Effectiveness of Brainwriting Techniques: Comparing Nominal Groups to Real Teams

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Abstract. Engineering designers need effective and efficient methods for idea generation. This study compares the effectiveness of group idea generation techniques to the combined efforts of individuals working alone with redundant ideas removed, so called "nominal groups". Nominal groups compared to real interacting groups is a standard approach for determine if a group idea generation method can produce better solutions then individuals working alone. This study compares nominal group data to existing data on a series of group idea generation techniques. Results show that groups using rotational viewing and representing their ideas with words & sketches, a hybrid 6-3-5 method, outperform nominal groups in number ideas and have an equal level of quality. This result is in contrast to comparing Brainstorming groups to nominal groups where nominal groups outperform Brainstorming groups. These results indicate that a team can be more effective than individuals working separately.

Keywords: creativity, idea generation, brainwriting

1 Introduction and Background

Over one hundred formal idea generation techniques have been developed in areas such as psychology, business, and engineering (Adams, 1986; VanGundy, 1988; Higgins, 1994). Some methods like Osborn's Brainstorming have received significant evaluation whereas for many graphical methods there is little data available.

One of the first studies using Osborn's Brainstorming method in engineering design included engineering professionals working on a realistic engineering problem and showed that groups using brainstorming produced fewer ideas than the combined efforts of an equivalent number of individuals working alone (Lewis, et al., 1975). This result, called productivity loss, is consistent with the vast majority of studies on variations of Osborn's Brainstorming (Mullen, et al., 1991).

While the data on Brainstorming techniques is extensive, there is far less data available on brainwriting techniques where communication is through written words or sketches. For brainwriting techniques, some data suggests that groups can be more effective than the combined individual efforts (Gryskiewicz, 1988; Paulus and Yang, 2000). Recent studies have focused on the development and evaluation of more effective idea generation methods in engineering and design related fields, including industrial design and architecture (Shah, 1998; Shah, et al., 2000; Van der Lugt, 2002; Shah, et al., 2003; Vidal, et al., 2004). These studies have used a mixture of sketches, verbal descriptions of ideas, and physical models in the idea generation process. Prior work on graphical brainwriting techniques (e.g., Brainsketching, C-Sketch, Gallery), has not compared nominal groups (non-interacting individuals whose non-redundant results are combined) with real interacting groups.

Our study compares nominal groups with group ideas generation methods: Brainsketching, C-Sketch, 6-3-5, and the first phase of the Gallery method. These methods are gaining popularity and exposure in the engineering research community, in addition to industrial application. They also form a diverse set of group idea generation techniques that vary in how ideas are exchanged and in the types of representations used (written words, sketches, etc.). To understand the theoretical basis of these method, we dissect them into two key factors (1) how a group's ideas are displayed to other members ("rotational view" or all are posted in "gallery view") and (2) the form of communication between group members (no communication, written words only, sketches only or a combination of words and sketches.) All other method parameters are kept constant for all experimental conditions.

1.1 Osborn's Brainstorming

The term "brainstorming" is frequently applied to idea generation techniques in general and not just to the technique developed and named by Osborn. Osborn's Brainstorming begins with a facilitator explaining the problem. A group then verbally exchanges ideas

following four basic rules: (1) criticism is not allowed, (2) "wild ideas" are welcomed, (3) building off each others' ideas is encouraged, and (4) a large quantity of ideas is sought. Despite the face validity of these rules, much research demonstrates productivity loss in brainstorming compared to an equal number of individuals working alone (nominal groups) (Mullen, et al., 1991).

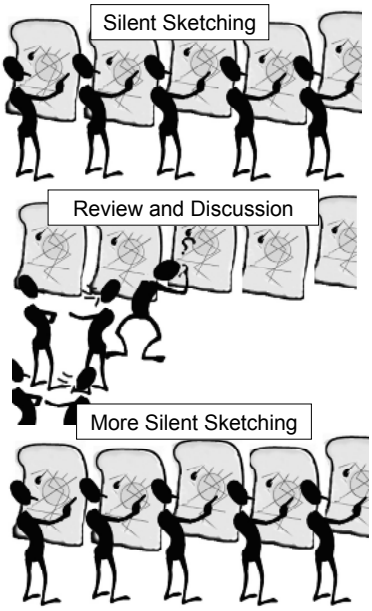

Fig. 1. Illustration of Gallery method

1.2 Brainsketching

In Brainsketching, individuals begin by silently sketching their ideas on large sheets of paper including brief annotations. Group members exchange drawings and silent sketching continues for another period of time (VanGundy, 1988). This technique allows for a visual means of expression, and so it is well suited for product design. Van der Lugt used teams of advanced product design students to compare Brainstorming to a variant of Brainsketching (that included the explanation of ideas between exchanges) (Van der Lugt, 2002). The Brainsketching variant led to more cases in which group members built on previously generated ideas than did Brainstorming.

1.3 Gallery

In the Gallery method, individuals begin by sketching their ideas silently on large sheets of paper. After a set amount of time, participants discuss their ideas and move about the room studying others' ideas. This review phase is followed by a second stage of silent sketching (VanGundy, 1988; Pahl and Beitz, 1996; Shah, et al., 2001). The review phase allows team members to clarify their ideas, and it provides social interaction.

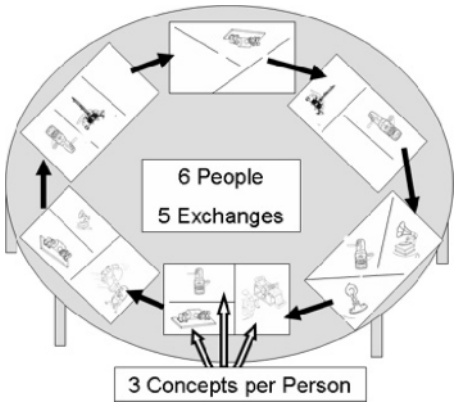

Fig. 2. Illustration of 6-3-5 and C-Sketch. Six people silently describe three ideas on a sheet of paper and then exchange papers

1.4 C-Sketch / 6-3-5

For 6-3-5 (Shah, 1998; Otto and Wood, 2001; Shah, et al., 2001) and C-Sketch (Shah, 1998), six ("6") participants are seated around a table, and each silently describes three ("3") ideas on a large sheet of paper. The ideas are then passed to another participant. This exchange goes on for five ("5") rounds. For the original 6-3-5 method, ideas are described using only words. In contrast, the C-Sketch, method permits only sketches. One advantage of C-Sketch over 6-3-5 is that sketches are typically ambiguous, and so one person may misinterpret aspects of someone else's sketch, which may lead to new ideas (Shah, et al., 2001). Other variations of 6-3-5 have also been proposed (VanGundy, 1988; Otto and Wood, 2001). One variation permits annotated sketches (Otto and Wood, 2001). In experimental comparisons with different conditions than those reported in this paper, C-Sketch and Gallery outperformed 6-3-5 (words only) for variety, quality and novelty of ideas (Shah, et al., 2001). Novelty is how unique a particular idea is and variety is how much of the design space is captured by a set of ideas. This previous study used groups of mechanical engineering undergraduates, mechanical engineering graduate students and professional designers. Each group was evaluated on all three techniques and a different design problem was solved for each of the techniques. This design eliminated individual differences as a noise variable but caused the technique results to be confounded with the design problem.

2 Experimental Approach and Research Questions

Engineers seek a robust idea generation method for predictably producing a large quantity of high quality, novel product solutions. Using a factorial design of experiments, our study explores the influence of the representation used to communicate ideas and how ideas are displayed to individuals. We seek to answer the following research questions:

- Research Question: How do the nominal groups compare to real groups in terms of quantity and quality of ideas?

This research questions is addressed systematically in the following sections. We discuss our experimental method, metrics for evaluation, data analysis approach and the results.

3 Experimental Method

We conducted a factorial experiment in order to explore the effects of two key factors on the outcome of group idea generation. The first factor controls how participants view the ideas, either all ideas are posted via gallery (on the wall), sets of ideas are rotated between participants, or they are not exchanged (individual idea generation-nominal groups). The second factor controls how participants represent their ideas. Participants either use written words only, sketches only, or a combination of written words and sketches to communicate ideas to their teammates. A 2 (Display of ideas: "gallery" or "rotational view") X 3 (Representation: words only, sketches only, or words combined with sketches) factorial experimental design is used (Table 2). No oral discussions are allowed during the session; all communication is written. This approach produces methods similar to 6-3-5 (Pahl and Beitz, 1996), C-Sketch (Shah, 1998), Brainsketching (VanGundy, 1988), or Gallery Method (Pahl and Beitz, 1996), as shown in Table 3. All participants solved the peanut sheller problem (Linsey, et al., accepted).

3.1 Factor 1: Display of Ideas

One key factor in this study is whether ideas are displayed all at once or whether participants see only a subset at any given moment. In the "gallery view" condition, all ideas generated by the team are posted on the wall, so all participants can see all of the ideas at the same time. This approach results in a method similar to Gallery Method or Brainsketching (VanGundy, 1988; Pahl and Beitz, 1996). In the "rotational view" condition, ideas are passed around the table, so that each participant sees only a subset of the ideas at any given moment. This condition is similar to 6-3-5 or C-Sketch (Pahl and Beitz, 1996; Shah, 1998; Otto and Wood, 2001).

3.1.1 Gallery View Condition- Similar to Brainsketching or Gallery Method

For the first 10 minute period, each student is given a number of paper sheets and told to write down at least two ideas on separate sheets of paper. Sheets are collected as participants finish, but are not displayed until the end of the period. The time period length is based on the available time and recommendations from the literature, which vary from five to 15 minutes (VanGundy, 1988; Baxter, 1995; Shah, et al., 2000). The ideal time period for the methods under evaluation is not explicitly known and is not one of the experimental parameters. At the end of the first period, all sheets are numbered and posted gallery style on the wall. In the four subsequent 7.5 minute periods, ideas are posted as they occur and participants are told to execute one of the following options:

2. Add new ideas to one of the posted drawings. Participants can request a drawing by writing down its number on a small sheet of paper.
7. Make a separate drawing that is related to the

Table 1. Experimental conditions

	Factor 2: Representation		
	Words Only	Sketches Only	Words and Sketches
Factor 1: View Condition	1	3	5
Gallery View			
Rotational View	2	4	6
Individual	7		8

ideas that are already posted, and write the number of the linked idea on the new sheet.

8. Start a completely new sheet after reviewing the posted ideas.

For the first 10 minute period, each participant is given a number of paper sheets and told to write down at least two ideas on separate sheets of paper similar to the "gallery view" condition. At the end of the period, the experimenter collects all sheets and systematically redistributes them such that each participant views each set of papers once. Participants cannot identify which one of their teammates had the sheets previously. In the four subsequent periods, lasting 7.5 minutes each, participants have the same options as in the "gallery view" condition: to add ideas to an existing sheet, to create a new product solution linked to another sheet or to start a completely new product solution. The exception here is that participants focus on the specific set of papers given to them at a particular instance in time.

Table 2. Experimental conditions and similar formal method

Experimental Condition	Similar Formal Idea Generation Method
1	Electronic Gallery (Aiken, et al., 1996)
2	6-3-5
3	
4	C-Sketch
5	Gallery
6	Brainsketching

3.1.2 Rotational View Condition- Similar to 6-3-5 or C-Sketch

For the first 10 minute period, each participant is given a number of paper sheets and told to write down at least two ideas on separate sheets of paper similar to the "gallery view" condition. At the end of the period, the experimenter collects all sheets and systematically redistributes them such that each participant views each set of papers once. Participants cannot identify which one of their teammates had the sheets previously. In the four subsequent periods, lasting 7.5 minutes each, participants have the same options as in the "gallery view" condition: to add ideas to an existing sheet, to create a new product solution linked to another sheet or to start a completely new product solution. The exception here is that participants focus on the specific set of papers given to them at a particular instance in time.

3.1.3 Nominal Groups

For the nominal groups, individual were assigned to work alone and were given the same amount of time. The nominal group data was taken two semesters after the group data was collected. The same professor taught the class and the same experimenter collected the data. During the semester the nominal group data was collected and prior to data collection, the participants in the nominal groups were accidently shown example peanut shelling machines (Fig. 3). These ideas were only shown briefly in class and the participants' data does not appear to be influenced.

The nominal groups were formed by randomly assigning the results from five individuals to a group and removing redundant results. Data is from twenty-four individuals whose results were used to create forty nominal groups.

3.2 Factor 2: Representation

The second experimental factor prescribes how the participants communicate their ideas to other participants (words only, sketches only with no words, or a combination of words and sketches). At the end of the sessions and after completion of the surveys, participants in either of the group sketches-only conditions labeled their sketches with brief descriptions to facilitate evaluation. American mechanical engineers are typically not taught to draw free-hand and therefore their sketches are usually difficult to interpret without annotations. The prior study (Linsey, et al., accepted) shows that the sketches only data shows a different pattern of results likely due to the poor sketch quality and effort required by teammates to interpret the drawings. For this reason, individual data was not taken and therefore no nominal groups.

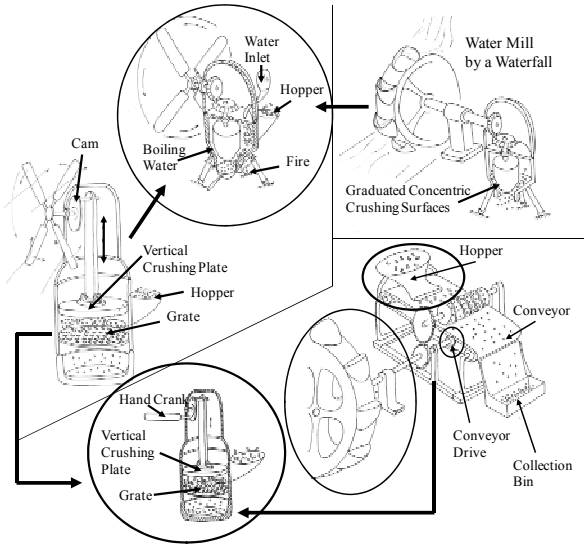

Fig. 3. Set of examples which were briefly and accidently shown in class to the nominal group participants

4 Metrics

For the nominal group data, only quantity and quality were measured since only these two metrics showed few differences between the idea generation methods. The same process as before was used (Linsey, et al., accepted). A new evaluator scored the quantity and quality data for the nominal groups. Prior to scoring the nominal groups, the evaluator was trained on two teams' results and then two additional teams' were scored by the evaluator to determine inter-rater agreement. Inter-rater agreement for quantity was 92% with a Pearson's correlation of 0.91. This indicates there is strong agreement between the two evaluators.

5 Results and Discussion

Interacting groups with appropriate idea generation methods can be more effective than nominal groups. The results show that real teams in rotational conditions develop a larger number of ideas than equivalent nominal groups (Figure 4). This result is consistent with the theory that one of the reasons for the observed productivity losses in real interacting groups as compared to nominal groups is due to production blocking (Mullen, et al., 1991; Nijstad and Stroebe, 1999). Production blocking occurs is when one team member is talking (producing ideas) and other teams members are listening. This causes them not to produce ideas. This result is also consistent with other hypothesized reasons for the productivity loss includging performance matching (individuals see how much their teammates are producing and adjust their productivity to match), and evaluation aprehension (Mullen, et al., 1991; Nijstad and Stroebe, 1999).

A clear interaction effective is observed in Figure 5 through the non-parallel lines. An ANOVA shows that there is a statistical interaction between the viewing condition and the representation meaning that both are statistically important and the effect of the viewing condition depends on what representation is used [Viewing Condition: $F(1,48)=2.2$, $p=0.15$, Representation: $F(2,48)=26.3$, $p<0.001$, Interaction: $F(2,48)=9.0$ $p<0.01$ and $MSerror=30.7$]. The representation implemented does not affect the nominal groups (individual idea generation), but has a substantial impact for the real groups. In real groups, the representation effects the communication between group members, whereas with individuals, the representation mainly serves to externalize internal ideas.

The statistical analysis in this paper does not include data from any of the sketches only conditions because the prior study (Linsey, et al., accepted) indicates that the results from sketches only conditions are likely significantly affected by the fact that US mechanical engineers are typically not taught to free-hand draw. So only the data from Words Only and Word & Sketches is analyzed and compared.

To maximize the number of ideas a team generates, a team should use annotated sketches to communicate their ideas. A hybrid 6-3-5/C-Sketch method that includes rotational viewing should be implemented. For an individual working alone, it does not matter what representations is used.

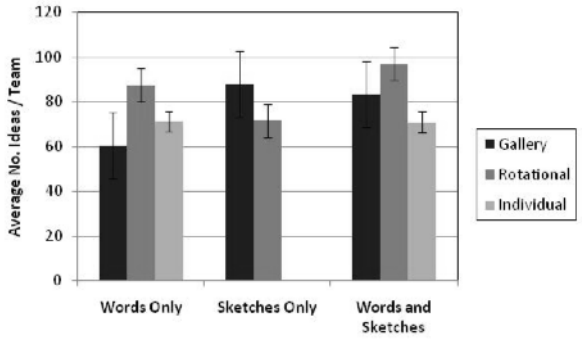

Fig. 4. Average number of ideas per team. Error bars are +/- one standard error

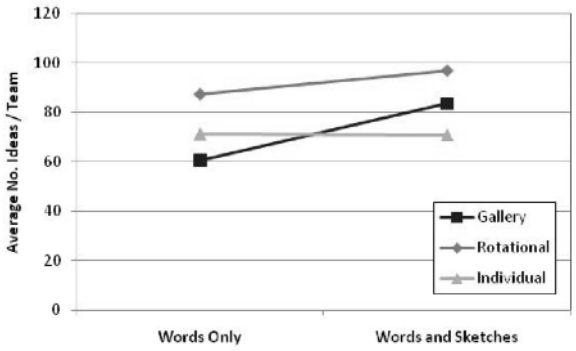

Fig. 5. Interaction effects between words only and words & sketches representations and the viewing condition

5.1 Quality

The representation has no effect on quality (Figure 6) or the distribution of quality (Figure 7) for the individual idea generation (nominal groups). This is not particularly surprising since the individuals are not communicating their ideas to anyone else and the quality scale is rather coarse. If the quality scale were finer, it might indicate differences between the representations.

The various conditions do have some effect on the quality of the ideas generated and the quality distribution (Figure 6 - 8). The prior study (Linsey, et al., accepted) did indicate that sketches only conditions tended to produce both higher quality ideas on average and fewer low quality ideas (Figure 6 and Figure 7), but this was likely due to the fact that many low quality ideas like "chemically removing the peanut shell" or "genetically engineering a peanut without a shell" are difficult to draw and therefore would have not been included by the participants.

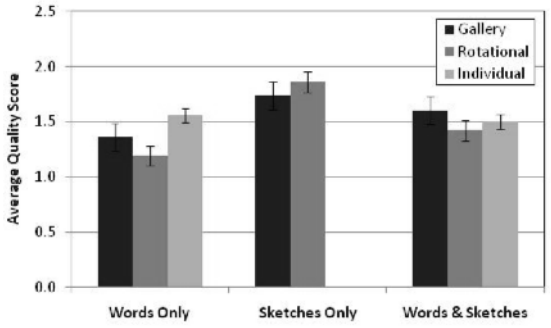

Fig. 6. Quality results. Each error bar is +/- one standard error

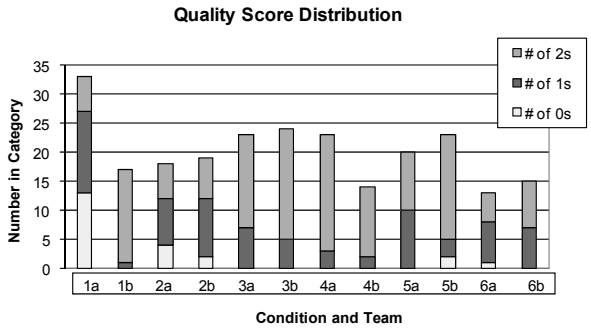

Fig. 7. Distribution of team quality scores (Quality Scores 1=technically feasible, 2=feasible for the context)

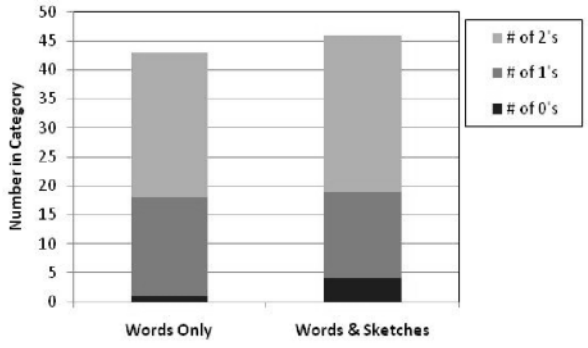

Fig. 8. Quality score distribution for individual idea generation (combined to form nominal groups)

The quality results indicate that words only should not be used for a large number of quality ideas in a team setting. The viewing condition (gallery verse rotational) had little effect on the average quality or the distribution.

These results indicate that when teams implement an effective method for idea generation, they can outperform the combined results of individuals (nominal groups). This result is in contrasted to results from Osborn's Brainstorming method where nominal groups generally outperform real teams (Mullen, et al., 1991).

6 Conclusions

Brainwriting techniques that include a combination of sketches with annotations, such C-Sketch or Gallery, can assist a team in creating more ideas than the combined efforts of the same number of individuals working alone with redundant ideas removed, referred to as "nominal groups". In contrast to this, prior experimental results from other studies on Osborn's Brainstorming show that interacting groups are less effective than nominal groups. These results indicate that designers should carefully select their group idea generation approach in order to obtain a successful process.

To maximize the impact of a group idea generation, teams should sketch their ideas and add annotations to enhance interpretation. Methods where individuals can all simultaneously work as opposed to methods where one person speaks at a time (e.g. Osborn's Brainstorming), will produce a greater number of ideas. A hybrid 6-2-5/C-Sketch method, where teams sketch adding annotations and then rotate ideas, is best for group idea generation.

This study compared nominal groups to real groups using techniques very similar to 6-3-5, C-Sketch and Gallery. Nominal groups were compared to real groups in a 3X3 factorial experiment. The first factor was how the teams represented their ideas (words only, sketches only or words & sketches) and the second factor controlled how ideas were exchanged (rotational viewing, gallery style, or no exchange-nominal groups). This factorial design leads to teams generating ideas in conditions very similar to 6-3-5, C-Sketch and Gallery. It was found that real teams using rotational viewing (e.g., 6-3-5, C-Sketch) created a greater number of ideas as compared to nominal groups. In contrast to this, real teams using gallery viewing produced significantly fewer ideas than the nominal groups.

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