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COMPARING THE USEFULNESS OF RULES & NO RULES IN ENGINEERING DESIGN BRAINSTORMING?

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ABSTRACT
The most common early-stage design technique is brainstorming based on Osborne's classical rules. This paper contributes to research which explores how brainstorming should be taught in the engineering design education. The research presented in this paper aims to understand the effects of brainstorming with, and without rules, and compares the productivity of each condition. Eight brainstorming sessions were held and recorded. These controlled tests used 2 groups (A and B) of 3 male participants, all in their 3rd and 4th year of Mechanical, Aerospace or Automotive Engineering at the University of Bath. The paper reports on the results from those controlled design experiments showing how rules affected the quality and quantity of ideas generated through the variance of moment-to-moment, interpersonal interactions. Quantity and quality were analysed by the researcher using a Likert scale and an inter-observer reliability check whilst the interpersonal interactions were analysed using Solnakar's Interaction Dynamics Notation (IDN). The results showed that the Natural condition - on average - generated 7.75 more ideas per test and 4.25 more *good* ideas per test, than the Rule condition. The IDN analysis highlighted the specific blocking effects which generated a significant number of ideas directly, by overcoming blocks, or indirectly, by blocking-inspired conversation. The controlled results also showed that participants in the Natural condition evaluated the ideas more effectively using intuition.

Keywords: Brainstorming, rules, criticism, blocking, controlled experiment.

1 INTRODUCTION

The most common early-stage design technique is brainstorming, which combines an informal approach to problem solving with a set of rules. Brainstorming was recently shown by Conradie et al., 2015 [1] to be the most-widely, voluntarily-used technique in their study of engineering design students. These brainstorming rules were created by Alex Osborn in 1953 to encourage participants to contribute, by banning criticism and negativity (blocks), resulting in the generation of a larger quantity of ideas. A common summary of the rules would normally contain: focus on quantity; withhold criticism; welcome unusual ideas; and combine and improve ideas [2].

Significant research has been conducted into engineering design brainstorming, specifically exploring the effects of the brainstorming rules. The results have varied. Meadow et al (1959) looked to further Osborn's research. They conducted a controlled experiment on design engineering subjects (8 groups made up of 6 subjects). Meadow et al [3] hypothesised that more solutions of good quality would be produced with brainstorming rules compared to without. The quality of the solutions was later evaluated by a trained rater. Meadow et al. found results in favour of Osborne's brainstorming rules.

More recently however, Nemeth [4], Bergner [5] and Sonalkar [6] have found evidence that calls into question the use of Osborne's brainstorming rules in engineering design. Nemeth et al. [4] hypothesised that the freedom or permission to critique, even criticise, could create an atmosphere of freedom and enhance the generation of creative ideas. Nemeth tested the potential value of permitting criticism and dissent by comparing the standard 'Brainstorming' condition with a 'Debate' condition (they conducted 83 tests). Nemeth's results demonstrated that criticism does not inhibit ideas and that debate and discussion is more conducive to idea generation than traditional brainstorming rules. Bergner [5] found that promoting wild ideas led to idea generation through the mechanism of the 'limit-handling loop' (overcoming limitations of the ideas). When wild ideas were subjected to judgment, it frequently led to the generation of ideas that fit the design requirements. Sonalkar [6] found that ‘blocks’ (which are obstructions to the content of the previous statement in a brainstorming session) didn’t always hinder idea generation and sometimes improved it. These researchers made us look at whether Osborne’s classical rules for brainstorming should be taught in the engineering design education. The research presented in this paper aimed to understand the effects of brainstorming with, and without rules, and compares the productivity of each condition. Furthermore, the research explored the effects of specific types of criticism (blocks) which can occur in brainstorming sessions and what these lead to in typical engineering design brainstorming sessions.

2 METHODOLOGY

This paper reports on the results from controlled design experiments. Several stimulating problems - previously used in design engineering - were utilised with (Rule condition) and without brainstorming rules (Natural condition). The aim was to understanding how rules affected the quality and quantity of ideas generated through the variance of moment-to-moment, interpersonal interactions.

The four different briefs were selected to create similar engineering complexity and similar potential stimulation of creativity. The brainstorming briefs were as follows: ‘How could a painting, in an art gallery, be cost-effectively protected from vandalism?’; ‘How can a household fridge be evolved to become more efficient?’; ‘Design a pill container and childproof dispenser for elderly people who suffer from joint diseases’; and ‘Can you evolve or design alternative windscreen wiper designs to reduce the common issues?’. The length of each brainstorming session was 45 minutes.

The video-recorded controlled tests used 2 groups (A and B) of 3 male participants, all in their 3rd and 4th year of Mechanical, Aerospace or Automotive Engineering at the University of Bath. The researcher had worked with all participants previously and was able to construct the two teams to ensure an equally positive group dynamic. In the first half of the tests, a Rule condition was adopted which used brainstorming rules. The rules were presented as a one-page set of instructions distilled from Osborne’s 1963 publication[2] including precise definitions of the *principles* ‘Defer judgment’ and ‘Reach for quantity’ and the *rules* ‘Focus on quantity’, ‘Withhold criticism’, ‘Welcome unusual ideas’, and ‘Combine and improve ideas’. The participants were made to strictly abide by the rules by the facilitator. The second half (conducted on a following day) adopted a Natural condition which used no instructions. At the end of each test an evaluation stage (15 mins) was conducted, where the participants intuitively chose the 3 most original and feasible ideas from the session. Table 1 summarises the experimental conditions.

Table 1. Details of the experimental conditions

	Painting brief	Fridge brief	Wiper brief	Pill brief
Rule condition	Group A	Group B	Group B	Group A
Natural condition	Group B	Group A	Group A	Group B

3 ANALYSIS

A full transcript was taken for every speaker turn. The ideas generated were highlighted from the transcript, with a detailed description of each noted down. Each idea was logged in an idea database to aid in the quality and quantity calculations. The ideas were rated for originality and feasibility on a 5-point Likert scale to allow cross-comparison between conditions. Precise definitions of each point on the Likert scale were constructed. Then 20% of ideas were scored by a different scorer as an inter-rater reliability test. The scores agreed for 92% of the ideas. A *good* idea was defined as one that received a rating of 4+ on one of the scales (originality or feasibility) and no worse than 3 on the other.

The transcripts of all the brainstorming sessions were then analysed using the Interaction Dynamics Notation (IDN) by Solnakar [6]. IDN is developed to represents a series of speaker *responses* as opposed to the speaker’s *expressions* which was common in design session analysis. The IDN can characterise moment-to-moment concept generation, such as transitions between ideas and facts, the presence of periods of sustained idea expressions and the occurrence of improvisational behaviour. This is specifically relevant for studying interactions which increase group productivity.

4 RESULTS

Table 2 highlights the total quantity of ideas generated in all eight brainstorms. On average, the Natural condition generated **7.75** more ideas, per test, than the Rule condition. Furthermore, in every problem, the Natural condition generated a higher quantity of ideas.

Table 2. Total Number of all Ideas Generated from the Controlled Testing

		Problem				
		Painting	Fridge	Pill	Wiper	Average
Condition	Rule	55	51	56	48	**52.5**
	Natural	74	54	63	50	**60.25**

The number of *good* ideas generated in each brainstorm can be seen in Table 3. For every brief, the Natural condition, generated more *good* ideas than the Rule condition which resulted in an average of 4.25 more per test. These results indicate that, the Natural condition creates more *good* ideas than the Rule condition.

Table 3. Number of Good Ideas Generated From the Controlled Testing Problems

		Problem				
		Painting	Fridge	Pill	Wiper	Average
Condition	Rule	5	7	7	11	**7.50**
	Natural	7	15	9	16	**11.75**

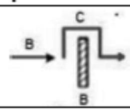
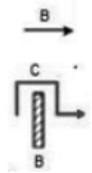
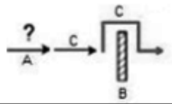
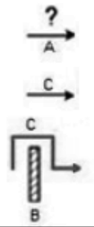
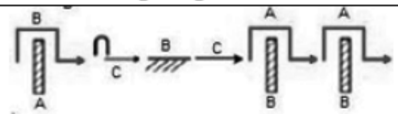
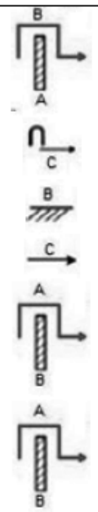
The evaluation phase involved a discussion through which each group intuitively selected the 3 ideas they believed to be the best when considering feasibility and originality. This phase was conducted to aid in understanding the effects of each condition on the selection phase, often following a brainstorming session. Table 4 shows, how the teams in the natural condition more consistently picked out the ideas which achieved scores of 8 in the researchers' analysis (the quality score shown). Overall the results highlight the improved effectiveness of intuitive concept selection under Natural conditions.

Table 4. Ideas selected inituitively by the teams compared vs. researchers' quality scores.

	Natural Condition		Rule Condition	
	Idea	Quality	Idea	Quality
Painting	**'Bracelet with Taser Inside and a Fence'**	*8*	**'Bracelet with Magnet Inside and a Fence'**	*8*
	'Fake Deterrents: CCTV and Prison Sentence Signs'	6	'Move Sideways on Rollers and Fence'	6
	'Airbag/Material to Defend the Painting with a Fence'	*8*	***'4 Screens'***	*7*
Fridge	***'Pop-up Fridge'***	*8*	'Waste Water Cooling'	6
	'Chest Fridge'	*8*	***'Interactive Fridge with Graphs for Savings'***	*7*
	'See-Through Door'	7	'See-Through Door'	6
Pill	***'Archimedes Screw with Pressure Points'***	*8*	'Pin Number/code'	6
	'Turning Sections'	*8*	'Turn and Marks Align'	6
	'Pressure Points on Bigger Lid'	*8*	***'Bubble Gum Dispenser'***	*8*
Wiper	***'Engine Air Out of Wiper Blades'***	*8*	***'Engine Air Out of Wiper Blades'***	*7*
	'Spongey Cleaning Housing'	7	'2 Parallel Wiper Blades'	6
	'Hydrophobic Glass with Cambered Screen'	8	'Warnings for Organising Change'	7

Using Sonalkar's notation, it was possible to explore in more detail what may be contributing to the improvements seen in the natural condition. In the data there appear to be several typical responses and behaviour patterns which are responsible for increasing idea quality scores. Firstly, 'overcoming blocks' appears to increase idea quality. Overcoming a block is when an idea or 'move' was criticised, but a participant was able to overcome the problem and persist on the course of the original concept. Without blocking, issues with an idea would never been stated, resulting in a lower quality idea. Table 5, shows an example of this, where several conversations (in close succession) are working on progressing the 'Chest of Drawers' concept. Each criticism inspires an idea to avoid the issue, resulting in a progressively increasing idea quality. Without blocking the idea flow in this example may have prematurely stopped, resulting in **one** significantly lower quality idea. The data showed that overcoming blocks is instrumental to increasing the quality, and in some cases the quantity of ideas.

Table 5. Transcript Excerpt from the Fridge Problem Showing the Development of the 'Chest of Drawers' Concept.

Transcript	Notation
	
B (move): I just looked, chest freezers are more efficient as the heat rises, so something that opens upwards is more efficient **B (block):** How could you get the food in, if we could think of a way of arranging the food **C (overcoming):** What about a chest of drawers, you pull something it would have a lid and then fridge underneath it	
	
A (question): So you pull it out, then open a next section up? **C (move):** So you pull it out and the lids are still closed, you then have a grid of 9 or something **B (block):** Is the drawer refrigerated or is the case. You could have the case and it sealed, otherwise the connections would have to be movable **C (overcoming):** I guess you would make the whole thing refrigerated then.	
	
A (block): I don't think it could be cooled though **B (overcoming):** (draws on whiteboard) You have an empty box, then a hollow edge with a seal around the inside. The hollow bit is refrigerated and the drawers fit inside, similar to a freezer **C (yes and):** And you could have that then separated into 4 compartments **B (support):** Yeah, these don't have to be high-tech **C (move):** It'd be pretty simple to use **B (block):** You'd have to pretty organised **A (overcoming):** But the fridge could help you out with that with diagrams etc on the top like a freezer **B (block):** Stacking bottles could be hard **A (overcoming):** But you could vary the compartment style to overcome that problem	

Blocking changes the flow of a conversation by promoting debate and discussion. This analysis also allowed us to study the specific blocking effects which generated a significant number of ideas. Three major types of blocking were identified (and their frequency in the natural (no-rules) condition is shown in table 7):

Negativity is a regularly used type of blocking. It is an extremely abrasive type of blocking which is confrontational and often results in a participant arguing back with an unconstructive response as they feel the block was personal. Negativity represents the types of blocking Osborn was trying to avoid.

Criticism is the most common type of blocking identified. It is an explanatory type of blocking which highlights the issues with an idea in a non-negative manner. Often the blocking response is short and to the point, which avoids expressing an opinion that could be viewed poorly and affect the group dynamic. The short response often inspired a productive response and highlighted significant issues that must be overcome.

Constructive criticism is the least common type of blocking however the most effective in terms of increasing idea generation. Constructive criticism often highlights the problem and an area which would aid in overcoming the block, stimulating a productive response. Table 6 shows an example of such a block.

Table 6. Transcript Excerpt from the Pill Problem - a Constructively Criticising Block

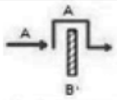
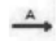
Transcript	Notation
	
A (move): Just a portable tube, and pills above, and you turn it round until the pictures or colours line up then one drops out **B (block):** But then you'd need to think about how you could only drop one at a time **A (overcoming):** Something saying hold this way up might help	 

Table 7. Quantity of Different Types of Blocking in all the no rules conditions

		Negativity	Criticism	Constructive Criticism
Problem	Painting	18	26	5
	Fridge	14	19	4
	Pill	7	10	0
	Wiper	11	19	3

5 DISCUSSION

The results and observations show that the Natural condition increased the overall idea quality. The Natural condition highlights: important design issues; provides barriers to allow development; and inspires debate and discussion. These have all been proven to improve idea quality. The research builds on other research in engineering design [5,6]. This may be useful in teaching engineering design brainstorming but further work is needed to propose and test new ways of brainstorming for engineering design

As Minzberg et al. [7] suggested back in 1976, in most real-world settings generating an excessive quantity of results means expending a significant amount of time sorting through ideas. This occurs when the idea base is polluted with low quality ideas which waste time and affect the final choices due to a loss of focus and interest. Osborn's rules were created to improve the productivity of media-related brainstorming, which are conducted in a different context to engineering design. Media-related brainstorming can be more receptive to 'wild' ideas, due to the non-technical nature of the industry.

However in design engineering, an excessively 'wild' idea will be: too costly to progress; too complicated to implement; or take too long to research.

Faste [8], who worked intensively on teaching brainstorming to engineering students using techniques from improvisation drama, may well have some of the clues to setting up better brainstorming practice for engineering design. He suggests that: 'Being our creative selves shouldn't need to be an unnatural state. Even in our daily lives we could all use more balance between the two equally useful states-of-mind of: intuition and logic. Problem solving requires both fresh ideas and informed judgment.'

6 CONCLUSIONS AND FURTHER WORK

The IDN aided in the quantitative idea analysis which found that the Natural condition generated 7.75 more ideas per test than the Rule condition. Furthermore, the Natural condition generated more *good* ideas (4.25 per test). The observations highlighted the specific blocking effects which generated a significant number of ideas directly, by overcoming blocks, or indirectly, by blocking-inspired conversation. The controlled results also showed that participants in the Natural condition evaluated the ideas more effectively using intuition. The observations highlighted three major types of blocking.
To validate these initial results, more tests should be undertaken. Using two problems with more teams in each condition, would increase the robustness of the experiment. This research could influence the generation of an updated set of rules for brainstorming and how it might be taught for engineering design.

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