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MORPHOLOGICAL ANALYSIS OF DESIGN CONCEPTS EMERGENCE IN DESIGN MEETINGS

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ABSTRACT

There is no consensus within the design research community on how to analyse design meetings. We explored a notable controversy concerning science and design. More specifically, we were interested in exploring whether previously neglected 'scientific' design methods can be adopted for use as analytic tools for design meetings. A specific method chosen for this purpose were morphological charts. Based on the definition of design by the C-K theory, which states that if there are no concepts there is no design, we have used morphological charts to reconstruct the emergence of design concepts in an architectural and an engineering meeting. This was done by analyzing video recordings of the both types of meetings.

Our results indicate that morphological charts are useful for the analysis of design meetings. Besides being capable of presenting the development of design concepts, morphological charts proved to be effective in reducing the time needed to analyze a rich set of data. We believe this complexity reduction offers the possibility of doing research on more (complex) design meetings more effectively, which is beneficial for generalization of findings.

Keywords: morphological charts, design meetings, design concepts, design research method

1 INTRODUCTION

There are many ways and many different possible tools to analyze design meetings [4, 9]. However, before deciding upon which tool (not) to use, or to introduce a whole new approach, we think it is first necessary to decide upon exactly what should be the focus of the analysis.

We will therefore first explain the theoretical background of our approach in section 1. Then the application of this approach will be described in section 2. This description is followed by the results and discussion of the outcomes in section 3. Finally, conclusions and remarks on future research will be given in section 4.

As well explained in the work of Cross, design is not a scientific activity [5, 7]. However, in the past a number of prescriptive design methods were developed as a result of "the aspirations to scientise design" [5, p.49]. These attempts were largely based on the view of design as an ill-structured problem solving activity [18]. Even though design undoubtedly includes stretches of 'normal' ill-structured problem solving [8, p.641], any model or description method that tries to reduce design to ill-structured problem solving is bound to miss important aspects of the design activity [10]. Recognising the fact that design is not a scientific or merely a problem solving activity, we wondered if any of the existing and largely neglected prescriptive design methods could help us to understand design by using them for research, rather than (as originally intended) for design activities. The motivation behind this idea was that, being developed on basis of scientific approach to designing, these prescriptive design methods 'automatically' meet the requirement for being methodical – one of the key characteristics of valid design research [6].

Although design might be understood as a social process [3], the statement that "there is no design if there are no concepts" [12, p.5] forms the basis for our research approach. Assuming that design thinking is related to design knowledge, and that knowledge is often something implicit, the definition of design by C-K theory [11, 12, 13, 14] allowed us to approach design concepts as indicators of design thinking. The following is a brief summary of the core elements from Hatchuel's and Weil's theory.

The C-K theory defines design as the interplay between two interdependent spaces having different structures and logics. This process generates co-expansion of two spaces, space of concepts C and space of knowledge K. The structures of these two spaces determine the core propositions of C-K theory:

- Knowledge – A piece of knowledge is a proposition with a logical status for the designer or the person receiving the design. Irrespective of the way in which this status is fixed, any form of logic, whether it be "standard" or "non standard", is in principle acceptable for a design theory. A set of knowledge is therefore a set of propositions, all of which have a logical status.
- Concept – A concept is a notion or proposition without a logical status: it is impossible to say that a concept, for instance an "oblong living room", is true, false, uncertain or not decidable. A concept is not "knowledge". Concepts capture the pragmatic notion of “brief” or “broad specifications” that can be found in innovative design.
- Space K – It contains all established (true) propositions (the available knowledge).
- Space C – It contains “concepts” which are propositions not decidable in K (neither true nor false in K) about some partially unknown set of objects called a C-set.

A design concept is a proposition that cannot be logically valued in K. Concepts are candidates to be transformed into propositions of K, but are not themselves elements of K (properties of K can however be incorporated into concepts). If a proposition is true in K, it would mean that it already exists and all is known that is needed about it (including its feasibility). Design would then immediately stop. There is no design if there are no concepts. Without the distinction between the expansions of C and K, design disappears or is reduced to mere computation or optimization.

General design knowledge can be differentiated into three categories: object knowledge, realization knowledge and process knowledge [1, p.388]. Van Aken states that the repertoire of a designer typically consists of general object knowledge; knowledge of the characteristics and properties of artefacts and their material. As such, a designer produces representations of the artefact to be made; the object-design [1, p.381]. We regard these representations to be the building stones for design concepts.

Proposed as a unified design theory, C-K theory focuses on innovative design [12]. However, the majority of cases in design do indeed concern mere computation, optimization and/or combinatory, which we would also like to capture as the possible outcomes of design meetings. Therefore, we propose the distinction between ‘integral design concepts’ (ID) and ‘redesigns’ (RE) [17]. Individual designers explicate their object design knowledge (iODK) by generating object-design representations, shown as small circles in Figure 1. From here, two types of synthesis are possible: either the representations are combined into ‘redesigns’ (RE) or transformed into ‘integral design concepts’ (ID).

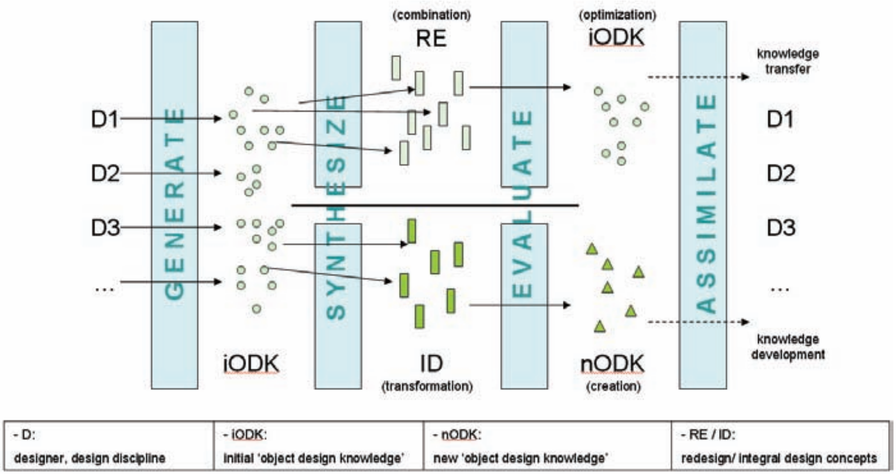

Figure 1. A model of knowledge transfer and knowledge development

The upper part of Figure 1 represents creation of redesign (RE) while the lower part of Figure 1 represents creation of integral design (ID). Of course, there is always the possibility to discard the presented knowledge as not relevant. Evaluation of ‘redesigns’ (RE) results in the same initial object design knowledge (iODK), which at most could be optimized, while from ‘integral design concepts’ (ID) completely new object design knowledge (nODK) can be created. The difference between the two design processes visualized in Figure 1 is that the first one results in knowledge transfer between the designers/participants involved, while the second one allows the possibility of knowledge development. One could argue that for the creation of ‘redesigns’ (RE) only design skill as a general human ability [7, p.33-47] is required, while the creation of ‘integral design concepts’ (ID) involves design thinking and creativity.
According to Boden [2] people can be credited with creativity in two senses, described as P-creativity and H-creativity: P stands for psychological and H for historical. P-creativity represents the creation of ideas which are new to the person that proposes them, whether this person immediately realizes their significance or not. These ideas are ‘new’ no matter how many other people may have previously had the same idea. H-creative ideas are novel with respect to the whole of human history, and people usually refer to them when they speak of ‘real’ creativity and ‘real’ innovative proposals. Regarding design we consider the transformation of object design knowledge introduced by different participants as a ‘team design’ P-creativity process. From this perspective, the lower part of Figure 1 represents the model of new object design knowledge (nODK) development within a design team configuration. Based on all the above, the focus of our analysis was to investigate the emergence of ‘integral design concepts’ (ID) during design meetings.

2 APPLICATION OF THE RESEARCH APPROACH

The design method we found most suitable for methodical reconstruction of ‘integral design concepts’ (ID) development was the ‘morphological chart’, which can be described as a “method to widen the area of search for solutions to a design problem” [15, p.292]. Morphological charts, which are essentially two-dimensional matrices, originate from the n-dimensional morphological box of Fritz Zwicky [19, 20]. The morphological box was developed in the period after WWII, when methodologists had the desire to base design processes on objectivity and rationality [5, p.49]. Interestingly, Zwicky himself described the morphological approach as ‘totality research’, which attempts to derive all the solutions of any given problem in an unbiased way [21]. Morphological charts require all functions to be defined and all possible solutions for each function to be listed, resulting in framing of the solution space. The remark from Jones that “there appears to be some justification for the belief that to make a morphological chart one must already possess sufficient knowledge, or sufficient imagination, to predict what the chart is going to reveal” [15, p.295], seemed to further justify the use of morphological charts for research of video recorded design meetings, as there the outcome of design processes is already known.

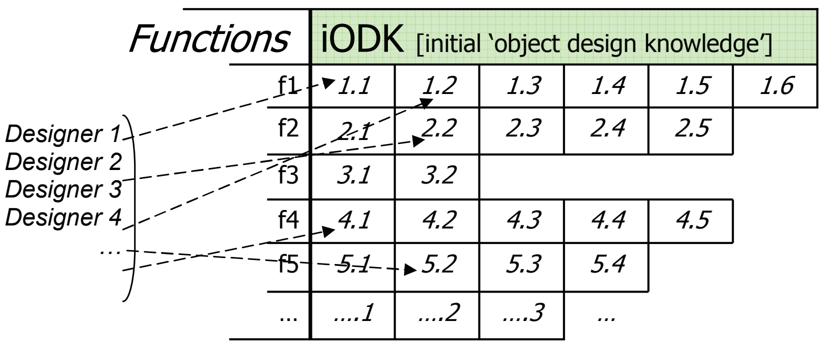

Figure 2. Principle of a morphological chart; functions on the left, object design knowledge representations on the right

Morphological charts were originally developed as a design method, while we used them as a research tool. Similar to the prescription for use of morphological charts as a design method [15, p.292-295], our first step was to construct the overviews of functions considered and representations produced, which would allow us to analyze the development of design concepts.

The definition of functions and representation of initial object design knowledge is based on the participants' interpretation of the design assignment. It is possible to make morphological charts for all individual contributions during a design meeting. However, even though research on individual roles during the process is more than worthwhile, we have limited ourselves to the analysis of the outcomes of this process. As such, instead of presenting individual or design-profession-based sets of charts, we have structured all the representations of the object design knowledge according to a predefined set of abstraction levels: 1) level of general ideas, 2) level of concrete references, 3) level of specific ideas, and 4) level of specified solutions. The used abstraction levels were more or less arbitrarily chosen during the discussion between researchers about morphological charts. The abstraction levels do not have a hierarchical structure. However, we can imagine that for research being done only within one discipline, a more specific and probably hierarchical set of abstraction levels would be used. One could go even further and rearrange the charts with regards to the relative complexity of the functions tackled during the design meeting. This could be done both following decisions of participants themselves, or based on the researcher's judgement.

In order to test applicability of morphological charts for the whole building domain, where two different design approaches meet (represented respectively by architects and consulting engineers), instead of choosing one specific discipline we performed a largely qualitative analysis of both an architectural and an engineering meeting. The data was independently processed by two researchers, who have two different backgrounds (1 from architecture and 1 from mechanical engineering). Firstly, each researcher made chronological overviews for both meetings, mainly using the video recordings. Secondly, the overviews were compared and differences in outcomes were discussed. This was also done mainly using the videos. Thirdly, based on this discussion, morphological charts consisting of functions and representations for each abstraction level were made, retaining the chronological structure. Finally, the development of 'integral design concepts' (ID) across the abstraction levels was reconstructed by defining the steps taken from the initial representations to the design concept integration.

3 RESULTS AND DISCUSSION

We analyzed one architectural and one engineering design meeting. Before presenting the results there are a couple of remarks that we feel need to be made about both design meetings. The design meetings showed only a small part of the whole range of aspects concerned with design: regarding design activities, stakeholders, design phases, decision moments, type of process etc.

The architectural meeting was concerned mainly with the feedback moments during the conceptual building design phase and involved only the architect and the clients. The architect already had a design proposal, based on the existing building on the site and on the existing building typology. From the meeting itself, the origins of new proposal were not clear. The architect did have meetings with a variety of advisers during the design process prior to the meeting with the clients. However, we do not know if and how the presented object-design emerged from those meetings. The engineering meeting represented a brainstorm session concerned with initial ideas generation. The brainstorm sessions have their own specific rules of conduct: no representation discussion/critique, decision taking and/or integration activities involved. Although these rules were not strictly followed, our view is that brainstorm sessions cannot be considered typical design meetings. Generally, in the 'complexity gradient' of design meetings, both used meetings could be placed on the lower end of the scale.

However, our specific focus was on the object design knowledge and the reconstruction of the development of design concepts using morphological charts as a research tool. As such, any (part of) design meeting would essentially do. This is also the reason why these meetings are not explained more extensively in their general context. The focus was instead on specific occurrences of design activities which indeed will be discussed in more detail in next sections. They should provide sufficient insight in the type of situations we analyzed.

3.1 The architectural meeting results

The architectural meeting was an example of a feedback session, where the client was informed about the latest developments in the design. In addition, the architect had the opportunity to inquire into aspects that were possibly not clear enough, and the client could also get some additional explanations on issues that were not solved or were not sufficiently worked out.

There were nine functions described by the participants during the meeting (Table 1), five of which were brought to the attention by the client and four by the architect. This indicates the evenly matched level of involvement with respect to content. Seven out of the nine functions were discussed in terms of representations on the level of 'specific ideas' (Figure 5), which clearly shows the focus of the design meeting.

Table 1. Chronological overview of described functions discussed during A1 meeting

By	When, time passed	Function	Abstraction level
architect	0:10	Waiting room	Specific ideas
client	0:14	Outside seating	Specific ideas
client	0:17	Access for hearses	Specific ideas
architect	0:24	Sanctuary	Specific ideas
architect	0:24	Catafalque (space)	Specific ideas
client	0:27	Seating (in chapel)	-
architect	0:32	window (sanctuary)	Specified solutions
client	0:38	AV accommodation ("theatre")	Specific ideas / specified solutions
client	1:59	2nd book of remembrance	Specific ideas

The participants did not explicitly describe the functions, but did move from one function to another. This sequence was actually to be expected in a feedback session.

Before presenting morphological charts, we would like to point out the difference between new representations and the optimization of the existing ones (both defined before or during the meeting). Furthermore, the explanations and discussions concerning the previously approved, before this meeting, representations were excluded from our analysis since they did not contribute to changing the object-design. For example, the explanation of the architectural idea on a 'catafalque space' was considered nothing more than that. It did not contribute to design in the sense that nothing new emerged from it.

Most functions and representations were introduced on the specific-ideas-level. Almost all representations were defined by the architect, half of them being optimizations. This was probably due the fact that discussion was based on the architect's drawings.

Explanation of the used text formats in the presented morphological charts: normal text represents contributions from the architect, **bold text represents contributions from the clients**, *italic text represents the undefined functions*, and highlighted text represents optimizations.

Function	object design knowledge representation	
Sanctuary 0:24	Its spirituality amplified 0:35	Meditative sort of space 0:35

Figure 3. Morphological chart – on 'general ideas level'

Function	object design knowledge representation		
Sanctuary 0:24	**Coventry Cathedral (coloured glass)** 0:32	Ronchamp (windows) 0:33	City centre church (circular area) 0:36
Garden -	Alhambra… 2:02		

Figure 4. Morphological chart – 'concrete references level'

<table>
<tr><th>Function</th><th colspan="10">object design knowledge representation</th></tr>
<tr><td>Waiting room
0:10</td><td colspan="10">Extending it (double the capacity)
0:12</td></tr>
<tr><td>Outside seating
0:14</td><td colspan="10">Add some…
0:15</td></tr>
<tr><td>Access for hearses
0:17</td><td colspan="5">color in paving (more obvious)
0:17</td><td colspan="5">Widen (for two cars to park)
0:20</td></tr>
<tr><td>Sanctuary
0:24</td><td colspan="5">More holes (in the wall)
0:33</td><td colspan="5">Built in seating
0:35</td></tr>
<tr><td>Catafalque (space)
0:24</td><td colspan="5">Whole thing bigger
0:26</td><td colspan="5">Splay the opening
0:27</td></tr>
<tr><td>Seating (in chapel)
0:27</td><td colspan="10"></td></tr>
<tr><td>AV accommodation (“theatre”)
0:38</td><td colspan="2">A door…
0:42</td><td colspan="2">A window…
0:34</td><td colspan="2">One room
0:44</td><td colspan="2">Bold arch. shape
0:47</td><td colspan="2">Room with ‘nose’
0:54</td></tr>
<tr><td>2nd book of remembrance
1:59</td><td colspan="10">An individual object
2:00</td></tr>
<tr><td>Garden
-</td><td colspan="10">More in this direction…
2:01</td></tr>
</table>

Figure 5. Morphological chart – ‘specific ideas level’

<table>
<tr><th>Function</th><th colspan="2">object design knowledge representation</th></tr>
<tr><td>Waiting room
0:10</td><td colspan="2">A two meter extension
0:14</td></tr>
<tr><td>Tall narrow window
0:32</td><td colspan="2">Stained glass
0:34</td></tr>
<tr><td>AV accommodation (“theatre”)
0:38</td><td>Mirrored glass…
0:39</td><td>Remotely operate equipment
0:40</td></tr>
</table>

Figure 6. Morphological chart – ‘specified solutions level’

No connections could be made between different contributions structured in morphological charts, meaning that object design knowledge representations were not transformed into integral design concepts during this architectural meeting. Based on a number of optimizations proposed to the already existing representations we can say that design potential was only partly realized during this architectural meeting.

3.2 The engineering meeting results

The engineering meeting could be regarded as an example of a rational problem solving approach, where the designers were given a list of criteria. There were already four functions defined prior to the engineering brainstorm session, which were used by engineers to aid the session. We have therefore limited ourselves to the analysis of the representations related to these four functions.
The four predefined functions were: 1) keeping the print head level, 2) protecting the print head, 3) print head activation and 4) print head angle.
There were more representations proposed during the engineering than during the architectural meeting, almost 100 (Figure 3) compared to 25. There were two clear examples of ‘integral design concepts’ (ID) development. These examples regard the representations for functions ‘keeping the print head level’ and ‘print head angle’. A note: in the morphological charts no distinction between contributions of different design professions is shown.

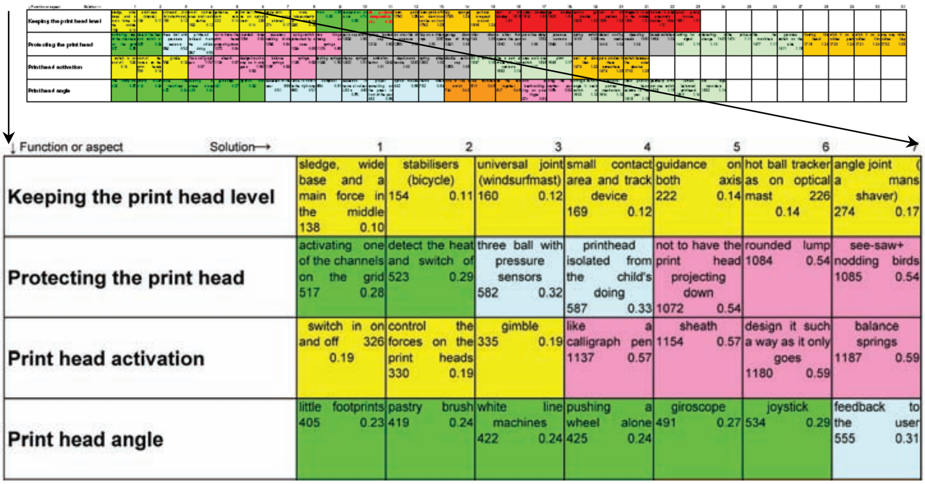

Figure 7. One of the initial overviews of the engineering meeting; the use of different colors (or shades of gray in the black-white print) provides an instant overview of the chronological pattern in relation to the amount of representations within the meeting

The development of the two integral design concepts happened within abstraction levels of their own predefined functions. No cross-function connections occurred between any abstraction levels of the different functions. Moreover, it happened in one sequence, without any pauses or changes of topics.

Function	object design knowledge representation			
Keeping the print head level	Air pockets suspension 0:26			
Print head angle	Feedback to user 0:31	Only correct in one way 0:32	Styling… to feel right 0:42	Comfy/only to work! 0:43

Figure 8. Morphological chart – 'general ideas level'

Function	object design knowledge representation			
Keeping the print head level	Sledge 0:10	Windsurf mast 0:11	A tram 0:26	Suspension on car 0:26
Print head angle	Footprints (toy) 0:23	Pastry brush 0:24	Joystick 0:29	Optical mouse 0:36

Figure 9. Morphological chart – 'concrete references level'

Function	object design knowledge representation			
Keeping the print head level	Stabilizers (based on sledge) 0:11	Small contact area and track device… 0:12	Hot ball, tracker like optical mast 0:14	
Print head angle	Project on paper in front of pen… 0:36	Thumb holes 0:39	Valve… lets ink through 0:40	Ring on finger, with pen attached 0:50

Figure 10. Morphological chart – 'specific ideas level'

Function	object design knowledge representation	
Print head angle	color LED's 0:33	Four switches… 0:43

Figure 11. Morphological chart – 'specified solutions level'

The first example, regarding solution search for 'keeping the print head level', shows how from an analogy situation between two different abstraction levels (Figures 9 and 10), at a certain point optimization on the concrete-references-abstraction-level regarding 'keeping the print head level' problem occurred (0:26). This car (suspension) reference in combination with a tram (distance between the rails and the overhead wires) resulted in the discussion between two design team members that lead to the integral design concept (ID): '…air pockets… that could be like a little suspension'.

The second example shows a richer picture of the development of an integral design concept. After a number of representations on the concrete-references-level (Figure 9, row 'print head angle'), a 'feedback to user' representation on the general-ideas-level was proposed (0:31). This representation was further optimized to 'only correct in one way' (0:32) on the same abstraction level, leading further through 'colour LED's' (0:33) on the specified-solutions-level (morphological chart 8) and 'project on paper in front of pen' (0:36) on the specific-ideas-level to the 'optical mouse' representation (0:36) on the concrete-references-level. Then, a new representation for 'doing it only one way' was proposed, by making 'thumb holes' (0:39, specific-ideas-level). The eventual reaction to these activities was the definition of 'styling… to feel right' (0:42) representation on the general-ideas-level. Prior to this occurrence, a new representation on the specific-ideas-level was proposed for 'doing it in one way' ('valve that lets ink through', 0:40), which was further optimized on the specified-solutions-level into 'four switches…' (0:43). The final step was the integration of 'comfortable' with 'the only way to do' on the general-ideas-level (0:43); which was used in its turn as a starting point for further optimization, as 'ring on finger… with the pen attached' (0:50).

Besides the two examples of transformation of object design knowledge into integral design concepts, there are a couple of other things to note on the engineering design meeting. The optimization of representations often happened when switching from one abstraction level to the other. For example, in the case of 'keeping the print head level' function, the concrete-references representations 'sledge' and 'windsurf mast' (Figure 9) were optimized into 'stabilizers' and 'small contact area and device' representations on the specific-ideas-level (Figure 10). However, this always happened within one of the predefined functions. No cross-fertilization occurred between different representations on different abstraction levels. As with the architectural meeting, in the case of longer time intervals also no connection with previously introduced representations was made.

Purely based on how the architectural and the engineering meetings proceeded, one might get the erroneous impression that design processes have a generally linear structure. This appears especially true for the architectural meeting, where one function after another was discussed sequentially, without coming back to it as was done during the engineering meeting. However, even the engineering meeting only showed stand alone representation sequences regarding one function, and no connections with previously discussed representations of other functions. As already stated, no cross-functional connections occurred between different representations on different abstraction levels. Both meetings showed that in case of longer time intervals no connections with previously introduced representations were made. For both types of meetings all used representation types were considered: sketches, words (explanations) and/or gestures (including pointing to the existing drawings).

4 CONCLUSIONS

The results indicate that globally the approach we chose was successful. The morphological charts provided a simple yet powerful support for the analysis of design meetings. Besides being capable of presenting the development of design concepts, morphological charts were effective in reducing the complexity of the rich research data, while maintaining enough accuracy for the intended analysis. They offered the possibility for selective examination of those aspects considered important, in our case the explicit object-design representations. The expectation is that the reduction of data complexity will increase clarity if more complex meetings are analysed. Besides, we believe that through this reduction of complexity the use of morphological charts in some cases can be a good alternative to the time-consuming protocol analysis approach. Since we mainly used the morphological charts for the analysis of video recordings, we believe that it would be worthwhile to also test them in 'live', real-time practice situations. Although we know how difficult it is to gather this type of design data, the 'choice' for the discussed meetings in this paper is a good example in itself, our recommendation for future research on the use of morphological charts would be to analyse more complex design meetings. We believe that the more complex the meetings are, the more useful the tool becomes.

In addition to investigating if morphological charts, originally a design method, could be used as a research tool, the aim of our analysis was to contribute to the field of design research by proposing 'integral design concepts' (ID) as indicators for design thinking and creativity, and showing how their emergence can be established.

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