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FACING THE BRAINSTORMING THEORY. A CASE OF REQUIREMENTS ELICITATION

Summary: Knowledge is still considered to be power and its externalization makes it possible for others to use that power. In this paper, we examine the theory of brainstorming, and the claim by father Alex Osborn that in a group session an individual can think of twice as many ideas than working alone. In the context of requirements elicitation, we performed an experiment on a "nominal" and a "real" group of participants, following a procedure based on the Jaccard index. However, the obtained results do not provide evidence to support the above opinion, because during a five-minute session, participants working individually produce over 43% more ideas than a group of different participants.

Keywords: brainstorming, theory, requirements, elicitation, usability, factors.

Introduction

Undoubtedly, the roots of the brainstorming approach lay in ancient times, when open gatherings were common practice and where every participant had the right to speak, ask and question a discussed idea; in present times we even tend to proudly define such a phenomenon as *collective intelligence*. However, it was Alex Osborn who first formulated its conditions and rules in his 1953 influential book *Applied Imagination*. His main suggestion states that group problem-solving considerably increases the quantity and quality of ideas produced.

Brainstorming is basically a technique to provoke and encourage creative thinking based on a general idea, during a workshop with a group of participants, including experts or novices. Osborn also claimed that the following rules

should be preserved in order to perform an efficient idea-generation phase during a brainstorming session:

- *group size* should be about five to seven; too many participants lead to an uncontrolled and unmanageable session; on the other hand, a small group is expected to produce an equivalent outcome;
- *criticism*, *evaluation*, *judgment*, or *defense of ideas* are not allowed, along with disapproving non-verbal behavior; however, all positive comments are welcome;
- *freewheeling* (free association) is encouraged; the more abstract, fantastic or even off-the-wall ideas are articulated, the better;
- *quantity and variety over quality*; the more ideas are put forward, the more likely it is to come across a valuable one;
- *combinations* and *improvements* are encouraged; varied and combined ideas are a hope for bringing some kind of innovation.

According to Osborn [1, p. 229], if we follow these rules, then "the average person can think up twice as many ideas when working with a group than when working alone". In other words, collaboration with others shifts one's mind into a higher level of creativity and imagination. Let us mark his statement as the null hypothesis (H_0), while the opposite, as the alternative hypothesis (H_a).

The above statement has been striking enough to provoke an investigation of related empirical studies, regarding the effectiveness of the generation of group ideas, available and published in the literature (journals and conference proceedings), as well as to verify this technique in self-conducted and self--controlled experiments.

Our study contributes twofold to the existing literature: to the best of our knowledge, this is the first attempt to verify Osborn's hypothesis in the context of requirements elicitation using mind-mapping techniques. Secondly, we have developed a procedure dedicated to comparing and evaluating the results obtained from individual and group brainstorming sessions. Moreover, we have gathered a set of 33 user interface usability factors, subjectively perceived by 20 participants.

The rest of the paper is organized as follows. In section 2 we provide a brief and focused discussion of the literature. In section 3 we describe the design of the conducted experiment and discuss the obtained results. The last section includes final conclusions and remarks.

1. Literature review

The literature review was drawn up in order to analyze the construct of similar studies, and to compare the results with those obtained from conducted research.

There have been many voices of approval, confirmation and delight regarding Osborn's theory, on the one hand; while on the other hand, even more researchers have questioned and depreciated its real value. Obviously, only some of them, due to the limitations of this paper, may be quoted and reflected in further discussion by the author.

Social psychology researchers were the first who questioned brainstorming as the most effective approach to produce solutions. In 1958, Taylor et al. [2] showed that so-called "nominal" groups (the same number of individuals producing solutions in isolation) outperformed brainstorming ("real") groups, with the same problem and amount of time. Bouchard and Hare [3] compared five-, seven-, and nine-man brainstorming groups with "nominal" groups. There was a significant effect due to the size and type of group. As expected, the larger groups generated more ideas and the individuals who brainstormed alone were more effective. A brainstorming group, over a wide range of sizes, inhibits rather than facilitates creative thinking, while the pooled effort of individuals is a far more productive technique than group effort. Some individuals may consciously neglect to pursue the same line of thinking [4, p. 135], or the existence of uniformity pressure and evaluation apprehension in closed groups may influence the productive generation of ideas, caused by a fear of being judged [5, p. 1071]. From other undesirable effects, the "sucker effect" is well-recognized, which is a particular form of social loafing, and stems from the perceptions that others in the group are withholding, or intend to withhold, the expected effort for solving a given task or problem [6, p. 575]. A variety of intrapersonal factors may also influence the commitment of individuals within groups, e.g. gender and cultural differences [7], diversity of cognitive styles [8], or various types of personality [9].

On the other hand, practitioners and the business press have presented group brainstorming as an important approach when generating solutions to different kinds of problems. For example, Kayser [10] claims that "[…] group sessions are the lifeblood of organizations; [...] groups have two assets that exceed those of any individual in the group: they possess more knowledge, and they can think in a greater variety of ways"; however, "these potential assets may not always be realized", because "[…] the group may fall into so much dysfunctional conflict that it cannot operate". Seshan goes even further and thinks that "[…] brainstorming is a popular method of encouraging creative

thinking and defensed judgment. The advantages of brainstorming are enthusiasm, broader participation, greater task orientation, building upon ideas exchanged and the feeling that the final product is a team solution" [11]. There are also different proposals to increase the effectiveness of the brainstorming participants, such as an additional set of rules to follow during a session with the presence of a facilitator who actively enforces the rules [12, p. 206], or asynchronous electronic brainstorming [13]. Note, that it has been evidenced that electronic brainstorming (EBS) significantly reduces or even eliminates the harmful blocking effects [14, p. 531] which naturally appear in verbal communication [15], and discards evaluation apprehension, because anonymity excludes the possibility to be negatively evaluated [16]. Participants of EBS sessions often pursue the same set of ideas, instead of considering a diverse and wide range of ideas, which may thereby decrease the number of ideas generated. To reduce this cognitive inertia, groups should be engaged in several simultaneous discussions or dialogues; if so, more ideas, more high-quality ideas, and more novel ideas are expected to be generated [17]. However, there are also critics who claim that "[…] the existing theoretical and empirical evidence does not provide sufficient justification to clearly establish EBS' superiority over nominal brainstorming for large groups" [18]. As always, some conclusions and judgments are credulous and some have been proved; thus the former should be treated as personal remarks while the latter as empirical findings.

The following question ultimately arises: if brainstorming groups in real-world or electronic settings perform so poorly compared to "nominal" groups (pooled individuals), why are companies still using them to solve crucial problems or tasks? Sutton and Hargadon [19] submit that "nearly all brainstorming research was done with participants who (1) had no past or future task interdependence; (2) had no past or future social relationships; (3) did not use the ideas generated; (4) lacked pertinent technical expertise; (5) lacked skills that complement other participants; (6) lacked expertise in doing brainstorming; and (7) lacked expertise in leading brainstorming sessions". In most laboratory experiments the participants were undergraduate or high school students [15], [20], probably without proper experience in brainstorming and any prior specialized knowledge required to solve the discussed problems. In others, too general questions were put forward, such as, how to reduce energy consumption [20], improve campus security [21] or tourism [22]. However, many companies use group brainstorming sessions to solve "heavy" problems, not only when other means fail and collective creativity is the only hope, but because a great number of creative ideas might emerge from people working together [23], designers

who have to conjure up new products [19], managers who have to produce new ideas to empower organizational behaviors [24], and so forth.

A brief analysis of the literature of requirements elicitation provides a few interesting examples of research devoted to measure the feasibility and effectiveness of particular creativity techniques. In [25], the authors conducted experiments on two projects with very different characteristics, where in each experiment they compared the performance of two teams, one of which used the developed EPMcreate technique and the other of which used brainstorming; in each, the former was proved to be more effective than the latter. On the other hand, in [26] brainstorming was reported to be the third most effective requirements technique, after "question and answer" and use cases, however, before customer interviews, storyboards, prototyping, questionnaires and requirements management. Besides this, the authors highlighted the possible advantage to be achieved by using synchronous as opposed to asynchronous collaboration. Per contra, the findings of review [27] show that "interviews, preferentially structured, appear to be one of the most effective elicitation techniques in a wide range of domains and situations". Experimental results [28] show that "efficient meetings greatly depend on the ability of the facilitator".

Others frequently used research methodologies, elicitation including *embodiment workshops*, where participants are asked to consider and discuss a set of questions or to write down ideas and discuss them with each other; occasionally video documentary is played in order to present the latest developments and capabilities concerning a given domain; *scenario-focused workshops*, conducted in small groups or individually, in which participants are introduced to short scenarios, both verbally and on paper, including a description relating to particular subjects [29].

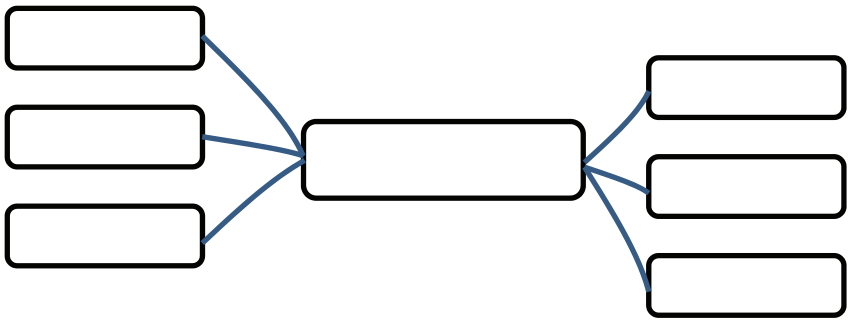
2. The experiment

By the experiment, we mean a set of two independent sessions, moderated by the author, each with a different group of people, equally counting 5 males and 5 females, computer science students with the average age of 21-23, with at least 3 years of experience in the field of using a personal computer for at least one hour per day. The first session consists of 10 "nominal" groups, thus each participant works alone with a pen and a piece of paper, whereas the second session consists of one "real" group with 10 participants. The duration of each session is limited to 5 minutes, which in our opinion is enough to spark creativity and imagination. The main and sole goal is to identify factors that influence user interface usability.

2.1. Experimental design

In both sessions, in the beginning, we ask participants to fulfill a simple metric, where we ask about their age, sex and experience. Next, in the first session only, we hand out for each nominal group one blank mind map (horizontally printed on an A4 format) with a single concept in the center, and six blank branches, representing major factors (Figure 1).

Figure 1. A blank mind map



Next, we ask participants to read a short instruction that explains the purpose of the research and asks them to legibly fill out the blank areas; where necessary, it is allowed to draw a maximum of three sub-branches for each single branch.

In the second session, we use a blackboard with a drawn mind map and gradually write down spoken ideas. We bear in mind the fact that group dynamics must be kept for idea generation, so we use simple techniques to secure the participants' attention and focus during the session.

2.2. Verification and evaluation method

Mind maps gathered in the first session are briefly checked in order to eliminate those which are completely irrelevant with the main concept. Fortunately, all of them were positively verified and could be further taken into account. Next, we transfer answers to a spreadsheet. The rows are sorted alphabetically, and analyzed in order to merge synonyms or multiple versions of the same words (e.g. "color" and "coloring", "intuitiveness" and "intuitive"). In such a manner, from 60 factors only 30 turn out to be distinct. Figure 2 below is an illustration of this set, using the "tag cloud" visualization technique.

Figure 2. The cloud of the first branch factors produced by "nominal" groups

After performing such a procedure, the results are ready to be compared and evaluated. For this purpose, we developed the following procedure.

Let *FN* and *FR* denote a set of first branch factors, generated by "nominal" and "real" groups respectively, where $|FN|$ and $|FR|$ is the cardinality of each set. The union of these sets is $FN \cup FR$ and the intersection is $FN \cap FR$, and analogously $|FN \cup FR|$ and $|FN \cap FR|$ are the number of elements in the intersection and in the union of these two sets.

The Jaccard index, computed for sets *FN* and *FR*, is given by:

$$J(FN, FR) = \frac{|FN \cap FR|}{|FN \cup FR|}$$

The index interpretation is straightforward: a value of 0 means completely dissimilar sets, while on the contrary, a value of 1 means completely similar sets.

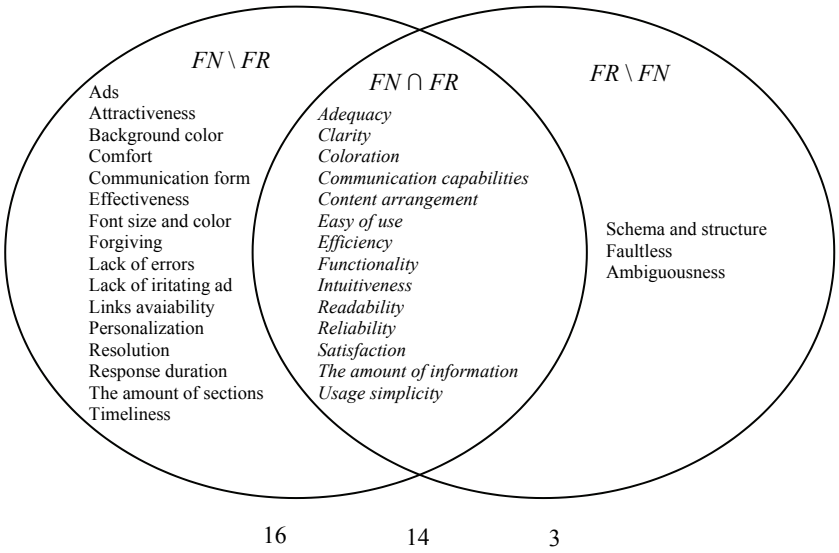
In our procedure, in the first step, the Jaccard index is estimated in order to compute the similarity between *FN* and *FR*. If its value is higher than a user-specified value *x*, then the sets are similar enough not to proceed further, and in consequence, the results obtained from nominal and real groups are almost the same or the same, and the procedure terminates. However, if the *J* value is below x, the procedure continues with the following steps.

For a given set *FN* and set *FR*, let *FN*' denote the set difference between the set *FR* and the set *FN*, thus $FN' = FN \setminus FR$ and is the set of all elements in *FN*, but not in *FR*. Analogously, $FR' = FR \setminus FN$ is the set of all elements in *FR*, but not in *FN*. In addition, beyond the main assumptions of Osborn's theory, sets

FN' and *FR*' can be evaluated in order to determine the level of knowledge adequacy, assessed by an expert or a group of experts, using, for example, the Likert scale or a self-made numeric, fuzzy or dichotomous rating scale. On such a basis, obtained scores by pooled "nominal" groups and a "real" group are compared, and the winner is chosen.

Let us analyze the above case again. The cardinality of the union is 33, while the cardinality of the intersection is 14, thus the Jaccard index $J(FN, FR)$ is $14 / 33 \approx 0.42$. For the given x equals 0.8, the value J tells us that the similarity of the sets *FN* and *FR* is significant enough to analyze the set differences *FN*' and *FR*'.

Figure 3. The difference sets *FN*' (left) and *FR*' (right) and the intersection of the sets *FN* and *FR* (center)



The above figure is a perspective on the differences of knowledge gathered from "nominal" and "real" groups. There is a relatively high difference (over 43%) between the number of ideas generated between these two groups. To sum up, given this result, we would be inclined to reject the null hypothesis (H_0), that is, in the case of requirements elicitation, in which the brainstorming technique was employed, working with a group did not encourage *the average person to think up twice as many ideas than when working alone*.

3. Discussion

Obviously, there are some limitations of this research. First of all, only one session for each group was conducted and juxtaposed with the other. Secondly, the number of 10 "nominal groups", and 10 participants of the "real" group might also be pointed out as being not sufficient enough to set out to disprove the null hypothesis. This eventually may lead to the rejection of the presented results. Although no judgment has been statistically proved, based on broad experience in using brainstorming techniques in a variety of contexts and to a wide range of social levels, intelligence and expertise of performing groups, a certain versatility has become apparent and simply begs for urgent evidence, obscuring advanced statistical apparatus. This fact motivates us to augment our current research in the near future. However, the state of the art seems to be comprehensive enough to grasp the previously discussed subjects of interest, research methodologies and final results. In summary, the developed procedure, and obtained results, despite the indicated drawbacks, are a good starting point that might spark a fruitful discussion leading to uncovering other facts that lay beyond the nature of brainstorming theory, in our opinion, not biased by the context of the research.

Conclusions

Have you ever wondered why a facilitator during a meeting routinely asks questions like: *what if*? *what else*? *why not*? Not only to acknowledge your opinion, but to provoke disagreement and criticism that might be stimuli for creativity, inspiration and enhancement, producing opposite or complementary ideas. The storm of opposite ideas and opinions might change the line of thought not only individually but for the whole group as well, boost creativity, imagination and ingenuity, which may eventually lead to the birth of an innovation. However, this phenomenon has not been revealed in the conducted experiment. Gathered knowledge from the individuals is greater in size as well as in relevance compared with the group of people. Many questions have arisen, especially about how to encourage and motivate people to externalize their possessed knowledge and to eliminate obstacles to communication. These issues are on the short list of pending research that assumes to facilitate IT tools in requirements elicitation.

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REWIZJA TEORII BURZY MÓZGÓW NA PRZYKŁADZIE POZYSKIWANIA WYMAGAŃ

Streszczenie: Wiedza jest ciągle postrzegana jako źródło siły, zaś jej eksternalizacja czyni ją dostępną dla innych. W niniejszym artykule poddano rewizji teorię burzy mózgów, w szczególności założenie jej Autora Alexa Osborna, że w trakcie sesji grupowej (realnej) pojedyczny uczestnik wygeneruje dwa razy więcej myśli (idei) niż w trakcie samodzielnej (nominalnej) sesji. W kontekście pozyskiwania wymagań został przeprowadzony eksperyment na grupach nominalnych i realnych. Do porównania otrzymanych wyników wykorzystano indeks Jaccarda. Otrzymane wyniki jednak stoją w sprzeczności z powyższym stwierdzeniem, pokazując, że o 43% więcej idei wygenerowały pojedynczy uczestnicy badania w porównaniu do ich grup.

Słowa kluczowe: burza mózgów, pozyskiwanie wymagań.