

The Effect of Group Composition on Divergent Thinking in an Interaction Design Activity

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ABSTRACT

Nearly 50 years of empirical research has suggested that social influences have an inhibiting effect on creativity in collaborating groups such as design teams. This suggests that design teams may not be as creative as they could be, resulting in a negative impact on the design process. In this paper we investigate the effect of group composition on creativity in terms of divergent thinking, in order to determine how best to support the creative process in design and the development of design environments. We present some novel results about ‘group think’, showing that real groups foster refinement of ideas while nominal groups foster duplication of ideas.

Author Keywords

Creativity, Divergent Thinking, Creative Thinking, Lateral Thinking, Group Think, Creativity Support Tools.

ACM Classification Keywords

H.5.2 **Information interfaces and presentation:** User Interfaces – Theory and methods; H.1.2 **Information Systems:** User/Machine Systems – Human factors.

INTRODUCTION

Well-known approaches within HCI such as Participatory Design (PD) and User Centered Design (UCD) epitomize the collaborative nature of design, bringing together stakeholders from diverse backgrounds to work together in both the analytical and creative practices of systems development. Even in design processes that do not explicitly encourage user participation, an individual designer rarely works in isolation.

Within design communities, many researchers [e.g. 11, 31] have developed design tools and environments to support the design process as a collaborative activity. Although there is a recognition of the need for theory [18], such tools and environments often have been developed on the basis of practical knowledge and experience with little underlying theory. While acknowledging the importance of such practical knowledge and experience, our research aims to inform the development of design support tools and environments by increasing our theoretical understanding of both individual and group creativity in design.

Many researchers [e.g. 9, 22, 32] have shown social influences to have an inhibiting effect on creativity in collaborative groups such as design teams. In particular, production blocking, evaluation apprehension and free riding have been identified as key inhibiting influences [10]. Building upon previous work [10, 20, 30, 35, 37], we have conducted an experiment in which we attempted to control these inhibiting social influences, investigating the effect of group composition on creativity in design.

Research looking at the measurement of creativity has considered the quantity of ideas, the number of categories of ideas and the creative quality of ideas to be indicators of creativity that we can measure with some reliability [34]. But the global phenomenon of creativity cannot be measured by a single metric [20, 22]. de Bono’s [8] emphasis on ‘lateral thinking’ and Lawson’s [21] closely related discussion of designers as ‘divergent thinkers’ suggest that the more lateral or divergent the thinking of a group, the more creative the group may be considered. An analysis of the effect on divergent thinking caused by varying group composition will provide a deeper understanding of creativity in design, complementing our previous research [36] and informing how better to support creativity in design teams.

In this paper, we first present an understanding of creativity in design, which has been developed through our research [37]. We describe how nearly 50 years of research has identified problems with creativity in groups. We present some of the results of an experiment in which we

investigate the effect that group composition has on creativity in design, as assessed by the level of divergent thinking in the group. We discuss the findings of our experiment and provide a focus for future research on supporting creativity in design.

CREATIVITY IN DESIGN

Across the HCI, CSCW and design literatures, terms such as *creativity* and *innovation* are often used to describe important features of the design process [23]. However, while such terms are often used when discussing the design process, fewer efforts are made to provide a definition of what these terms mean and what is actually involved in the process of creativity. There is, however, a long-standing literature mainly within psychology that has attempted to define and understand creativity [e.g. 2, 5, 13, 15, 19].

Defining Creativity

Definitions of creativity have been developed and evolved over several decades. There have been three main concepts by which creativity has been defined: the creative process [e.g. 5, 19], the creative person [e.g. 13, 15] and the creative product [e.g. 2]. While the focus of definitions of creativity has evolved over time, from process to person to product, these are all essentially important components of creativity [21]. Each individual, or member of a group, has certain creative abilities (i.e. the *creative person*); she may explore and transform conceptual spaces, combining matrices of thought [19] (i.e. existing ideas or concepts) to generate new ideas (i.e. the *creative process*); and these ideas may consist in or lead to the development of a final product (i.e. the *creative product*). Previous research has tended to focus on the embodiment of creative ideas in subsequent products, viewing the latter as the ‘creative product’. In our research, we focus on creativity as the production of the ideas themselves – the product of *design*, rather than the product of *implementation*.

Drawing on previous work, we consider a design idea to be creative if it is new or unusual to the mind in which it arose (novelty) [5] and conforms to the requirements of the design problem (appropriateness) [21]. However, while this gives us a definition of creativity, it does not operationalize it in terms that we can measure experimentally. Torrance [34] has developed scoring metrics for measuring creativity that map closely to our definition – originality, fluency and flexibility. *Originality* considers the unusualness or ‘creative strength’ of the ideas, and maps to our notion of novelty. *Fluency* represents the total number of relevant ideas produced, and maps to our notion of appropriateness. *Flexibility* considers the number of different approaches or categories of ideas produced. de Bono’s [8] emphasis on ‘lateral or divergent thinking’ and Lawson’s [21] discussion of designers as ‘divergent thinkers’ suggest that the more lateral or divergent the thinking of a group, the more creative the group may be considered. Torrance’s metric of flexibility is effectively a measure of such divergent or lateral thinking.

Many researchers [e.g. 9, 22, 32] have found nominal groups to outperform real groups in terms of originality and fluency, but have not investigated flexibility. In our previous work [36], we have investigated creativity in terms of novelty and appropriateness (i.e. originality and fluency), finding equivalent performances between nominal and real groups when social influences on creativity were controlled. In this paper we investigate flexibility (i.e. the divergence of thinking of the groups) as a measure of creativity.

The Problem with Creativity in Collaborative Design

Gennari and Reddy [12] describe the design process as ‘human activity, involving communication and creative thought among a group of participants’. A fundamental question about activities such as design that involve a social component is: what effect does the social nature of this activity have on creativity?

In 1958, Taylor *et al* [32] conducted a study comparing real groups (i.e. face-to-face interacting groups) with nominal groups (i.e. individuals working on their own and then collating their outputs to form a cumulative output), to test Osborn’s claim that ‘the average person can think up twice as many ideas when working within a group than when working alone’ [26]. Taylor *et al* found that nominal groups produced nearly twice as many non-replicated ideas as real groups, refuting Osborn’s claim. Since the Taylor *et al* study, over 50 empirical studies have shown nominal groups to outperform real groups [22]. The implication of this body of research is that collaborating groups, such as design teams, are not being as creative as they could be.

The three major explanations that have been explored thoroughly by the creativity community as to why nominal groups outperform real groups are the social influences of procedural mechanisms (i.e. production blocking), social psychological mechanisms (i.e. evaluation apprehension) and economic mechanisms (i.e. free riding).

Production blocking has been argued [e.g. 10, 20] to be the most important cause of nominal groups’ outperforming real groups. Production blocking is common when ideas are expressed verbally within a group. The problem with this form of interaction is that group members are prevented from simultaneously expressing their ideas. They may subsequently forget their ideas or suppress them because they may feel their ideas are less relevant as time passes. Another problem is that they may rehearse their ideas internally, preventing them from concentrating on what other members say. Finally, if group members are prevented from expressing their ideas as they occur, they may be discouraged from producing further ideas. To mitigate the effects of production blocking, some researchers [e.g. 9, 28] have moved towards using synchronous interaction techniques for expressing ideas. Prante *et al* [29] describe the use of single display groupware (SDG) and synchronous groupware systems (SGS) to prevent production blocking in real time collaboration.

Evaluation apprehension occurs when group members fear criticism from others within the group. This can prevent group members from expressing ideas. The negative effect of evaluation apprehension reduces the number of ideas produced in groups. To overcome the negative effects of evaluation apprehension, it has been suggested by some researchers [e.g. 28] that anonymous means of expressing ideas remove an individual's identification with an idea and therefore help encourage people to express their ideas without fear of criticism. Some technologies described in the CSCW community [e.g. 9, 29] allow for anonymizing individual input, thereby mitigating evaluation apprehension.

Free riding, otherwise known as social loafing, is the result of group members' becoming lazy, relying on other members in the group and not contributing as many ideas as they could. When working in a group, group members may assume the group's output to be assessed collectively, whereas when working alone one has to take responsibility for one's own performance [10]. Therefore, assessing members within a group on their individual performance rather than the group collectively reduces the effect of free-riding. Paulus [27] also refers to social stimulation as a way to reduce the impact of free-riding – encouraging a high motivation level in groups by increasing accountability for individual performance. Providing groups with a comparison standard increases their performance and providing explicit feedback about individual performance also increases performance of group members.

Much of the research aimed at increasing the effectiveness of group creativity has looked at production blocking, evaluation apprehension and free riding, presenting methods and techniques to reduce the dampening effects of these factors on social creativity [10]. Much of this research has only increased the effectiveness of real groups over nominal groups slightly in some conditions, while there are still many cases where nominal groups outperform real groups [e.g. 9, 22, 32]. As nominal groups have frequently been shown to outperform real groups in terms of creativity, some researchers [e.g. 10, 20] have suggested that the process of idea generation should be performed by nominal groups in order to increase creativity.

In our previous research [37] we have developed a theory that shows how real groups have the potential to generate more creative ideas than nominal groups by taking advantage of shared domains of knowledge. Fischer [11] argues that 'the unaided individual mind is highly overrated ... much of our intelligence and creativity results from interaction and collaboration with other individuals'. Each individual has a domain of knowledge and within this domain of knowledge has a collection of existing ideas and concepts. An individual has only the ideas and concepts in her own domain of knowledge as a basis for producing creative ideas, whereas in a real group individuals can interact with each other, externalizing their ideas and concepts and making them available to others [e23, 24, 37].

Our theory [37] explains how real groups have the potential to take advantage of these shared domains of knowledge thereby allowing them to generate more creative ideas than nominal groups. By externalizing ideas and concepts, more combinations of ideas and concepts can be derived, therefore producing more creative ideas.

Building upon previous research in reducing the social influences on creativity, we extend consideration of procedural mechanisms, social psychological mechanisms and economic mechanisms to include a fourth type: operational mechanisms. We define operational mechanisms to include, for example, group size and group composition. In this paper we investigate the effect of the operational mechanism of group composition on creativity.

Experimental Overview

Rotter *et al* [30] conducted a study observing the effects on creativity due to different group compositions in the design process. Rotter *et al* [30] analysed creativity in terms of the number of creative ideas (i.e. fluency and originality) to identify which group composition was the most effective and efficient. However, the Rotter *et al* [30] study did not control social influences between conditions. In the individual condition, the participants were told to write down their ideas. However, in the other conditions involving a group component the participants were also allowed to communicate verbally. This form of verbal interaction adds a confounding variable of production blocking, resulting in a difference between the conditions [37]. Secondly, if group members can verbally express their ideas rather than just writing them down, a confounding variable of evaluation apprehension is also introduced [37]. The resultant effect of these confounding variables between the conditions means that the results cannot be relied upon. In addition to this, in the nominal-real and real-nominal group conditions, the participants were not allowed in the latter half of the experiment to bring up ideas they had previously generated. According to our theory [37], if the externalization of participants' ideas and concepts is prohibited, there is a resultant inhibiting effect on creativity.

In our previous work [36] we built upon the research of others [22] and our own [37] to observe the effect of the operational mechanism of group composition on creativity assessed in terms of fluency and originality. In contrast to the results shown by Rotter *et al* [30] and the abundance of research showing nominal groups to outperform real groups [e.g. 9, 22, 32], we found there to be no significant differences in performance between the conditions. Our controlling of the social factors that acted as confounding variables in previous studies resulted in increasing the productivity of real groups compared to nominal groups. In this paper, we analyze the results of our experiment further and consider the effect of the operational mechanism of group composition on creativity in terms of flexibility – the divergent thinking of the groups.

While creativity is rarely assessed in terms of flexibility, the latter has a strong relationship to techniques used in design such as affinity diagramming [4] and mood boards [7]. Such techniques are used to reveal patterns and relationships between ideas leading to more creative solutions. Rotter *et al* [30] argue that the expression of an idea in a real group causes all the members to think along the same lines, leading to duplication of ideas. However, the empirical evidence from our research [36] showed that real groups produce *less* duplication of ideas, suggesting that participants' awareness of ideas generated by other participants inhibited duplication. Each participant brings a different set of knowledge and background to a design activity. The potential combinations of this diversity should generate diverse categories of ideas. It was therefore hypothesized that the number of categories of ideas generated in response to a given design problem would be greater when participants worked in a real group condition rather than in a nominal condition (H1). In a nominal group, each participant is forced to improve and combine ideas within her own domain of knowledge, rather than being able to take advantage of the externalization of other participants' knowledge and ideas. Hence, it was also hypothesized that nominal groups would generate more ideas within categories compared to real groups (H2).

Method

The experiment had a between participants design. The experiment manipulated one independent variable, the operational mechanism of group composition, which consisted of four levels: 1) Nominal Groups; 2) Nominal-Real Groups; 3) Real-Nominal Groups; and 4) Real Groups. The dependent variable was creativity in terms of flexibility – the number of categories of creative design ideas generated in response to a given design problem. Many researchers [e.g. 6, 21] argue design to be a special case of problem solving. Therefore in order to scope this experiment we used a collaborative problem solving design activity as an instance of design. It was predicted that the number of categories of ideas generated in response to a given design problem would be greater when participants worked in a real group condition rather than a nominal condition; and that nominal groups would generate more ideas within categories than real groups.

Participants

Ninety-six participants took part in this experiment, twenty four per condition. The participants varied in age from 18 to 46, with a mean of 22.9 years. All participants were from the University of Bath, consisting of undergraduate students, postgraduate students and university staff. The participants were recruited from lecture rooms and mailing lists and were paid £5 for participating in the experiment.

Apparatus

On each participant's desk was a 12" display IBM x31 ThinkPad and a USB Microsoft IR Mouse. Each of the ThinkPads had an internal 802.11g wireless connection

which allowed it to communicate with a server. An A4 piece of paper was stuck to the desk, giving information relevant to the experiment: Osborn's four brainstorming rules [26], the rules of the experiment, and the design problem. The latter was covered by an overlay until the experiment started (see Procedure section). Each participant's desk was shielded by tall dividers to prevent communication between participants.

Each ThinkPad was running a custom built stand-alone Windows application – the Idea Generator (see Figure 1). In the top right of the screen is the generated ideas textbox – this is where a participant writes her idea when she thinks of one. To submit an idea, participants could either press the 'submit' button located in the bottom right of the screen, or press the 'enter' key on the keyboard. The generated ideas textbox could be cleared by pressing the 'clear' button in the bottom right of the screen. In the bottom left of the screen is a condition label that indicates to the user which condition they are currently in – individual (i.e. nominal) or group (i.e. real). In the top left of the screen is the pooled ideas textbox. This textbox displayed recorded ideas dependent on the current condition and could not be edited. In the nominal condition, only the participant's own ideas could be viewed. In the real condition, all participants could see the ideas generated by themselves and others. In the nominal-real condition, when the condition changed from the nominal sub-condition to the real sub-condition all ideas generated by each participant during the nominal sub-condition were pooled into the pooled ideas textbox. In the real-nominal condition, when the sub-condition changed from the real sub-condition to the nominal sub-condition, all ideas generated by the group during the real sub-condition remained in the pooled ideas textbox during the nominal sub-condition.



Figure 1. Idea Generator Software.

In a separate room to the experiment was the experimenter's table. The experiment was recorded here. In the participants' room were two cameras which each

viewed two participants. The output from these cameras was fed through a monitor displaying a real-time image to the experimenter. The image was also captured via a DV recorder for future analysis. The experimenter also had access to a HP Tablet PC that ran the Windows Remote Desktop application to access the server remotely. This allowed the experimenter to change the sub-condition during the nominal-real and real-nominal experimental conditions.

The server was a standard desktop PC that ran Microsoft's SQL Enterprise Server version 8.0. An SQL database ran on this server, storing ideas generated by the participants and other information: who generated the idea; the condition in which the idea was generated; and the date and time the idea was recorded. The server was also used to play audio files of instructions to the participants via Windows Media Player.

Procedure

Participants were run in groups of four in a sound-proof lab. At the outset the participants were taken to the back of the lab where the pre-recorded instructions were played. Pre-recorded instructions were used to minimise the experimenter's contact with the participants. The start of the pre-recordings gave an overview of the experiment: the condition the participants had been assigned to; a description of Osborn's brainstorming rules; some rules to abide by during the experiment; a description of the software; the warm-up exercise; and the design problem for the actual experiment. After each audio file the experimenter asked the participants if they had any questions and tried to answer them to best of his ability. Creativity was never mentioned, as Amabile [2] argues that participants' performance changes if they are aware that they are being assessed on creativity.

The groups were assigned to one of four conditions:

1. *Nominal Condition*: Participants work individually for 16 minutes.
2. *Nominal-Real Condition*: Participants work individually for 8 minutes and then as a group for 8 minutes.
3. *Real-Nominal Condition*: Participants work as a group for 8 minutes and then individually for 8 minutes.
4. *Real Condition*: Participants work as a group for 16 minutes.

Osborn's brainstorming rules were given to the participants to help them with the idea generation process:

1. *Criticism is ruled out*. Adverse judgement of ideas must be withheld. No one shall criticise anyone else's ideas. Say anything you think of.
2. *Freewheeling is welcomed*. The wilder the idea the better. It is easier to tame down than think up. Do not be afraid to say anything that comes to

mind. The further out the idea the better, this will stimulate more and better ideas.

3. *Quantity is wanted*. The greater the number of ideas, the greater the likelihood of winners. Come up with as many as you can.
4. *Combination and improvement are sought*. Suggest how the ideas of others can be joined into still better ideas.

In contrast to previous experiments, these brainstorming rules were included on the information sheet attached to each participant's desk. This was done to relieve the cognitive load on each participant, so that they could focus more on the design problem at hand.

Based on previous research [10], participants were told three rules by which to abide in order to control confounding variables:

1. You may not communicate with anyone else once the experiment has started – to control production blocking.
2. All ideas contributed will be anonymous – to control evaluation apprehension.
3. We are assessing the ideas of individuals, not the group collectively – to control free-riding.

Once again, unlike other experiments, instead of just verbalising this information it was also included on the information sheet attached to the participant's desk so they could reference it when desired.

After the background information had been provided to the participants, they were asked to gather round one of the ThinkPads which was running the Idea Generator software. While an audio recording played a description of the software, the experimenter pointed to the relevant parts of the screen.

The warm-up exercise was used to accustom the participants to the experiment and the software they would be using. The exercise lasted two minutes and was based on an adaptation of the tourism problem [32] for the European community:

'Each year a great many European tourists go to America to visit. But now suppose that Europe wanted to get many more Americans to come to Europe during their vacations. What steps can you suggest to get many more Americans to come to Europe as tourists?'

The experimenter asked all the participants if they understood the problem and gave an example idea of 'providing cheaper trans-Atlantic flights'. Once all queries had been dealt with, the experimenter asked the participants to take a seat at a desk and open up the Idea Generator software. When everyone was ready, the two minute warm-up exercise began.

After the two minutes all participants were asked to come to the back of the lab. The experimenter checked for inappropriate responses (i.e. personal comments, criticisms), closed the Idea Generator software on each

IBM ThinkPad and cleared the SQL Server of all ideas from the warm-up exercise. If the experimenter found inappropriate responses, he explained to all the participants why they were inappropriate. After dealing with all queries by the participants and upon being satisfied that everyone was content, the experimenter began the design problem experiment.

Unlike other experiments which gave non-specialist problems such as the tourist problem [32], it was decided to give a design problem within the domain of HCI, in order to relate the findings of the experiment more to design in that domain. The problem was named the Pervasive Computing Scrolling Problem and was like other design problems in that it was open-ended and ill-defined:

‘You have been asked to design an interaction technique for scrolling on a pervasive computer system with a 61” plasma screen. The technique should allow the user or users to scroll up, down, left and right.’

The experimenter asked all the participants if they understood the problem and answered any questions without giving information as to possible solutions to the problem. Once all queries had been dealt with, the experimenter asked the participants to take a seat at a desk and open up the Idea Generator software by selecting the appropriate icon on the desktop. Participants were then informed that they could remove an overlay on the information sheet that revealed the experimental problem. This allowed the participants to reference the problem as they worked. The experimenter told the participants that the experiment would last sixteen minutes. Before the experiment started the experimenter started recording the participants and then informed them that they could begin.

For those participants who were in the nominal-real or real-nominal condition, the experimenter changed the condition after eight minutes via the experimenter’s computer. Upon the change in condition, the label on the participant’s computer changed to indicate which condition the participant was in, and the experimenter also verbally communicated this from the experimenter’s room to make the participants aware of the change in condition.

After the sixteen minutes were completed, the experimenter asked all participants to stop typing; close down the Idea Generator software; and remain seated. The experimenter then stopped the recording and handed each participant a questionnaire.

While the participants were completing the questionnaire, the experimenter printed off a form for a post-analysis of each participant’s ideas. The post-analysis was designed to assess if the ideas generated were novel. The experimenter went round each participant and asked them to say for each of their ideas whether it was: (i) a new idea – a combination of two or more existing ideas; (ii) an old, existing idea applied to a new context; or (iii) other, and if other could

they specify. This classification of ideas is similar to that used by Benami and Jin [3].

RESULTS

The dependent variable we observed in the experiment was flexibility, i.e. the number of categories of ideas generated [34]. Ideas were identified based on sentence structuring and copyright law. The latter reflects a history of quite careful thought on the nature of ideas and was useful in this context. Each response generated by the participants was analysed for the occurrence of nouns. The occurrence of these nouns led to a natural categorisation (i.e. a tree structure) of ideas depending on the level of detail provided by the participants. This is similar to a method presented in [17]. For example:

- 1) Movement
- 1.1) Movement > Hand
- 1.1.1) Movement > Hand > Glove
- 1.2) Movement > Foot

Copyright law [1] distinguishes between *ideas* and *expressions of ideas*. Applying this concept to our data, one noun specified the *idea* (e.g. Movement), while multiple nouns which fell under ideas where denoted as *expressions of ideas* (e.g. Movement > Hand). Categories were determined by *ideas*, allowing us to count the number of categories of ideas and therefore assessing flexibility/divergent thinking for each group. Replications of ideas were identified if a subset of nouns were generated after a longer subset had been created; i.e. you could not generate a branch in the tree which already existed.

Having developed a systematic method for identifying ideas, we next developed a systematic method for identifying which ideas are creative. Most other studies [e.g. 9, 22, 32] when considering the number of creative ideas simply assume every idea to be creative, taking account of duplications. However, in accordance with our definition of creativity [35-37], in order for an idea to be deemed creative it must be both novel and appropriate. We first assessed all participant-generated responses for their novelty by using a retrospective protocol administered immediately after the experiment. Following [5], this gave us the participants’ own assessment of the novelty of their responses. (It should be noted that our categorisation of ideas from the responses based on sentence structuring and copyright law merely categorised the ideas and did not manipulate them. We therefore assume that the novelty of a response indicated by a participant also holds for the categorised ideas.) Following [21], appropriateness was then determined using a simple checklist to make sure that each idea conformed to the requirements defined during the problem statement – the interaction techniques should allow the *user* or *users* to scroll *up, down, left and right*.

The Effect of Operational Mechanisms on the Number of Categories of Ideas

The number of categories of creative ideas for each condition was calculated for each group. The mean number of categories of creative ideas generated in each condition can be seen in Table 1.

Table 1. Mean (and SD) number of categories of creative ideas for all four conditions.

	N	N-R	R-N	R
Number of Categories	16.83 (2.71)	16.33 (4.89)	17.5 (2.59)	18.00 (3.03)

The data were analysed using an unrelated one-way ANOVA. No significant differences were found between the four conditions. Therefore, Hypothesis 1 (that the number of categories of ideas generated in response to a given design problem would be greater when participants worked in a real group rather than in a nominal group) was not supported.

The Effect of Operational Mechanisms on the Number of Ideas within Categories

The number of creative ideas, including duplicated ideas, per category for each condition was calculated for each group. The mean number of creative ideas per category can be seen in Table 2. Note that an idea could be creative (i.e. novel and appropriate) and yet be a duplicate of a previously expressed idea if the participant expressing the duplicate were unaware that the idea had previously been expressed.

Table 2. Mean (and SD) number of creative ideas, including duplicated ideas, per category for all four conditions.

	N	N-R	R-N	R
Number of Creative Ideas	2.40 (0.27)	2.31 (0.25)	2.12 (0.28)	2.00 (0.38)

No significant differences were found across the four conditions using an unrelated one-way ANOVA. However, as can be seen from Table 2, there was an apparent difference between the nominal and real conditions. Since our hypotheses related specifically to these two conditions, the analysis was extended to a pair-wise comparison between the nominal and real conditions, to investigate this apparent difference. The data were analysed using a t-test. A statistically significant difference was found between the nominal and real group conditions ($t = 2.224, p = 0.038$). Hence, our hypothesis (H2) was supported with nominal groups producing more ideas within categories than real groups.

DISCUSSION

Creativity in terms of flexibility (i.e. divergent thinking) was assessed as a result of altering the operational mechanism of group composition while controlling the social inhibitors of creativity – production blocking, evaluation apprehension and free riding. It was hypothesized that participants would be more divergent thinkers when working in a real group condition rather than in a nominal group condition. It was found that there were no statistically significant differences in the number of categories of ideas produced across the conditions (H1). A statistically significant difference was found between the nominal and real conditions in the number of ideas produced within categories (H2).

The proposal that this difference was due to duplication of ideas in the nominal groups is confirmed by analysis of the data in Table 3, which presents the mean number of creative ideas per category for each condition with duplicates removed. Analysing the data presented in Table 3 using an unrelated one-way ANOVA, no significant differences were found between the four conditions. Indeed, the numbers of non-duplicated creative ideas were almost identical between the nominal and real conditions. Hence, the significant difference between the nominal and real conditions in Table 2 can be explained by the duplication of ideas in the nominal condition.

Table 3. Mean (and SD) number of creative ideas, excluding duplicated ideas, per category for all four conditions.

	N	N-R	R-N	R
Number of Creative Ideas	1.70 (0.30)	1.80 (0.30)	1.58 (0.20)	1.69 (0.27)

Given that nominal groups tended to duplicate ideas more than real groups, why then did we not find more divergence of categories of ideas produced by real groups, as predicted by H1? Another factor may be at work here, causing the bunching of ideas within categories in the real condition. The improvement and combination of existing ideas will result in refined ideas which are non-duplicated, but will often belong to the same categories as the existing ideas. This obviously increases the number of ideas within categories rather than the number of categories generated.

Further analysis of our data investigated the occurrence of refined ideas. Refined ideas were identified using our methodology for identifying ideas. An idea was considered refined if a new node extended an existing node in the tree structure to form a new branch. For example, we might have the idea ‘movement’, which might then be refined to ‘movement of the hand’. The percentage of refined ideas, including duplicated ideas, was calculated for each group. The percentage of refined ideas (number of refined ideas/number of ideas * 100) for each group was calculated to remove the effect of variance in the numbers of ideas

across groups. The mean percentage of refined ideas can be seen in Table 4.

Table 4. Mean (and SD) percentage of refined ideas, including duplicated ideas, for the nominal and real group conditions.

	N	R
Percentage of Refined Ideas	21.17 (9.70)	35.67 (10.80)

The data were analysed using a t-test. A statistically significant difference was found between the nominal and real group conditions ($t = 2.42, p = 0.029$). However, a refined idea could also be a duplicated idea. Therefore, to obtain a purer measure of refinement we removed duplicated ideas from our analysis. The mean percentage of refined ideas excluding duplicates can be seen in Table 5.

Table 5. Mean (and SD) percentage of refined ideas, excluding duplicated ideas, for the nominal and real group conditions.

	N	R
Percentage of Refined Ideas	25.17 (12.94)	37.67 (9.75)

The data were analysed using a t-test. A statistically significant difference was found between the nominal and real group conditions ($t = 2.06, p = 0.047$). Hence, we have shown that, with or without duplication, real groups refined significantly more ideas than nominal groups. The refinement of ideas within categories in the real condition (Tables 4 and 5) and the duplication of ideas in the nominal condition (Table 2) may combine to explain the bunching of ideas within both conditions that led to the absence of a significant difference between the nominal and real conditions in Table 1.

Rotter [30] argued that real groups would duplicate more ideas than nominal groups due to ‘group think’ [16] or group norms [33]. Our previous work [36] suggested that duplication is more likely to occur in nominal groups than in real groups. The research reported in this paper confirms this suggestion. Rather than duplicate ideas, group members who participated in the real condition *refined* their own ideas and the ideas of others within the group. For example, a participant within one group generated the idea of voice interaction by speaking commands aloud to the screen, while another participant proposed that the user could speak commands into a microphone on a headset. These were considered different ideas, but belonged to the same category. The externalization of ideas in the real group condition led to participants generating refinements of those ideas within categories.

Through our analysis of the refined ideas generated by real groups we can deepen our understanding of the operation of group norms. We have argued [37] that the major benefit

of working in real groups is the access that group members have to each other’s ideas and concepts, allowing the members of a real group to go beyond the confines of their personal experience, ideas and knowledge to produce ideas inspired and informed by those of other group members. Through further analysis of the refined ideas produced by the real groups, we identified whether this refinement was due to group-think (i.e. a refined idea following on from another group member’s idea) or self-think (i.e. a refined idea following on from the participant’s own ideas). Table 6 shows the percentage of ideas generated through refinement by group-think and self-think respectively for the real group. We do not need to consider the nominal group here as their refinements can only be caused by self-think. Once again, percentages were used to remove the effect of variance in the numbers of ideas across groups.

Table 6. Mean (and SD) percentage of refined ideas caused by either group-think or self-think.

	Group-think	Self-think
Percentage of Refined Ideas	75.45 (18.00)	25.55 (18.00)

The data were analysed using a Chi-squared test. A statistically significant difference was found between the percentages of refined ideas caused by group-think and self-think respectively (Chi-squared = 81.87, $p \leq 0.001$). Hence, group-think may be seen to be the major contributor to the refinement of ideas in real groups.

CONCLUSIONS AND FUTURE WORK

In this paper we report an experiment investigating the effect of the operational mechanism of group composition on creativity in a collaborative design scenario. In the experiment we manipulated group composition in four levels: nominal; nominal-real; real-nominal; and real groups. We analysed the resultant effect on creativity in terms of flexibility – the number of categories of creative ideas generated as solutions to a given design problem and the number of creative ideas generated within categories.

The results of the experiment include an important difference from the results of previous research, with our study showing real groups to be equally as creative as nominal groups when social influences are controlled. This finding contradicts an abundance of literature showing nominal groups to be more creative than real groups [e.g. 9, 22, 32] and refutes the claim based on this literature that creative activities are best performed by nominal groups [e.g. 10, 20].

There was no statistically significant difference between the real and nominal groups in the number of categories of ideas generated. There was a difference in the number of ideas per category when we included duplicated ideas, while this difference was removed when we excluded duplicated ideas. While each participant in the nominal

group condition was limited to her own domain of knowledge and therefore could generate ideas based on only this domain of knowledge, participants in the real group condition tended to refine ideas within categories, inhibiting divergent thinking. We argue that while one of Osborn's brainstorming rules – 'improvement and combination are sought' – has a positive effect on creativity through the generation of ideas, it has an inhibiting effect on divergence of thinking, resulting in group think. While Rotter [30] argued that group think would cause duplication of ideas, we have shown that the influence of group think actually leads to the refinement of ideas.

We have provided a deeper understanding of the idea generation process across various group compositions. An ongoing research question still to be addressed is whether we can further enhance real group creativity in order to reach its theoretical potential [37]. Lack of divergent thinking, whether caused by duplication or refinement, could be having a detrimental effect on creativity, as argued by de Bono [8] and Lawson [21]. Further research into promoting divergent thinking while supporting the improvement and combination of ideas is a potential path to fulfilling this vision.

Our findings also suggest that we need to support the various operational mechanisms of group composition throughout the design process, allowing the team to adapt to different group compositions as needed. Based on our previous research [36] and the research reported here, and in contrast to the recommendations from other research [e.g. 10, 20] to support creative activities through nominal groups, we argue the need to support the various group compositions. Design is a dynamic activity changing between individual, sub-group and group compositions. If creativity is to be supported effectively, design environments need to support the dynamics of the design team. Technologies need to be used to provide support for dynamic change of group composition while controlling social influences. The dynamic nature of the group can be supported through different interaction spaces inherent in various technologies [25]. Controlling the effect of social influences on creativity has been investigated by some researchers [e.g. 29, 31] in the CSCW community, developing technologies to reduce the inhibiting factors of production blocking and evaluation apprehension. We are not suggesting that social influences can or should be totally controlled in design activities, but technologies can be used to mitigate the impacts of social influences, potentially maximizing creativity across group compositions that may be imposed by external constraints.

In our ongoing work, we are conducting further analyses of the data, enabling us to understand how best to support the dynamic nature of design to facilitate creativity. Through the further analysis of the results of this experiment we hope to generate additional design requirements [e.g. 14] for the support of creativity in collaborative design environments. From these design requirements we are

looking towards developing a support tool – Public Social Private Design (PSPD) – which uses technologies to support design teams to be creative by controlling social influences and facilitating the dynamics of group composition.

With answers to these research questions, we can look towards supporting creativity, improving the practice of design and the development of design environments, leading to more usable and useful systems, products and applications.

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