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A SOFTWARE TOOL FOR OBSERVATION AND ANALYSIS OF DESIGN ACTIVITY

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1. Aims and Objectives

The identification of successful design strategies is an important objective of empirical design research [Bender et. al. 2001a]. Therefore we observe individual heuristics of experienced professional designers within a cross sectional laboratory study [Bender et. al. 2001b].

To cope with some typical problems of observing complex cognitive activity, a software tool for observation and analysis of individual design procedures has been developed. The tool can be customised and therefore is applicable to other types of observation and analysis of complex cognitive activity.

2. Observation and Analysis of Complex Activity

Observing design activity is a challenging endeavour because the units of analysis have high complexity, the definition of variables is difficult and "pure" influences can hardly be isolated, even in a laboratory environment. In addition, many variables cannot be observed directly.

For data acquisition some fundamental approaches can be followed [Atteslander 1995]:

- observation of the acting participant;
- analysis of contents and results of activity;
- questioning the participants about their activity.

Different forms of systematic observation have been established (loc. cit.):

- participative vs. non-participative;
- covered vs. uncovered;
- single vs. several observers;
- with vs. without technical support;
- self vs. external observation;
- continuous vs. discrete.

The focus in our study is on non-participative, uncovered, and external observation to avoid reactive influences on the participants caused by the activities of the observer. However, the developed software tool also applies to the other types of observation strategies.

3. Process Models of Design Methodology as a Reference for Design Activity

To formulate hypotheses about design procedures, a reference model is needed. Design methodologies, such as the one established by Pahl & Beitz [Pahl & Beitz 1996], deliver process models for different phases of the product development process. Based on these process models different categories for the observation of design processes can be identified (Table 1).

Table 1. Categories for the analysis of design processes ([v.d. Weth 2001], p.79)

category	occurrence of category	observed aspect
basic operations	writing, drawing, erasing, ...	fundamental steps of behaviour not related to a plan of action
documents	drawing, own sketch, catalogue of DIN-standards, ...	final and intermediate working results, sources of information
sub-functions	guiding, bearing, locking, adjusting	different problem areas of a design task
phases of problem solving	goal analysis, searching for solutions, elaboration of solutions	sub-processes of problem solving
breakdown of these phases	processing, controlling, organising, and operating of procedure	TOTE-model oriented refined breakdown of sub-processes
main design operations	collecting requirements, weighting requirements, ..., complete embodiment design, ...	successive sub-operations, (defined and derived from design methodology)
variants	occurrence of solutions and solution ideas for singular sub-functions	progress of solution referring to singular problem areas
amount of variants	amount of simultaneous considered solution variants (for singular sub-functions)	progress of the decision process for the final embodiment of the solution
product characteristics	function, assembly, recycling, ...	more or less definite sub-aspects of the solution
emotions	qualitative description, classification: positive/ negative	emotional characterisation of behaviour

In our research project, the *main design operations* have been identified as the most appropriate categories for observing design activity, whereas *variants, amount of variants* and *product characteristics* have been chosen for evaluating individual design success.

3.1 A Process Model for Conceptualisation

Conceptual design can be subdivided into cognitive problem solving actions, like *information*, *definition*, *creation*, *evaluation*, *check*, and *decision*. ([Pahl & Beitz 1996] p. 139 ff.) Basic design operations associated with these actions (Table 2) are appropriate variables for observation of individual design activity in the conceptual stage of design.

Table 2. Basic design operations in the conceptual design stage

	hypothetical basic operations
information	identify task and requirements
definition	abstract to identify the essential problems
	establish function structures
creation	search for working principles
	combine working principles into working structures
	select suitable combinations/ principle solutions
	firm up into principle solution variants
evaluation/decision	evaluate variants against technical and economic criteria
	definition of principle solution (concept)

3.2 A Process Model for Embodiment Design

A procedure analogue to the above leads to the variables for observing embodiment design activity (after [Pahl & Beitz 1996]., p. 201).

Table 3. Basic design operations in the embodiment design stage

	hypothetical basic operations
preliminary layout	identify embodiment-determining requirements
	produce scale drawings of spatial constraints
	identify embodiment-determining main function carriers
	develop preliminary layouts and form designs for main function carriers
	select suitable preliminary layouts
	develop preliminary layouts and form designs for remaining main function carriers
detailed layout	search for solutions to auxiliary functions
	develop detailed layouts and form designs for main function carriers
	develop detailed layouts and form designs for the auxiliary function carriers and complete overall layout
	evaluate against technical and economical criteria
completion and checks	optimise and complete form designs
	check for errors and disturbing factors
	complete overall layout
	definition of overall embodiment design

For further refinement, these basic operations can be related to documents, working methods and media used by the participants which are - at least for design experts - observable entities.

4. A Software Tool for Observation and Analysis of Design Activity

Within the study "Applicability of Design Methodology in Early Phases of the Product Development Process[1]" [Bender et. al. 2001b]

- influences of a Design Methodology Education (DME);
- influences of individual design heuristics and procedures on design performance; and
- effective strategies for acquisition and internalisation of methodological design faculty/ capability are investigated in a cross-sectional approach (Figure 1).

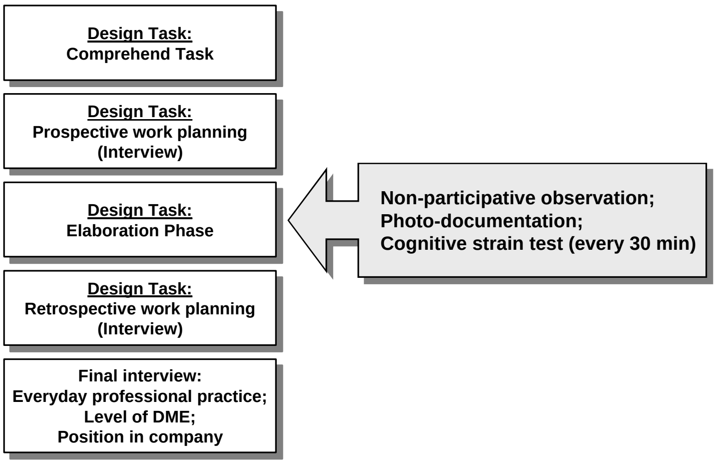

Figure 1. Design of Experiment for a cross sectional study

Experienced professional designers are confronted with a complex design task at the conceptual and preliminary design stage. Their individual design approach is observed using photo documentation and non-participative, uncovered, and external observation. In addition, individual cognitive characteristics, such as working memory, the tendency to mental distraction, and the ability to cope

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with mental stress are tested. Individual mental representations of the course of the process – such as goals and plans– are investigated before and after the session using structured interviews.

Normally, a non-participative external observation of design activity uses written protocols, photo or video documentation. These protocols might be pre-structured, but will still occupy much of the attention of the observer. In addition, the protocols have to be transcribed afterwards which might lead to typical transcription errors. To avoid these problems a software tool for direct data acquisition on observed design activity has been developed.

4.1 Data Capture: The Protocol Function

For data capture, a protocol function has been implemented into the software tool. It is based on the basic design operations and the reference processes for the conceptual and embodiment design stage mentioned above. Theses basic sets of operations have been slightly refined for the ease of observation, as well as for the adaptation to specific characteristics of the given design task. The software delivers a graphical user interface on which icons for each of these basic operation are arranged (Figure 2), and a database for recording the entered data.

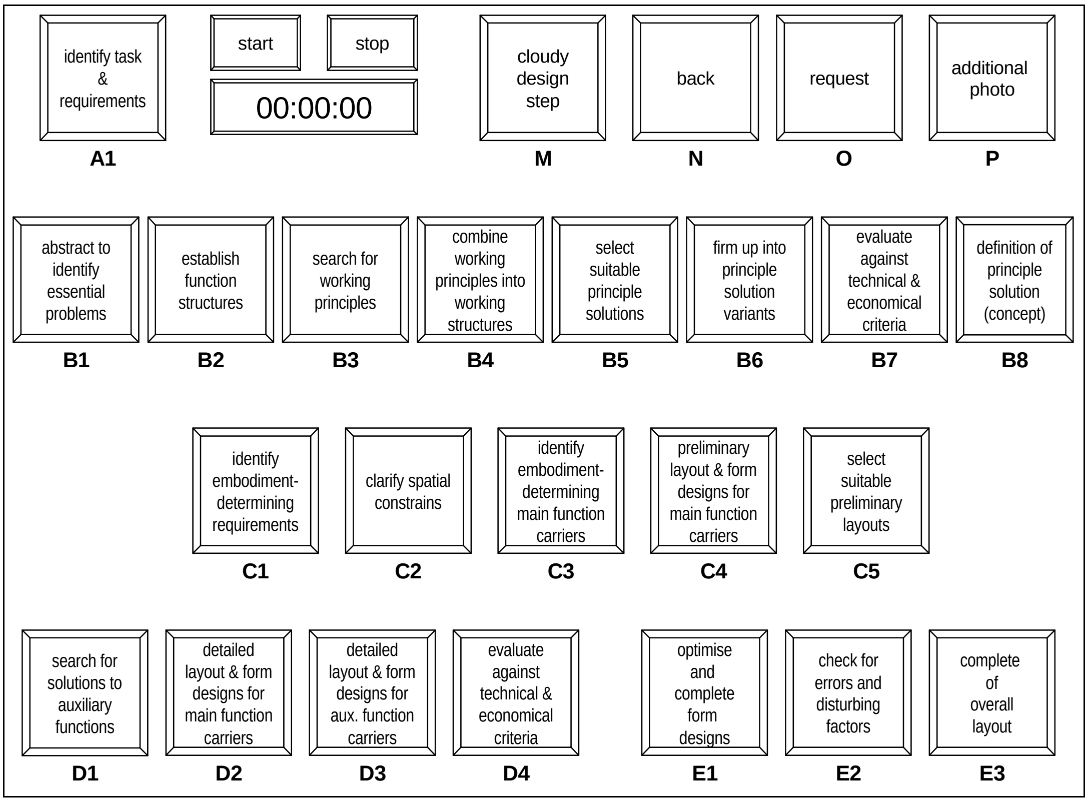
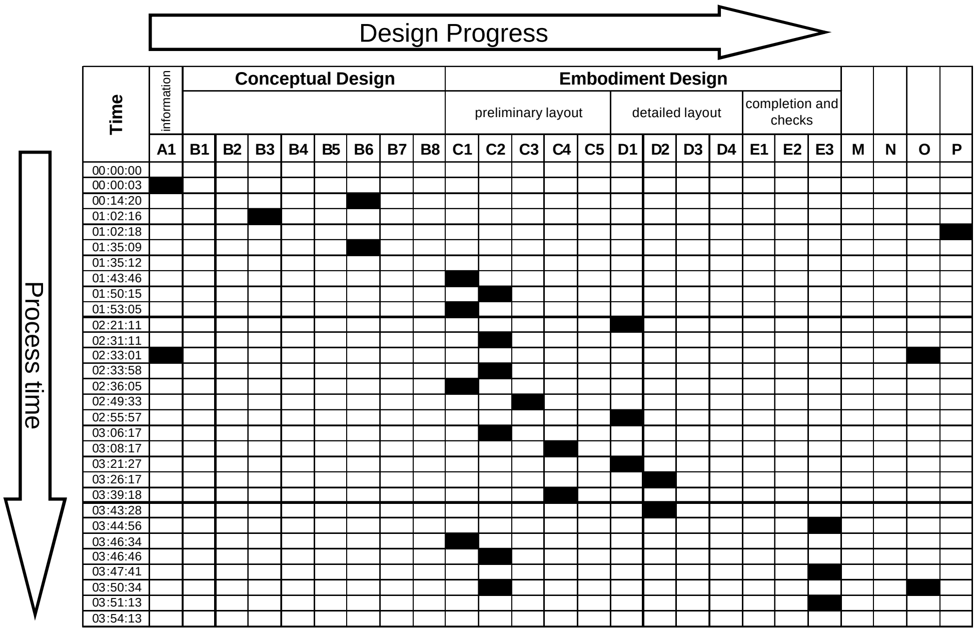


Figure 2. Screenshot of the input mask of the software tool

Whenever the observer identifies a change of design operation he or she has to click on the related icon and the change is entered into a database. The period of time a participant continues a specific operation is recorded automatically. Although trivial for a computer, this feature constitutes a major time-saving compared to manual time-stamping of the data. Some additional buttons have been added to undo incorrect data input operations and for the registration of remarks of the observer e.g. regarding ambiguous design steps that have to be checked within the interview.

4.2 Data Analysis: The Data Processing Function

For the analysis of the captured data, some fundamental methods can be used [Bender et. al. 2001a]. The transfer of data from a protocol to process charts and transition matrices normally requires much effort. The software provides a data processing function, which automatically delivers results of analyses such as process matrices (Figure 3).



Time	information	Conceptual Design								Embodiment Design															
										preliminary layout					detailed layout				completion and checks						
	A1	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	C5	D1	D2	D3	D4	E1	E2	E3	M	N	O	P
00:00:00																									
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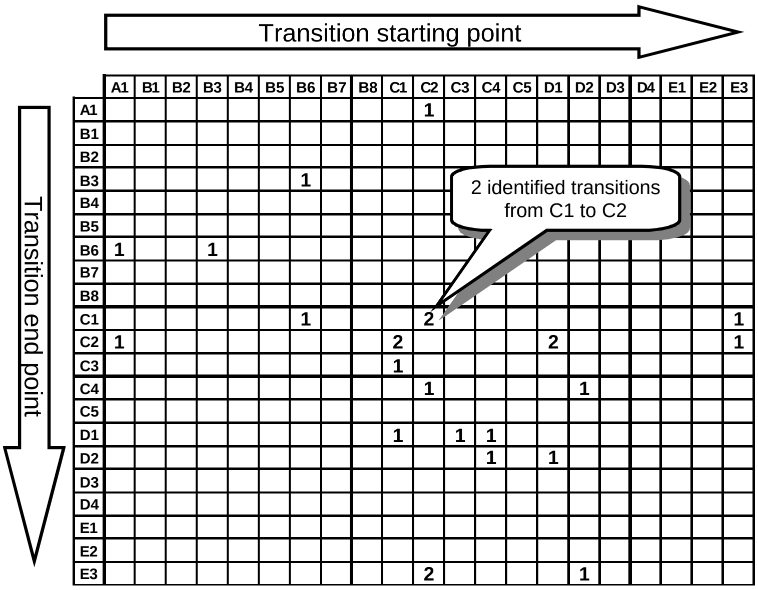
Figure 3. Screenshot data analysis: Process chart

For further analysis, transition matrices (introduced by [Fricke 1993] for the analysis of design processes) are created automatically (Figure 4). These matrices allow the comprehensive visualisation of *number* and *size* of observed transitions between two design operations in one diagram (see the example C1(row) to C2(column) in Figure 4).



	A1	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	C5	D1	D2	D3	D4	E1	E2	E3
A1											1										
B1																					
B2																					
B3							1														
B4																					
B5																					
B6	1			1																	
B7																					
B8																					
C1							1				2										1
C2	1									2					2						1
C3										1											
C4											1					1					
C5																					
D1										1		1	1								
D2													1		1						
D3																					
D4																					
E1																					
E2																					
E3											2					1					

2 identified transitions from C1 to C2

Figure 4. Screenshot of data analysis: Transition matrix

This software tool allows real-time data capture, automatically processes fundamental data-analyses and therefore increases the efficiency of empirical research. The tool can be easily customised for use with other types of research based on the observation and analysis of complex cognitive activity in a laboratory or a field context.

When the tool is used without video-taping the observed processes, no recording of the actual process is available for further analysis or correction. The use of the tool immediately summarises the observed data, as with many other documentation methods related to observation. Whether this is a problem depends on the other steps in the research project. For an exploratory study, where the categories of the variables are still uncertain, the protocol function might be less useful: the data processing function still remains useful as the protocol function can also be used based on other sources of data. For full studies, involving large numbers of observations, the use of the tool will definitively be beneficial.

5. Conclusion

To prevent observed activity from being influenced more than necessary by the observation itself, non-participative, uncovered, and external observation is an appropriate approach. To reduce the effort involved in protocols and data analysis, both crucial elements of laboratory research have been integrated into a software tool which has been successfully tested in an empirical study. It is expected, that the tool can be applied to comparable studies.

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References

[Atteslander 1995] Atteslander, P, "Methoden der empirischen Sozialforschung", Berlin, New York, 8th rev. Ed., 1995.

[Bender et. al. 2001a] Bender, Bernd, Kammerer, U., Pietzcker, F., Blessing, L.T.M., Hacker, W., "A Systematic Approach to Observation, Analysis, and Categorisation of Design Heuristics", in: Culley, Steve et. al (Eds.)., Proceedings of ICED'01, Glasgow UK, Design Research. Theories, Methodologies, and Product Modelling, Bury St Edmonds & London, 2001, pp. 197-204.

[Bender et. al. 2001b] Bender, Bernd, Kammerer, U., Pietzcker, F., Blessing, L.T.M., Hacker, W., "Successful Strategies for Complex Design in Early Phases of the Product Development Process – an Empirical Study", in: Culley, Steve et. al. (Eds.), Proceedings of ICED'01, Glasgow UK, Design Research. Theories, Methodologies, and Product Modelling, Bury St Edmonds & London, 2001, pp. 173-180.

[Bortz & Döring 2002] Bortz, J., Döring, N., „Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler", 3rd rev. Ed., Berlin, Heidelberg, New York, 2002.

[Fricke 1993] Fricke, G., „Konstruieren als flexibler Problemlöseprozeß. Empirische Untersuchung über erfolgreiche Strategien und methodische Vorgehensweisen beim Konstruieren. Düsseldorf, 1993.

[Pache et. al. 2001] Pache, M. et al., "Sketching Behaviour and Creativity in Conceptual Engineering Design", in: Culley, Steve et al. (Eds.): Proceedings of ICED'01, Glasgow UK, Design Research. Theories, Methodologies, and Product Modelling. Bury St Edmonds & London, 2001, pp. 461-268.

[Pahl & Beitz 1996] Pahl, G. and Beitz, W., "Engineering Design – A systematic Approach", 2nd rev. Ed., London, 1996.

[Römer et. al. 2001] Römer, A. et. al., "Effort-Saving Product Representations in Design, Results of a Questionnaire Survey", in: Design Studies. The International Journal for Design Research in Engineering, Architecture, Products and Systems, Vol.22, 2001, pp. 473-491.

[v.d. Weth 2001] v. d. Weth, R., „Management der Komplexität – Ressourcenorientiertes Handeln in der Praxis". Bern, 2001

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