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Relating the quality of the idea generation process to the quality of the resulting design ideas

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Abstract

In earlier research we used linkography to examine how the use of sketching influences the design idea generation process. Linkography is a structuralist research approach in which a network of links between design ideas is constructed, based on evidence found in the protocol. This network is then further analyzed to make inferences about the qualities of the design process under investigation.
To increase the validity of linkography as a research approach, we still have to verify whether a more creative idea generation process indeed brings forth more creative ideas. The main hypothesis is that ideas with a strong structure of connections with earlier ideas are more 'creative' than ideas without such a strong structure of connections.
This study is compares the participants' appraisal of 192 ideas, generated in 4 idea generation meetings with the link structures that lead tot these ideas. The results show a positive relationship between the well-integratedness of ideas and the creative qualities of those ideas.

Keywords: Creative design, empirical study, process, problem solving techniques

1. Introduction

The majority of the research on idea generation meetings focuses entirely on the results of these meetings as dependent variables. In our earlier research [1], we took a different perspective, by exclusively using the process qualities of such meetings as dependent variables. We applied linkography [2], a structuralist research approach from the field of design thinking research. In our adaptation to linkography, we analyzed the links between ideas in idea generation meetings in order to investigate the quality of the structure of the idea generation process. In linkography, the evidence for -or against- the presence of a link is determined for each possible combination of ideas in a meeting.

We made the basic assumption that 'well-integratedness' is the key process variable for determining the quality of the process. In our working definition, a well-integrated idea generation process is an idea generation process that has a strong network of connections between ideas. In terms of linkography, such a strong network of links can be regarded to have the following three attributes: 1) A large number of links with earlier ideas; 2) Links between ideas generated by various participants, and 3) A proper mix of different types of links: small alterations, direct variations and wild leaps.

This research approach allowed us to investigate the functioning of sketching in design idea generation meetings, by comparing the process characteristics of various ways of including sketching in the brainstorming process.

However, we still have to verify whether a well-integrated idea generation process indeed brings forth high quality ideas. The main assumption is that ideas with a strong structure of connections with earlier ideas are more 'creative' than ideas without such a strong structure of connections. In this paper we take the perspective of the group members that generated the ideas, rather than independent judges. The main reason for this is that ideas in idea generation meetings are more like 'snapshots' of a process, rather than autonomous and stable solution states. However, the consequence of taking this specific viewpoint is that this study only partly meets the main research objective. The research question to be answered in this paper is: "What is the relationship between the group members' appraisal of design ideas and the well-integratedness of the linking structure of these ideas?"

2. Assessing CPS meetings

2.1 Assessment of the creative qualities of ideas

The majority of the empirical research on the functioning or the effectiveness of creative problem-solving techniques uses experimental designs, in which differences in outcomes are compared between a group receiving a certain 'treatment' and a control group. The treatment typically consists of a certain idea generation technique applied to the group, e.g. [3]. The control group is subject to either no treatment, or a more conventional type of idea generation technique. The outcomes usually consist of the quantity, and sometimes the quality, of the ideas generated. As most of these studies refer to the quantity of ideas, or quantity of 'good' ideas generated per person per time unit, they really investigate the supposed efficiency, rather than the functioning of creative idea generation meetings. Functioning is assumed to correspond with efficiency, perhaps for the pragmatic reason that efficiency can more easily be operationalized into relatively objective dependent variables.

Consequently, studies into the functioning or effectiveness of idea generation groups mainly assess the quality or the quantity of ideas generated, as the main claims regarding the value of idea generation meetings are related to these two aspects. The more rigid behaviorist research approaches only accept the quantity of ideas generated as a reliable measurement of the functioning or effectiveness of idea generation meetings, e.g. [4], mainly because it is the only dependent variable that is directly observable.

There are two issues that limit the appropriateness of these approaches. The first is that brainstorming ideas are treated as self-contained entities, or solutions, while oftentimes they are not; the context of the ideas before and after the idea under observation is needed to achieve a proper understanding of the idea [5]. This collides with the generally applied practice of randomization of ideas to be judged in the fore mentioned studies. The second issue is that, especially within a design context, the principal function of idea generation meetings appears to be to explore new search directions and to create leverage for search directions among the team members [6], in addition to functioning as a means for generating a large quantity of ideas to be used in the design process.

To overcome these issues, we limited the scope of this study to using the way that the participants themselves feel about the ideas that they, as a group, generated. The drawback of this is that it is not a very objective means of appraising the creative qualities of ideas, and therefore provides only limited insight in the main purpose of this research (relating the creativeness of the process to the creativeness of the resulting ideas). With this study we can only make inferences about the relationship between the group members' appraisal of the creativeness of the ideas and the creativeness of the linking structure that lead to these ideas.

2.2 Assessment of the creative qualities of the process

In creativity research, hardly any instruments take a process perspective for assessing the effectiveness of idea generation techniques. In their comprehensive review on creativity assessment instruments, Puccio and Murdock [7] concur that: *"Despite great interest in applying and teaching strategies and models of creative thinking (e.g. Torrance & Presbury, 1984), few measurements explicitly examine aspects of the creative process" (p. 14).* Even though Puccio & Murdock state that there are 'few' explicit creative process measurements, they do not report any in their overview. We will look for a suitable research approach in the adjacent area of design thinking research. This research area is more familiar with investigating the structure of problem solving processes, mainly through protocol studies, see [8]. Already Newell & Simon [9] described the structures of problem solving processes by 'Problem Behavior Graphs', which show 'states of knowledge' in the nodes of the diagram, and 'operators applied to the states of knowledge' as connecting lines between the nodes. Dwarakanath & Blessing [10] constructed decision trees of design experiments based on -what they interpreted as- the major problems and alternatives considered. Both the problem behavior graph and the decision tree require the researcher to backtrack the design process as if it were a rational decision-making or reasoning process. The association processes that occur while group members generate ideas are quite distant from such rational processes, which make these methods less suitable for analyzing idea generation meetings. Other approaches have principally the same difficulties, which disqualify them for application in the field of creative problem solving.

One research approach that does not rely on regarding designing as a rational decision making process is proposed by Goldschmidt , e.g. [2]. This approach, known as 'linkography', directly addresses the ways in which designers make connections with previously generated design information by recording the links among design moves. By analyzing the linking between the moves, linkography purports to: *"...be instrumental in comprehending structural patterns of design reasoning" (p. 72).* The general approach followed by Goldschmidt is to first subdivide a protocol of a design experiment into moves. Then, for each move, the existence, or non-existence, of links with each of the earlier moves is determined.

Linkography is a suitable research approach for investigating the structure of idea generation processes as it does not require assuming a rational process of decision making or reasoning. We adjusted the linkography approach in order to make it applicable to idea generation meetings [1]. One of the principal changes that we made is that, for analyzing idea generation meetings, we opted for investigating the linking between design ideas, rather than design moves.

2.3 Well-integratedness as a process measure of creative quality

Now that we have found a research approach that allows us to describe the structure of an idea generation process, we still have to determine which characteristics constitute a creative idea generation process.

The main focus when looking at creative group processes should be directed towards the ways in which group members interact. Gruber [11] states about the creative process*: "Interesting creative processes almost never result from single steps, but rather from concatenations and articulations of a complex set of interrelated moves" (pp. 177-178).* Dorst [12] suggests integration as an important factor in design activity. A well-integrated idea generation process can be expected to show signs of making use of the information gained earlier in the process. Following this line of thought, a well-integrated idea generation process has a strong network of links.

A large number of links is a prerequisite for such a strong network, but there are more requirements. It is also important to achieve insights into the extent to which participants build on their own ideas, or on each other's ideas. The very reason for having a group meeting is for the group members to interact in their problem solving efforts, by making use of each other's knowledge and previous experience. This is especially relevant for multi-disciplinary teamwork - which is often the case in design projects- as these projects require the integration of knowledge from the separate disciplines represented, which cannot be accomplished by the team members separately. If the amount of building on their own ideas is very high, the group process is not well-integrated, even though the individual processes may have many connections with earlier ideas.

Finally, a distinction needs to be made between being well-integrated and Goel's [13] concept of 'early crystallization', which means that the search for new directions for design solutions is abandoned prematurely. Early crystallization may lead to the designers often connecting to earlier ideas, because those ideas have become part of a rigid frame of reference. However, the types of these connections will be different than for a normal associative idea generation process. Early crystallization will involve a process of predominantly small alterations. In a well-integrated idea generation process, wild leaps, direct associations, and small alterations are balanced. Too many wild leaps indicate a lack of progress in the idea generation process, and too many small alterations indicate premature crystallization.

This section of the paper discussed two different approaches for assessing the quality of idea generation meetings. The outcomes approach focuses on analysing the results of meetings to infer their creative qualities, while regarding the process itself as a 'black box'. The process approach focuses on the linking structure within the process, while discarding the outcomes as dependent variables. We could not uncover any studies that relate the two perspectives by comparing the outcomes to the process qualities in idea generation meetings. In the empirical study reported below, we attempted to take a few steps to fill in this void.

3. Empirical study

The linkographs of four experimental meetings from an earlier study [1] were analyzed. Each of these meetings consisted of five advanced product design students who were involved in a course in facilitating creative problem solving meetings. Each meeting was moderated by an experienced professional creative problem solving facilitator.

The following design assignment was developed with these requirements in mind: 'How to make traveling by car fun for children?' The participants were asked to generate ideas for products to make traveling by car fun for children. The assignment involved generating ideas for a particular multi-functional family car.

In each meeting the 'brainsketching' technique [14], [15] was applied. During brainsketching, participants sketch ideas individually in short rounds. After each round they briefly share their ideas and then switch papers. In the next round they use the ideas already present on the worksheet as a source of inspiration. Usually about five such rounds take place.

In the convergent phase following the divergent brainsketching phase, the participants selected ideas by means of colored sticky dots. Each participant received four red dots to select the most surprising ideas, and four green dots to select the most feasible ideas. After putting down the green and red dots, they also received one blue dot to select the idea that 'they would be most excited about to develop further'.

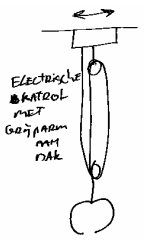
For the 192 ides generated in the four idea generation meetings, the link structures and the idea selection by the participants (the green, red and blue dots) were recorded.

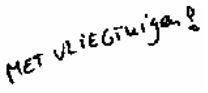
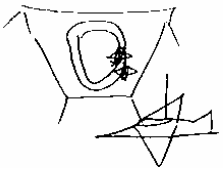
3.1 Method: Linking structures

In order to be able to directly connect the creative qualities of the idea to the creative qualities of the process, we used the individual ideas as the unit of research. As a measure of the creative quality -or well-integratedness- of the process we analyzed the structure of links that lead to the idea. Such 'link structures' of ideas were constructed by tracing the line of connections with earlier ideas made.

For instance, consider meeting 1 idea 48 'Racetrack with planes on ceiling, planes suspended from strings so that they glide in the turns'. Table 1 shows the selection from the protocol of the related ideas.

Table 1: Sample of fragments from protocol of meeting 1

No	i.d.	Label	time	Picture	Subject explanation of idea
				Round 1	
4	III/C/1	Winch with remote control suspended from roof	36.43	 (Electric winch with grab on ceiling)	C: That is kind of a winch on the ceiling, with some kind of a rail .. that you can grab all kinds of things on the back seat with some kind of a remote control .. That you can let it go from one side to the other … That you can lower it and grasp things with your grab.

5	III/C/2	Racetrack upside down on roof	37.44	 (Racetrack on roof [upside down])	C: And,some kind of race track on the roof .. so that you can look at the ceiling, and that there are cars that stick to the ceiling that drive laps. C: Yes, this is drawn a bit awkward D: So, they .. just on the ceiling C: Yes, simply against the ceiling, so that the cars drive upside down
				Round 5	
47	III/D/11	Racetrack for planes on roof	61.15	 (with planes!)	*(written close to idea 5: Racetrack upside down on ceiling)* D: .. and I liked that one very much as well *(points at idea 5)* .. that idea for on the ceiling .. and you could do that with little airplanes, because they are in the air anyhow...
48	III/D/12	planes hang on strings so that they glide in bends	61.38		*(arrow from idea 47)* D: ... and you could align them nicely in two tracks next to each other and hang them from a string so that they really glide in the bends

From the linkograph, we can observe that idea 48 by designer D has just one -supplementary- link: with idea 47 'Racetrack with airplanes'. Then, following upwards, idea 47 has a modification link with idea 5 by designer C: 'Racetrack upside down on roof'. In turn idea 4 has a tangential link with idea 4: 'Winch with remote control suspended from roof'. This leads to the following link structure (see figure 1):

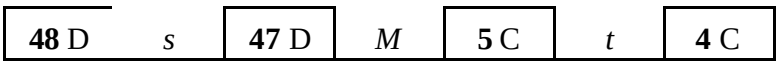


Figure 1: Link structure of idea 48.

In this figure, bold numbers refer to the idea identification code, Letters in roman refer to the designers identification code and letters in italic refer to the link type: Supplementary, Modification or Tangential. This distinction is based on a categorization of the nature of ideas provided by Gryskiewicz [16]. Supplementary links refer to small alterations, modification type links refer to direct associations in a similar direction, and tangential links refer to wild leaps into different directions.

The link structure of idea 48 has, in total three links, one of which is a 'self-link' (a link made by a designer with an earlier idea generated by him- or herself). The link structure contains one supplementary link, one modification link and one tangential link. These figures are then indexed to be able to compare between ideas: The *link-type indices* indicate the nature of the connections that are made. They consist of the number of links of a certain type, divided by the overall number of links in a link matrix. For idea 48, the supplementary link type index, the modification link type index, and the tangential link type index have the value of 0.33 each.

The other dependent variables used are the *number of links* in a link structure, and the *number of participants*, which relates to the amount of group members who contributed to the idea, by represented by a link in the link structure.

In the previous example, the link structure is linear; each idea makes a connection with just one earlier idea. But a link structure can also branch out, for instance in the following example, idea 51 'Armrest with games, shaped like a car' by designer A in the same meeting (figure 2):

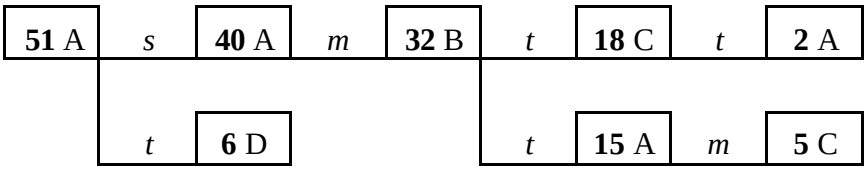


Figure 2: Link structure of idea 51 in meeting 1.

This idea branches out twice: Idea 51 has two links with earlier ideas (ideas 40 and 6), and in turn, idea 40 has two links with earlier ideas (32 and 15).

3.2 Idea appraisal by participants

As the first 'quality of ideas' measure, we looked at the number of sticky dots that the participants attributed to the ideas. Next to the number of red dots (surprising), green dots (feasible) and blue dots (excited to develop further), we also wanted to provide a synthesizing 'score' of the participants' idea evaluation, which we based on the following formula:

$$\text{Score} = [\text{green dots}] + [\text{red dots}] + 2*[\text{green AND red dots}] + 4*[\text{blue dots}] \quad (1)$$

This score was based on the notion that in order to be successful, it is of primary importance that an idea needs to spawn motivation among the participants to be developed further, hence the high value given to the blue dots. Also, if we follow Barron's [17] notion that creativity in ideas is 'novelty that is useful', ideas need to be both surprising and feasible. Therefore we gave extra weight for each combination of a red- and a green dot, which, in total, gives equal value to a blue dot and a combination of a red and a green dot. So, for instance, idea 32 in meeting 3, 'side-panels of the car are construction game board' received five green dots, one red dot and one blue dot. This lead to a general score of the idea evaluation of idea 32:

$$\text{Score (idea 32 meeting 3)} = [5] + [1] + 2*[1] + 4*[1] = 12 \quad (2)$$

Which is the 3rd highest score among the ideas.

4. Results

For the 192 ideas analyzed, link indices indicating well-integratedness of the linking structure were investigated.

The differences were examined between the group of ideas that received at least two dots of a certain color, and the group of ideas that received less than two dots of that color by means of independent sample t-tests. The dividing factor of two dots was chosen because it indicates that at least two of the participants agreed that the idea is high on feasibility (green), originality (red), or motivation to develop further (blue). Also, the significance of the difference between groups of

low- and high 'score' was calculated. Here, the ideas were divided into groups of ideas that received a score of less than seven, and more than seven, to identify the ideas which received a substantial amount of interest of multiple participants during the convergent phases of the idea generation meetings.

The general dependent variable, 'score' showed four significant differences between means. For the group of ideas with a score of at least seven, the number of links is significantly ($p<.05$) higher (score =7: $\underline{X}=7.25$; score<7: $\underline{X}=2.68$). The number of persons involved in the linking structure is also significantly higher ($p<.05$; score ≥ 7: $\underline{X}=3.08$; score<7: $\underline{X}=2.13$. Finally, the tangential link index is significantly ($p<.05$) lower for the high score group (score =7: $\underline{X}=.24$; score <6: $\underline{X}=.41$).

The group of ideas that were noted as 'feasible' by the participants (the ideas that received two ore more green dots) has a significantly ($p<.01$) lower level of tangential links (For green = 2: $\underline{X}=.19$; for green<2: $\underline{X} = .33$). The linking structures of these ideas also contain significantly more links with earlier ideas ($p<.001$; for green=2: $\underline{X}=7.05$; for green<2:$\underline{X}=2.60$). And, number of participants contributing to the ideas is significantly higher for the ideas that were seen as feasible by the participants ($p<.01$; for green =2: $\underline{X}=3.05$; for green<2:$\underline{X}=2.11$).

For the group of ideas that were seen as 'surprising' by the participants (two or more red sticky dots), the group of ideas with more than two red dots has a significantly ($p<.005$) higher number of participants contributing to the ideas (for red=2: $\underline{X}=2.92$; for red<2:$\underline{X}=2.112$), which indicates that the instantiation of these ideas compounds more of a group process, rather than an individual process.

For the blue dots, the ideas that the participants are excited about to further develop, no reliable inferences can be made, as the number of cases in the blue=2 group –this group contains only four ideas– does not allow for statistical analysis. However, for the number of links in the link structures, the means of the group with two or more blue dots (n=4) is much higher than for the group with less than two blue dots (blue=2: $\underline{X}=10.25$; blue<2: $\underline{X}=2.91$). Even though this is quite a big difference, does not allow for making reliable inferences. This leaves us with at most a suspicion that ideas which the group members select to further elaborate have a larger network of links.

5. Discussion of results

The results of this study show that there is a strong connection between the number of ideas in a link structure and the perceived quality of that idea, measured by the variables of 'surprising', 'feasible', and 'motivation to further pursue'. Especially the number of links influences the participants' appraisal of the ideas. Both for the higher score and the higher feasibility groups, a significantly amount of links was found.

As could be expected, ideas that were seen as feasible had a lower level of wild connections in the link structures, and longer developmental paths, indicated by the number of links in the link structures.

One remarkable result was the lower level of wild-leap type connections made for the higher score group. One would expect that ideas resulting from an idea generation meeting that received the most support would have a balanced combination of the different link types. The low score

group has an exceedingly high level of tangential links, meaning that there are many wild leaps into new directions made without further development and exploration of those directions.

It is interesting to notice that both the ideas that were seen as 'feasible' and –especially– the ideas that were seen as 'surprising' had contributions from relatively many group members, meaning that selected ideas came forth through a group process rather than an individual process. And, two of the four ideas that they were particularly excited about to develop further (two or more blue dots) even had contributions in the link structure from all five participants. This can be explained in two ways. One is that group processes provide better ideas than individual idea generation processes, as brainstorming literature claims [18]. The other is that, because the group generates the ideas, they have more leverage to be used in further design activity. This second explanation is in line with the results from a survey among professional designers, where creating leverage for ideas was seen as one of the main benefits of idea generation meetings [6].

6. Conclusion

The analysis of the idea selection of the participants generally underwrites the assumed relationship between the well-integratedness of the process and the appraisal of the ideas. To recall, a well-integrated creative process has a large network of links, a low level of self-links, and a balance of link types. The link type indices did not provide clear-cut results, but ideas that were regarded as creative by the participants indeed had more links and resulted from processes in which a high amount of participants contributed directly.

In this study a particular, and debatable, view on the relationship between the process and outcomes of idea generation meetings was taken. In general, the opinions of participants themselves are not considered to provide strong scientific evidence. However, in the context of a larger design process, it is these participants who have to become excited by the design ideas generated in the meeting, so that they will have motivation to take them further in the design process. That is why, in this particular study, we considered the participants' opinions to be quite relevant.

At the moment we are involved in an additional study that attempts to explore the relationship between the link structures and the appraisal of the ideas by a pool of independent judges. With the results of that study more definite inferences can be made regarding the main assumption that ideas with a strong structure of connections with earlier ideas are more 'creative' than ideas without such a strong structure of connections.

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