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USE AND USEFULNESS OF MAIL SURVEYS AS A METHOD OF DESIGN RESEARCH

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1 Introduction

The empirical study of design processes has become a common topic of many design-related publications of recent years. Without doubt, this tendency is in part due to the increased awareness that in the past, the development of tools and methods too often relied on "single findings, on assumptions (often established as 'facts'), or on 'experience', i.e. generalised subjective observations" [1]. While different views on design research still exist, the principle that a design-related problem needs to be understood before a solution can be developed seems to be undisputed. While the application of methods from social sciences in design research has already been discussed e.g. in [3], this paper focuses on conducting empirical studies that

- aim at capturing design activity that takes place in a professional setting,
- explore a large ($n > 100$) random sample and
- are based on self-administered questionnaires.

The most important methods that meet these requirements are mail and internet surveys. Since most standard literature on this topic (e.g. [4]) deals with a quite general target group, the objectives of this contribution are to

- identify requirements of mail surveys targeted at designing companies,
- discuss the potential of internet surveys
- and to give recommendations based on own experiences in this field.

2 Methods from social sciences in design research: an overview

Engineering design is a complex activity that involves products, processes and probably first of all: people. Their activities require methods to capture, analyze and describe human behavior – a traditional domain of social sciences. Atteslander [8] identifies four main categories of empirical research methods in social sciences: *content analysis, experiment*, *observation* and *survey*.

Methods belonging to the first category play a somewhat special role since their unit of analysis is the outcome of human activity rather than human behavior itself. *Content analysis* is recognizable in Hales' research, who coined the term "Forensic Analysis of the Design

Process" [11]: "Obviously, an analysis of what happened during a design project involves reviewing all the available documentary, physical and testimonial evidence, and arriving at opinions as to what occurred. However, just as the design process is best carried out in a systematic fashion, so should the analysis." [op. cit.]. Another example of design research with a strong emphasis on content analysis is described in [12].

The objective of an *experiment* is to study human behavior in a controlled situation in which the subjects (people and where required artifacts) become part of an artificially created, controlled and reproducible process. Del-Rey-Chamorro and Wallace used an experimental setup to study the access and use of design-related information [13].

Observation is defined as the systematic recording and interpretation of observable behavior in natural situations at the time of its occurrence. Observational studies are determined by the parameters structure, openness and participation. Unstructured studies do not rely on a predefined observation pattern and therefore cannot be used to test hypotheses – only to develop new ones. Unlike in an open observation, the participants of a covert study are not aware that it takes place. Finally, the researcher can decide whether or not to participate in the activities of its subjects. For a recent example of a structured, open, non-participative observational study in design research refer to [14].

Methods based on a *survey* approach also aim at gaining an understanding of human behavior in natural situations – but not necessarily at the time of its occurrence. They always require some kind of deliberate communication between the subject(s) and the researcher which implies that the participants need to reflect on their own behavior (or the behavior of others) and to recall facts. Apart from questionnaire-based surveys (which will be discussed in 3 ff.), the socio-scientific definition of 'survey' also includes interviews, which are a common instrument in many design research projects (e.g. [9]).

In reality, however, the distinction of these four empirical research methods is blurry. Moreover, they are almost never used separately. This difficulty is illustrated e.g. by the study of Bender [10] in which engineering design students, after completing a questionnaire, were given a design task and observed while solving it. Afterwards, the results (i.e. notes, sketches, design drawings, etc.) were analyzed. What makes this case especially interesting might be the question, whether the main part was an experiment or an observation since one can argue that the subjects (i.e. engineering design students) were put into a situation that was "natural" in some way because it resembled a design exam.

Regardless of the method(s) used, the quality of an empirical study is defined by the following criteria [8] [10]:

- **Objectivity:** the degree to which the (uninterpreted) results are independent from the individual who obtained them.
- **Reliability:** the level of precision and reproducibility that can be achieved in measuring specific attributes.
- **Validity:** the extent to which a study can actually measure what it intends to measure.
- **Empirical relevance (or external validity):** the transferability of results to reality.
- **Efficiency:** the cost-benefit ratio of a study.

A mail survey can be defined as an empirical study in which subjects answer a questionnaire without the supervision of an interviewer. In terms of the abovementioned criteria, mail surveys – unlike any other methods – seem to offer superior *efficiency* in achieving a high level of *empirical relevance*. It can also be expected that *objectivity* is high since the evaluation of questionnaires leaves comparatively little room for individual interpretation. However, while thoughtful planning can assure a high level of *validity*, the lack of control over the subjects puts a big question mark on the *reliability* of the results. Usually, it cannot even be verified if the questionnaire has been completed by the addressee or by some other individual.

3 Conducting mail surveys of designing companies

Given that most engineering design takes place in a professional setting, all difficulties of conducting mail surveys of businesses apply [4]. While this area of survey methodology is well established, there are some important design-specific issues that are discussed in this section.

3.1 Avoiding survey error

The biggest advantage a mail survey possibly offers, its empirical relevance, is limited by *sampling*, *coverage* and *nonresponse error*. Sampling error, the result of not surveying all elements of the survey population (e.g. all design engineers), is inevitable and can only be reduced by increasing the sample size and/or narrowing down the survey population (e.g. all design engineers working in the Italian sports car industry).

Coverage error occurs when not all elements of the survey population have an equal or known nonzero chance of becoming part of the sample frame, which is defined as the subset of the survey population from which the sample is drawn. For instance, creating a sample frame by typing “engineering design” into an internet search engine and filtering all companies from the results would bring about a considerable coverage error since any companies that are not on the internet would be excluded from a potential survey.

When conducting mail surveys of designers, it can be argued that those individuals who respond always differ systematically from those who do not: only designers whose workload allows them to complete the questionnaire will send it back. Nonresponse error, however, would only occur if this reason was relevant to the study (e.g. a mail survey that investigates the workload of designers).

3.2 Constructing the questionnaire

Quite obviously, the first step in constructing a questionnaire is defining its questions. These should be based on the hypotheses that result from the underlying design research questions. However, a hypothesis such as, e.g., “Design faults of complex products are regarded as more severe than design faults of simple ones” (see [7]), bears at least three fundamental methodical questions: 1. What is a design fault? 2. How can its severity be measured? 3. What can be a suitable measure of a product’s complexity?

The first question demonstrates the necessity of researchers and subjects sharing the same terminology. The questionnaire must therefore give clear definitions of relevant terms (e.g. “In this study, the term ‘design fault’ relates to any unexpected and unwanted behavior of a

product that is caused by its design"). In general, inconsistencies in terminology between academia and industry – even with apparently common design-related terms – have to be considered, e.g. by referring to "the development of new solution principles for a fundamentally new problem or task" instead of using the word "original design" as defined by Pahl and Beitz [1].

The two other questions that arise from the example hypothesis illustrate the problem of objectively measuring certain design-specific attributes. Clearly, this is the greatest challenge in the construction of the questionnaire since a question such as "How complex is your product? [1: very simple - 10: very complex]" is rather unlikely to yield unbiased answers. In the example, a possible solution might be to deduce the complexity from several less subjective attributes, such as the number of parts, employed technologies, product price, etc. However, when several questions are necessary to capture a single attribute, it is vital to instruct participants to think of one specific design project, one specific product, etc.

Pre-testing the questionnaire on a preferably large group of individuals composed similarly to the survey population is always a good idea since it can give answers to e.g. the following questions:

- Which questions were misinterpreted by the subjects?
- Which questions were felt difficult to answer?
- Were the subjects inclined to refuse answering certain questions?
- Were there any suggestions for further questions?
- How much time did it take to complete the questionnaire and was this amount of time regarded as acceptable by the subjects?

Coping with the problem of refusal is always a difficult challenge as in most companies, product development is a very sensitive area. Assuring confidentiality and, where possible, anonymity in the questionnaire may be helpful in this regard. Finding out how much time it took the pre-test participants to complete the survey form is important inasmuch as giving this information on the final questionnaire (e.g. "Tests have shown that filling out usually takes less than five minutes") can help to convince individuals to take part – if, of course, the necessary time is indeed short. Inevitably, this leads to the question how much time for completing a questionnaire is acceptable. Unfortunately, the truth is probably "No time at all!", as one designer, who was asked this question during the pre-test of the survey in [7], put it.

3.3 Survey implementation

Response rate is the most often cited success criterion for mail and other self-administered surveys. According to Dillman [4], who states an average response rate of 21% for surveys of businesses and organizations, implementation procedures (e.g. multi-contact strategies including pre-notice- and several reminder letters / phone calls) have a much greater influence on response rates than the design of the questionnaire.

As already indicated in 3.1, one of the first difficulties encountered is setting up an appropriate sample frame. Tax records, which are publicly accessible in some countries, promise minimum coverage error, yet usually do not reveal any relevant characteristics of the listed businesses (especially not whether they are engaged in any kind of product

development). Commercial business databases, which are available online (mostly as pay-content) or on CD/DVD, offer more information on individual companies, sometimes even naming the heads of product development. Yet, even the most leading of such directories cannot cover the entire survey population.

Once the sample is drawn, there is the problem of ensuring that the questionnaire is forwarded to the right person (i.e. a designer), which is particularly difficult in large companies. A possible solution can be a procedure in which randomly selected companies from the sample frame are contacted by phone and only those firms added to the sample in which a designer has agreed to participate in the study. However, apart from being immensely time-consuming, such a course of action would render response rates more or less meaningless and make the whole study extremely vulnerable to nonresponse error.

Even though defining a sample frame and drawing a sample of designing companies is an intricate task, it is probably a bad idea to use the same sample again. The mail survey described in [6], which took place more than six month after the study in [5] but used exactly the same sample, only achieved a response rate of 21.3% compared to 37.7% of its predecessor.

The main objective of the cover letter is to (re-)convince the addressee that the reward for participating in the study outweighs the costs of completing and returning the questionnaire. Reasoning that participation helps to improve design methodology (implying that design methodology is the basis for successful design in practice) could be conceived as too "academic" whereas the attempt of bringing forward cost-saving arguments in this context might even seem pretentious.

When offering the addressee access to the future results of the study as an incentive for participating, it must be ensured that such interest can be indicated without being associated to the questionnaire, e.g. by adding a separate reply card (this might appear trivial, but as discussed in 3.2, anonymity can be an important issue).

Personalized cover letters usually have a slightly positive influence on response rates [4]. However, since it is difficult to clearly identify designers within a company, the potentially positive effect of personalization might be outbalanced by addressing the wrong person. In the survey described in [7], great efforts were made to personally identify the questionnaire addressees. By referring to the information from the business database from which the sample was drawn and subsequent research on the internet, 794 out of 1.006 recipients were known by name. Since only a small minority could doubtlessly be recognized as designers, most of the addressees were owner-managers, CTOs and other members of upper management. However, the response rate among this group reached 18.5% compared to 13.2% of the group that received impersonal correspondence.

3.4 Internet surveys

Designers, assuming that computers are one of their most important tools and therefore having better access to and knowledge of the internet than the general public, seem to be an interesting target group for web based surveys. Among the advantages that can be expected by applying such a technology are:

- **Unambiguous results:** Unlike with paper based questionnaires, it is e.g. impossible to put a mark between two check boxes or to chose several options instead of one. Furthermore, automatic verification of result validity can help to avoid contradictory answers.
- **Interactivity:** Where appropriate, questions can be automatically skipped. Help and information can be given at request without sacrificing clarity (e.g. by hyper-linking a design relevant term to its definition; see 3.2)
- **Seamless data integration:** When participants manipulate the same data base that is used for statistical analysis the need to input questionnaire data (manually) is eliminated.
- **Open access:** When no sample frame can be defined, web surveys can be still be used to collect questionnaire data expecting that potential participants respond to e.g. announcements in engineering related journals and/or web pages.

As an alternative to the effort of programming and hosting an own web survey, researchers nowadays can turn to one of numerous commercial providers of remotely-hosted web surveys (e.g. www.surveyconsole.com). These services offer their customers a kind of "questionnaire construction kit" that allows them to define questions in all imaginable formats. Once the study is finished, the data is made available in a wide range of formats (CSV, SPSS, MS Excel, etc.). Still, the decision to host a web survey remotely always comes at a certain expense of flexibility.

The main issue with internet surveys, however, is most likely nonresponse, since not all designers have the possibility or the permission to use the internet (which is subject to restrictions in many companies). When not conducting open access internet surveys – which, for obvious reasons, lack almost any criteria of good empirical practice – there is still the problem of addressing all the elements from the sample frame. While from a technical point of view, it would make sense to use e-mail for that purpose (cost savings, direct linking to the URL of the survey, etc.), contemporary practice regarding unsolicited electronic messages ("spam") suggests that such a procedure would have a disastrous effect on response rates.

The questionnaire recipients of the mail survey in [7] where given the choice of either filling out the paper version or to log into a web survey using a personal access code. The declared purpose of this code was to prevent abuse and to allow the participants to return to the questionnaire at a later point in time. Out of the completed sample of 173 only 27 participants preferred the online questionnaire of which no more than 18 finished it, corresponding to 15.6% and 10.4% of all respondents respectively. After completing the actual web survey, 16 subjects took the opportunity to evaluate the online questionnaire. The diagram in Figure 1 shows the reasons for using the online survey form instead of the enclosed paper questionnaire.

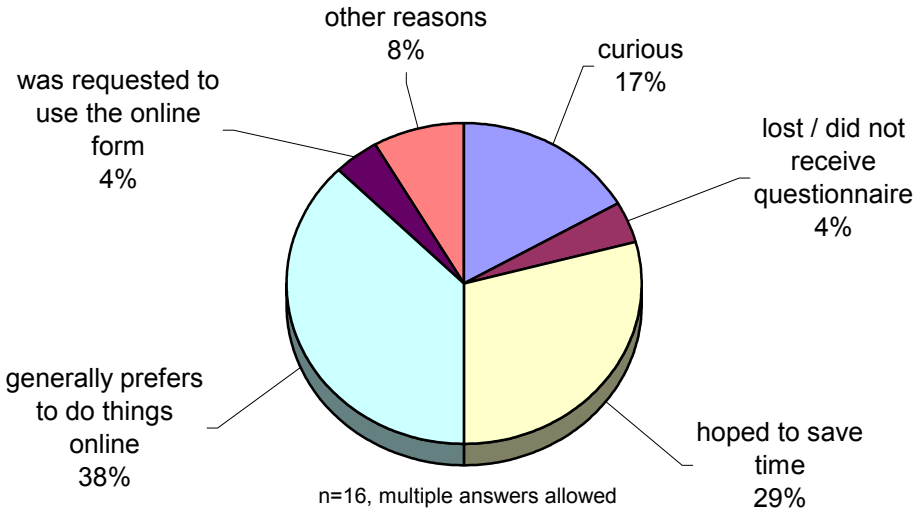

Figure 1. Reasons for preferring the web survey over the paper questionnaire in [7]

4 Recommendations

Concluding from our own experiences, we feel able to give the following recommendations for conducting mail surveys of designing companies:

- Contrary to common expert opinion [4] [8], our observations suggest that the length of a questionnaire does have a substantial influence on response rates. The key to keeping the survey form short is to provide expedient default answers and to avoid open questions (which require the participants to write down the answer). Consider that designers hardly ever "describe" when selecting the answer option "Other (please describe)", which happens rarely. Use the opportunity to test the questionnaire on suitable representatives of the intended target group.
- When using design-related terms, existing inconsistencies in terminology, especially between researchers and practitioners, must be considered. Give clear definitions of what is to be understood by the term "designer", "product", "requirement", etc.
- A designers' pool of experience usually encompasses a number of design projects and several products. Depending on the objectives of the study (and where it is not necessary for other reasons; see 3.2), it can be useful to let the subject refer its answers to one specific project, product, etc., in order to avoid an undesirable degree of generality in the answers.
- In most companies, product development is a very sensitive area. Explicitly assure confidentiality and, whenever possible, anonymity.
- It is often difficult or impossible to identify a designer within a company. Impersonal cover letters, however, should be avoided. Trying to address a member of upper management instead seems to be the better strategy. In any case, ask the receiver to forward the questionnaire if necessary.

- When addressees are given the choice between an online and a paper questionnaire, a vast majority will prefer the conventional form, making a dual approach (as described in [7]) a probably unrewarding endeavor. This finding also implies that postal mail surveys which completely abandon paper questionnaires in favor of an online form would likely receive lower response rates.
- The effort of conducting a mail survey should not be underestimated. A possibly good cost-benefit ratio notwithstanding, the required organizational and financial resources to prepare, mail and analyze hundreds of questionnaires can be considerable and altogether not necessarily lower compared to other methods.

5 Conclusion

Whereas the success of a mail survey greatly depends on questionnaire design and implementation procedures, its usefulness as an instrument of design research is for the most part determined by the research questions that need to be answered. The overall challenge results from the complexity of the phenomenon of design rather than designers as a target group.

It seems to be a common misconception that mail surveys are a cheap and less laborious alternative to other methods e.g. a series of interviews. Per se, they are neither an alternative in terms of effort, nor in terms of research methodology.

The biggest advantage mail surveys of designing companies offer – the efficiency in retrieving results with a high level of empirical relevance – can only be achieved, when the general rules for conducting surveys of businesses are followed while avoiding some design-specific pitfalls of which the most important ones have been discussed in this paper.

References

[1] Pahl G. and Beitz W., "Engineering Design – A systematic approach", 4th ed., Springer, Berlin, 1996

[2] Blessing, L., "What is this thing called Design research?", Annals of the 2002 CIRP Design Seminar, Hong Kong, 2002.

[3] Bender B., Reinicke, T., Wünsche, T. and Blessing, L., "Application of methods from social sciences in design research", Proceedings of the 7th International Design Conference, Marjanovic, D (editor)., The Design Society, Dubrovnik, 2002

[4] Dillman, D., "Mail and Internet Surveys – The Tailored Design Method", 2nd edition, John Wiley & Sons, New York, 2000

[5] Wünsche, T. and Blessing, L., "The familiarity with and the use of disassembly-supporting connections in Germany's manufacturing industry – a survey", Proceedings of the 8th International Design Conference, Marjanovic, D. (editor), The Design Society, Dubrovnik, 2004

[6] Reinicke, T., "Einsatz von Bewertungsmethoden – eine empirische Untersuchung", Technical Report TUB-KTEM 15-2003, Technical University Berlin, 2003

[7] Gries, B., Gericke, K. and Blessing, L., "How companies learn from design flaws: Results from an empirical study of the German manufacturing industry", Proceedings of the 15th International Conference on Engineering Design, Samuel, A. (editor), The Design Society, Melbourne, 2005 (publication pending)

[8] Atteslander, P., "Methoden der empirischen Sozialforschung", 8th edition, de Gruyter, Berlin, New York, 1995

[9] Meißner, M., Meyer-Eschenbach, A. and Blessing, L., "Adapting a design process to a new set of standards – A case study from the railway industry", Proceedings of the 8th International Design Conference, Marjanovic, D. (editor), The Design Society, Dubrovnik, 2004

[10] Bender, B., "Erfolgreiche individuelle Vorgehensstrategien in frühen Phasen der Produktentwicklung", VDI-Verlag, Düsseldorf, 2004

[11] Hales, C., "Ten Critical Factors in the Design Process", Proceedings of the International Conference Failure Prevention Through Education: Getting to the Root Cause Cleveland, 2000.

[12] Dowlen, C. and Shackleton, J., "Design History of the Car: An Empirical Overview of the Development of Layout and Form", Proceedings of the 14th International Conference on Engineering Design, Folkeson A. et al. (editors), The Design Society, Stockholm, 2003

[13] Del-Rey-Chamorro, F. and Wallace, K., "A Study of Information Retrieval in the Aerospace Domain", Proceedings of the 14th International Conference on Engineering Design, Folkeson A. et al. (editors), The Design Society, Stockholm, 2003

[14] Badke-Schaub P. and Stempfle, J., "Analysing Leadship Activities in Design: How Do Leaders Manage Different Types of Requirements?", Proceedings of the 8th International Design Conference, Marjanovic, D. (editor), The Design Society, Dubrovnik, 2004

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