The participatory conception, implementation, and evaluation of new technical systems and technology-supported services is divided into four concrete steps and associated usability engineering activities in accordance with the "human-centered development process" of DIN EN ISO 9241-210: (1) Understanding and describing the context of use, (2) specifying usage requirements, (3) developing design solutions, and (4) designing solutions. By purposefully iterating these steps until the design solution meets the usage requirements, the design can be based on a comprehensive understanding of the users, work tasks, and the working environment and also take complex reciprocal socio-technical dependencies into account. By using methods of mass surveys an extremely effective and efficient realization can be achieved, especially for steps (1), (2), and (4). In order to decide which method can be used meaningfully, the time dimension has to be taken into account—whether it is a long-running process that provides for regular iterations and revisions of the technical components or whether it is a completed development process that is no longer adapted after finalization of the specification. Depending on this, methods from either the field of longitudinal studies or from the field of cross-sectional studies are preferable (see Fig. 1).

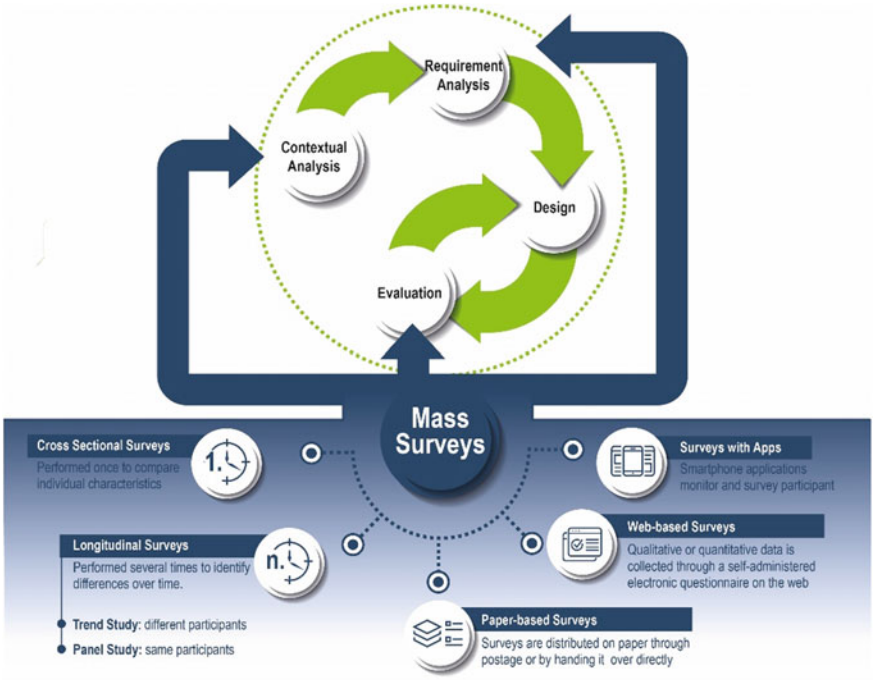

Fig. 1 Methods of mass surveys applied in the human-centered development process

In the following sections, concrete best practices for the use of mass surveys from application-oriented practice will be presented and discussed with regard to their strengths and weaknesses. The aim was to identify the requirements for the design of innovative technical systems and technology-based services with a "large" sample size in all examples.

2 Longitudinal Studies

Longitudinal studies are designed to investigate changes in social and individual processes over time. In contrast to cross-sectional studies, longitudinal studies are conducted at multiple points in time and the results are compared between the different times. Two different forms of longitudinal studies are distinguished: the panel study, where the same sample is used at each point in time, and the trend study, where different samples are used at different points in time.

2.1 Panel Studies

The data from panel studies are difficult to collect and they are more costly to gather than data from cross-sectional studies [Hsi07]. Beyond that there is always a loss of data, for example when some of the former participants are not available at the next point of data collection. Therefore, the sample at the beginning must be sufficiently large that the loss can be absorbed. However, a systematic bias might occur as characteristics of those participants who no longer participate in the data collection might correlate with aspects of the object of investigation, e.g., they might be not participating anymore because they are too old (in the case of age differences) or too ill (in the case of medical research). The advantage over cross-sectional studies is a greater capacity to display the complexity of human beings, including characteristics and behavior [Hsi07]. Also, panel data allow a direct "before and after" comparison on an individual basis when a within-subject design is given, since data exists for the same person at different points in time. In studies concerning decriminalization or the use of new therapy forms, for example, this is indispensable. Finally, such studies highlight dynamic relationships, that is, correlations can be found and interpreted.

2.2 Trend Studies

Contrary to panel studies, trend studies contain different samples, so many more participants are needed overall. The acquisition of participants is thus more time-consuming and costly. But as a benefit, every sample is tested only once, and no potential systematic loss exists like it does with panel studies. However, another kind of systematic bias within the sample might occur as in all voluntary surveys: participants with less interest in the topic of the survey are less likely to answer the voluntary questionnaire. With the results of a trend study it is possible to interpret variations in data based on the whole sample, which should represent the population. It is not possible, as it is in panel studies, to attribute variations directly to interindividual differences, as here a between-subject design is used. In this form of investigation, the data of different samples is collected at each round of implementation so that not individual changes but rather generic differences are identified. In order to achieve representative and generalizable results, however, the respective sample, the so-called cohort, is built up in a way to be as comparable as possible, for example with regard to age, gender, social, and cultural background. It can be stated in conclusion, that if the main research focus is on evolving trends of, for example, technology use over time rather than, for example, individual learning effects, a trend study is more applicable than a panel study. Panel studies are only important if the focus is on individual change over time.

The first challenge when setting up a trend study is to involve a large number of participants who are representative for the population. One good way is to contact professional address providers, who may even sort or restrict your sample to condi-

tions important for the research, like a specific age group. For the long-term trend study of the "Tech4Age" project [Wil16, Mer17] the authors used the service of DHL and sent a 26-page paper-based questionnaire to 5000 people of 60 years or older equally distributed over the whole of Germany. Initial case numbers in the thousands are normal in trend studies, as only 10–20% of the questionnaires are returned. Sending out such huge numbers of questionnaires entails a lot of handwork for a small research group, which might be another reason to pass this over to a professional service provider. The response rate will depend on the topic, size, and appearance of the questionnaire. Therefore, it is recommended to keep the questionnaire as short as possible and frame it with a covering letter that explains the topic and the necessity of the research in short and comprehensible sentences. A postage-paid envelope should also be included to avoid costs for the participants. As an incentive it should be mentioned in the cover letter how important the opinion of the participant is for that field of investigation. Some surveys also offer a prize draw, giving those people who return the questionnaire the opportunity to win a small prize. Nevertheless, return rates over 15% are rare for these voluntary random requests, so ten times the number of surveys should be distributed than answers required. Overall, the bigger the sample is, the better and more trustworthy the results will be. Trend studies might contain both qualitative and quantitative questions. However, as big sample sizes are to be dealt with, the analysis of qualitative data would be enormously time-consuming. Therefore, it is better to concentrate on quantitative research and use open questions and qualitative research only if necessary. If the trend study is paper-based, it should be kept in mind that all incoming questionnaires have to be transferred to electronic media for further data analysis. It is thus preferable to handle this by means of an automatic read-in process during the scanning of the returned questionnaires. There are programs specialized in this approach (e.g., Remark), but the questionnaire has to follow a specific layout in terms of size, position, and answer categories for this to work properly. This has to be considered when designing the questionnaire.

3 Cross-Sectional Studies

In empirical research, one speaks of a cross-sectional study or cross-sectional design when an empirical investigation is performed once. In contrast, a longitudinal study is performed several times in succession. Cross-sectional studies compare the results of each participant and provide information about the prevalence of a behavior or attitude. Moreover, the data can provide a "snapshot" of individual characteristics at a specific time. The procedure of a cross-sectional study is generally quicker, easier, and cheaper compared with longitudinal studies. Furthermore, there is no data loss, due to the fact that one participant is only interviewed once [Sed14]. But simultaneously this limits the studies because they do not permit indications of data differences over time [Lev06]. This makes it hard to find causal correlations. The obtained values form the dependent variables.

4 Best-Practices for Methods of Mass Surveys

4.1 Web-Based Surveys

A web-based survey can be used to conduct qualitative as well as quantitative research [Eys02]. Data is collected through a self-administered electronic set of questions on the web. Web-based surveys are used for data collection and should be incorporated when the study design as well as the questionnaire are fully defined and developed.

Depending on the electronic tool used to conduct the survey, its physical appearance and presented information can usually be adapted easily. Web-based surveys additionally offer the potential to create a dynamic questionnaire, that is, questions are hidden or revealed depending on the former answers of participants. This prevents the participants from getting bored or frustrated with questions they can not or do not want to answer. Also, further specific questions can be asked, making the collected data much more informative. Regarding data quality, web-based surveys have further advantages. The used electronic tool can monitor data input and give feedback on whether a question is missed or data input is wrong. These are some reasons why web-based surveys have been claimed to reduce respondent error and increase the completeness of responses.

But these functions also come with disadvantages. Participants might be "forced" to answer certain questions to proceed and therefore might not choose the most suitable answer, but simply click randomly in order to proceed. This shows that the design of web-based surveys needs to be tested extensively as the electronic questionnaire is the sole form of communication between investigator and participant. To detect incorrect inputs, the software needs to know which answers are valid. For quantitative studies with closed-ended questions this is quite easy to determine. But in the case of qualitative research with a lot of open-ended questions it becomes a lot more difficult to determine the right answer and therefore use this error detection function. Our experience has shown that web-based surveys should be used for quantitative studies with few open-ended questions, the answers to which can be determined quite well in terms of type as well as possible length [Ras17]. The use of a web-based survey to conduct qualitative research with open-ended questions should yet be considered, as this type of survey avoids the transcription of handwritten answers for analysis.

Web-based surveys are suitable for reaching a large group of participants with a small team of investigators. Therefore, and because of the instant recording of data, web-based surveys are frequently described as potentially time-, effort-, and cost-saving.

The recruitment of participants for web-based surveys can be done in different ways. There are several examples with quite good results recruiting via web, e-mail, or social media [Ras17, The17, Bro16]. Web-based surveys are less intrusive as participants do not need to answer the survey immediately but can rather choose a time and place to answer the survey free from stress. Research has shown that recruitment via web, e-mail, or social media is not representative regarding a whole

population but is suitable for reaching individuals with particular characteristics or interests, e.g., potential users of a certain game, experts in robotics, or users of electronic health records [Bes04, Top16]. Users of social media platforms like Facebook are adequate in terms of representative population characteristics [Rif15]. Limited access to the internet, security issues, and technical problems might also indicate differences among participants.

All in all, web-based surveys are a suitable and cost-efficient way to conduct quantitative research among individuals with specific characteristics in a short period of time.

4.2 Paper-Based Surveys

Paper-based surveys, as the name already implies, are surveys that are distributed on paper via mail or by handing the surveys directly to participants. Because of the heavy use of online surveys in recent years, paper-based surveys are sometimes seen as outdated, although there are still advantages to paper-based surveys in comparison to online-based designs.

One advantage is the fact that not every age group addressed in a study uses computers and online services on a regular basis. People aged between 50 and 75 years show significantly less initiative to complete online surveys and prefer the use of the paper-based form [Bec09]. In order to account for visual impairments of older people, the font of the paper-based surveys can be scaled to an appropriate size, without affecting display problems by deforming or distorting the typeface on the screen. An example of an analysis which often needs a sample that spans multiple different age groups and where a paper-based survey would be appropriate is the Kano analysis. The Kano analysis is based on the Kano model, a model which is used to examine product features with regard to their impact in early stages of the development of innovative products and aims at effectively integrating different target groups into the developmental process [Bra16] for example used the Kano model to analyze different customer requirements with regard to a technical mobility aid. To categorize product features, a positively formulated question and a negatively formulated question are asked straight after each other. After several product features are assessed in this way the model is built and design recommendations can be deduced [Kan84].

The use of the paper-based form of survey is also appropriate for age-independent samples. Some surveys require the participation of a specific sample, e.g., experts of a specific field, which might be hard to find. In this case, it might be easier to give the survey in person to a subject, e.g., at a conference or a meeting, than sending the survey online via e-mail, as people usually have a pen to hand and are willing to fill out a survey on the spot at an event instead of answering online questions after an event. An example of a study based on expert ratings was published by [Bro13]. The researchers studied services with regard to medical care in the future and administered a Delphi study. A Delphi study is a systematic, multi-level analysis

of experts' ratings. A panel of experts convenes and gives feedback on selected topics by means of a survey in two or more rounds. After each round an anonymized summary of the experts' ratings from the previous round as well as the reasons they provided for their ratings is created and given to the sample in the next round. It is believed that during this process the range of answers will decrease and the group will converge towards the "correct" answer. The Delphi study is an example where a paper-based survey would be highly recommended.

Although there are a lot of advantages of paper-based surveys, there are some disadvantages as well. Paper-based surveys deploy finite resources (including paper) and are therefore not environmentally friendly in large quantities. Moreover, the high cost for material, printing, and mailing are not to be underestimated and should be considered especially for large cohorts. The processing of the data sets also requires a number of additional resources, since the questionnaires must generally be digitized before the concluding evaluation. Finally, and foremost, paper-based surveys are not dynamic, or rather they can only be dynamic to a certain extent. That means that it is more complicated to form groups of people who answer questions based on their answers to previous questions, something which is easily achieved in web-based surveys through the integration of dynamic loops.

4.3 Large-Scale Surveys as Part of a Smartphone Application

Study designs to investigate user behavior and the effect of apps on users typically require direct contact between participants and examiner as part of participant recruitment and briefing, as part of the instruction of experimental hardware as well as during surveys. However, the direct contact can cause effects of social desirability on the participants' behavior and opinion, especially since health-related behavior is socially relevant. During investigations of usage duration and drop-out rates, further biases can result from specifying an end time of the experiment, by the users "persisting" despite the fact that their motivation has declined. Another problem is the Hawthorne effect. This effect is defined as a change in behavior resulting from the participant's consciousness about his participation in a study. The salience of the study situation is further increased by personal contact, the use of study-specific devices, the knowledge of an end date, and additional interviews.

One solution addressing the described drawbacks are surveys and behavior tracking by smartphone applications and persuasive self-monitoring systems. Since the recording of data is already an integral part of the monitoring system, these data can be evaluated in the context of a certain research question. The widespread use of smartphones makes it possible to let participants use their usual phone instead of unusual, study-specific devices. The core of the proposed method is denoted by providing a smartphone application in common app stores. As part of the installation process, the user is informed about their participation in the surveys and agrees to this and to the collection of their data. For comparative studies, one of several app versions may be randomly assigned during installation. Relevant data can be

recorded as far as possible during use. Usage duration should be taken into account here.

The described process of recruitment and the exclusion of direct contact establish a distance between participants and examiner and thus ensure anonymity for the participants. This is important in order to avoid a feeling of being observed or evaluated, which could encourage the participants to act in what they consider to be a socially desirable way. The possibility for participants to use their own smartphones, the availability of established distribution paths (app store) as well as the exclusion of purely study-related activities and a temporal limitation increase the naturalness of the usage situation. Additionally, making the application available in an app store answers the question of whether participants would use the application in real situations. The composition of the user group with regard to the recorded data can also be determined without sample bias, although limited information might be available about the users' demographic variables in cases where not explicitly queried.

Experiences indicate that the Hawthorne effect and socially desirable behavior can be largely avoided with the chosen study design. However, while studies with a classical design report low dropout rates, smartphone-based surveys and data monitoring studies commonly face dropout rates of around 75% already after one week. This is comparable to results from media usage surveys, which show that on average 80% of all installed apps are not used. Another limitation of app-based investigations is a sample of participants who are already interested in the objective or who have higher affinity to digital technologies. This method is therefore only recommendable if the characteristics of users who download the app can be expected to match the characteristics of the target population. Furthermore, the final number of participants is difficult to predict, which is why sufficient time for advertising and PR of the app needs to be ensured.

In order to have valid experimental data, both active and passive usage should be recorded. In this case, high exclusion rates are to be expected to influence the quality of experimental data. Finally, the development effort is not to be underestimated. The smartphone application must be a market-ready product, with users expecting technical support as well as constant bug fixes and functionality extensions. It is important to consider that this approach is not suitable for investigations that require additional information to the data collected by the monitoring system. It is, however, suitable to investigate application usage and to compare different application components on use behavior tracked by the monitoring functions.

5 Conclusion

The aim of this chapter is to demonstrate different best practice examples in the field of mass surveys. A brief theoretical introduction to the subject of mass surveys and human-centered development designs was given before various forms of research in the field of mass surveys were presented. In a first step, longitudinal studies—trend and panel surveys—were discussed. In a second step, cross-sectional studies as an

alternative approach were presented. The focus of the latter chapter was on web-based and paper-based surveys as well as surveys with smartphone applications to realizes large-scale surveys.

Regardless of the methodology used, it must be borne in mind that the data collected may contain personal information which must be treated with due care. In addition to the principles of data protection, such as data economy, earmarking, and transparency, strong anonymization procedures or, in the case of investigations in within-subject design, consistent pseudonymization can be used to ensure that the data can no longer be directly assigned to any person. In addition to the consideration of corresponding rules, which are a partial aspect of Responsible Innovation and Research (RRI), the ethical, legal, and social implications of research should be considered prospectively and all involved stakeholders should be taken into account in the sense of a continuous participation.

The overall aim was to link theoretical background with information and practical experience in the interdisciplinary research project Tech4Age (www.tech4age.de) and thus demonstrate the advantages and disadvantages of these methods.

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