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STIMULATED IDEATION SESSIONS IN PRODUCT PLANNING: ASSESSING QUANTITATIVE RESULTS OF INDIVIDUALS AND GROUPS

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1. Introduction

Many literature sources mention Product Planning as a critical phase in engineering design, although its actual meaning is not shared by the whole scientific arena. In design context, the most popular definition refers to the meaning attributed by Pahl et al. [2007], whose schematization of New Product Development cycles is largely accepted. The authors adhere to their definition. Consistently, the thrust of Product Planning is the identification of new product features capable of creating new market opportunities through increased customer benefits. The paper focuses on strategies to support companies, R&D teams, engineers and designers in the creative process of idea generation.

Among the different techniques adopted in industry to support product planning, the well-known Brainstorming method, originally developed by [Osborn 1953], shows a wide diffusion [Geschka 1996], [Coates et al. 1997]. This approach is extensively adopted in the industrial practice, because it can be easily and intuitively used, even if it is often implemented in a naïve way, not fully aligned to original Osborn's recommendations. Furthermore, the method can involve the customer in an active way, with the aim of collaborating in the generation of new product ideas. Several practices and techniques to support brainstorming sessions have been experimented during the years, e.g. Synectics [Gordon 1961], Brainwriting [VanGundy 1984], Mind Maps [Buzan and Buzan 1996], Bodystorming [Oulasvirta et al. 2003]. However, companies often develop their own customized Brainstorming method, according to their needs and the actors they are capable of involving.

Notwithstanding its wider diffusion in industry, several issues are still open about ways and opportunities of employing Brainstorming efficiently. Osborn stressed the importance of focusing on the quantity rather than on the quality of the generated ideas, by claiming that the abundance of hints gives rise to greater chances of achieving successful outcomes. However, too many alternatives create considerable problems in the selection phase and the scarce quality of the outputs can lead to not lucrative results. In addition, whereas Brainstorming advocates claim that such a method is more effective than entrusting idea generation to a plurality of individuals working separately, other studies e.g. [Furnham 2000], [Rietzschel et al. 2006] assess that groups employing Brainstorming produce a smaller quantity of ideas (besides less feasible).

The recalled aspects are still debated in the scientific community since they strongly affect efficiency and efficacy of brainstorming techniques. In such a context, this paper contributes to the discussion further. More in particular, we focused our investigation on some factors influencing the performance of ideation sessions with the aim of providing insights into the development of procedures and

instruments capable of exploiting Brainstorming and/or other analogical reasoning techniques at their maximum potential.
According to the introduced general objective, the paper is organized as follows. Section 2 briefly recalls the main debated issues related to the application of Brainstorming and introduces the specific objective of the investigation. Section 3 presents the followed research method that is based on an experimental activity devoted to compare different ideation approaches. Section 4 presents the outcomes of the investigation. Eventually, discussions and conclusions about the achieved results are presented in Section 5.

2. Background and specific objectives of the research

Brainstorming is a technique adopted in several fields (from management to engineering) to support idea generation tasks. The widespread interest for Brainstorming has led scholars to perform several studies aimed at investigating the factors that affect the fruitful application of this technique in practice. The research in the field is influenced by different perspectives, related to Human Psychology, Sociology and Knowledge/Information Management, since, for its nature, the creative process behind Brainstorming involves cognitive aspects and interactions among individuals.
Related literature mainly concerns the organization of Brainstorming sessions, the modalities of performing Brainstorming (with particular emphasis on individuals working alone or in teams), and the potential benefits arising from the adoption of structured procedures, computer-aided tools and other instruments to enhance the process efficiency.
Several scholars, e.g. [Brown and Paulus 2002], [Isaksen et al. 2005], have performed experimental activities focused on the evaluation of the efficacy of Brainstorming sessions carried out in teams or by individuals (nominal groups). Comparative studies revealed that the number of ideas generated by teams is lower than the sum of ideas arising by the same individuals working alone. More recently, [Khon et al. 2010] performed an investigation to correlate the organization of the sessions and the expected outcomes of product development tasks. They discovered that the group organization into non-interactive individuals is more advisable when there is the need of generating a wide variety of solutions to a problem. On the contrary, if the goal is to explore some solutions in depth, they suggest a configuration based on a group composed by interactive participants. Linsey et al. [2011] further elaborated the topic, showing that group idea generation methods significantly affect the total quantity of generated ideas, as well as the number of high quality concepts, but they have no significant effects for either novelty or variety of solutions. In [Brown and Paulus 2007], as well as in other works, investigations about the sociological dynamics that arise during sessions with interactive individuals have been carried out with the aim of understanding their impact on the process. The results show that the outcomes of the generation activities are strongly influenced by the way through which ideas are presented and shared. Even [Linsey et al. 2011] identified the great role played by information communication and sharing in determining fruitful results. Furthermore, [Khon et al. 2010] highlighted the "fixation" phenomenon that appears when Brainstorming participants are exposed to others' ideas, leading to a strong reduction of the novelty of the outcomes.
Notwithstanding the recalled limitations ascribable to working with interactive modalities, scholars acknowledge the great potential triggered by the information flow within groups and claim that the usage of methods and procedures for organizing sessions and idea exchange can enhance idea generation. Under these conditions, interactive participants can be as effective as individuals working alone [Brown and Paulus 2007]. Even [Linsey et al. 2011] claims that both individuals and group interactions are important in the idea generation process since new ideas are developed upon ideas coming from other group members. Furthermore, [Hender et al. 2002] provided some insights about the use of creative techniques as Group Support Systems. The research confirms that tools and techniques providing stimuli can have large implications for the creative outcomes of teams. The need of organising brainstorming sessions and increasing the related creative outcomes has pushed the development of several computer-aided tools in the last years, as surveyed by Hüsig and Kohn [2009], giving rise to the so-called “electronic brainstorming” [Aiken et al. 1994].
The survey elucidates how different goals and conditions affect the suitability of classical Brainstorming and a complete agreement among scholars has not been fully reached yet. At the same time, in the field

of engineering design, specific forms of analogical thinking are considered, being they based on cognitive and/or intuitive ideation processes, e.g. [Gero et al. 2013]. Within the initial stages of engineering design cycles, such as Product Planning, human creativity is particularly important, as the task consists in identifying business opportunities, hence, in an engineering design perspective, basically proposing new product attributes. In this sense, the various proposals to support this stage mirror the Brainstorming process and differ according the involved actors and the way designers are guided in the exploration of potential opportunities. In this sense, with respect to different ways to conduct ideation in Product Planning, the paper intends to investigate:

- the role played by the way ideation stimuli are offered;
- the differences between individual tasks and ideation activities performed by cooperating groups.

More precisely, the specific objective of the paper consists in comparing the effectiveness of ideation sessions in presence of stimuli. The aim is to elucidate the difference between individuals working alone and groups cooperating in the ideation activity. The research activity focuses on the quantity of generated ideas as a first proxy of the effectiveness of ideation tasks. This factor is, besides, the reference index of Brainstorming practices.

3. Research method

The accomplishment of the research objectives introduced in the previous section has been carried out through an experimental activity involving individuals working alone and in teams. The method adopted to perform the research is described in detail in the followings.

3.1 Experiment and stimulation alternatives

In order to provide a clearer picture of the role played by stimuli in Product Planning, two different kinds of hints have been investigated. On the one hand, the authors have explored the capability of vague indications and general guidelines in terms of supporting the generation of new product ideas and/or new product attributes, intended as unprecedented features or benefits. In this sense, a valid option is represented by the Six Path Framework (SPF), proposed within the Blue Ocean Strategy (BOS) [Kim and Mauborgne 2005]. With reference to the BOS, this tool is deemed as the most valuable for addressing the search of new sources of competition for existing artefacts. However, at the same time, NVP's capability of guiding towards the identification of novel product attributes is criticized in the literature [Aspara et al. 2008], [Borgianni et al. 2011], because of vagueness and the imprecise definition of the guidelines.

On the other hand, a novel tool has been employed that claims to perform a careful exploration of the design space that pertains to product planning [Bacciotti et al. 2016]. The creation of such an instrument was based on the exploration of numerous NPD experiences, leading to radical innovations. In particular, the new drivers for customer satisfaction have been observed and subsequently abstracted and organized in a specific framework. The tool constitutes therefore a supposedly thorough collection of stimuli, which are claimed to be suitable for any kind of product or service. Further details are available in [Bacciotti et al. 2016], as well as the prototype software that eases the administration of stimuli, namely iDea, is freely accessible on the Internet: http://goo.gl/AwzZHF. A detailed description is not provided hereby for the sake of brevity.

Thus, in order to perform a comparison between different stimulation settings, the conducted experiments were characterized by diverse:

- stimulation modes: SPF vs. iDea;
- number of people participating to the ideation session: individuals vs. groups.

3.2 Organization of the creative sessions

The volunteer participants to the multiple kinds of texts were the students from the class "Product Development and Engineering", Master Degree in Mechanical Engineering, University of Florence, Italy. The students of the Academic Year 2014/15 carried out individual tests, while groups of students of the Academic Year 2015/16 were randomly arranged for cooperative ideation sessions.

As both the samples of experimenters were asked to participate in two sessions, involving the two alternative stimulation modes, the authors proposed the students different themes in order to avoid biases or basing their thoughts on the outcomes of the previous experience. In other words, each sample of students (regardless they were entrusted to work individually or in groups) was shared in two sets, one of which attempting to generate as many new product attributes as possible for a camera and the other one performing the same task with reference to a domestic coffee maker. Shifting from one stimulation mode to the other, the same individuals or groups were requested to propose novel benefits with respect to the subject they did not analyse in the first session. The topics were considered mass products, for which no prior information should be acquired by the testers, thus speeding up the ideation sessions.
All the sessions (differing in employed tools, number of participants and topic) were limited to the duration of 3 hours, so as to perform a valid comparison between the investigated treatments. The students were trained on the use of both the SPF and iDea (roughly 4 lecture hours) prior to the conduction of the first and second experiment, respectively. A further request of each session consisted in describing a new product implementing some of new generated ideas, which were considered the most suitable for a successful commercial launch. This final output is supposed to represent a measure of the novelty and the usefulness of the ideation sessions, but, by limiting the scope of the present paper to quantity of ideas, such an aspect will not be discussed within this manuscript.

4. Outcomes and statistical evidences

The present Section is organized in paragraphs. The first paragraph shows the results of the whole testing campaign in terms of quantity of generated ideas. The second one points out to which extent the cooperation among testers has contributed to boost the volume of the ideation sessions. The third paragraph discusses whether nominal groups would have outperformed cooperating teams, as it is claimed by several authors with respect to classical brainstorming.

4.1 Ideation sessions and quantity of ideas

The outcomes in terms of volume of generated ideas are reported in Table 1. In the Table, an ID has been assigned to each single idea generation session. The indexes identified as "Camera", "iDea" and "Group" are dummy variables (0/1), which indicate the administration conditions of each test:

- if "Camera" is 1, the topic of the ideation activity is a digital camera; a domestic coffee maker otherwise;
- if "iDea" is 1, the ideation task has been carried out by benefitting from the stimuli offered by the framework and the prototype software described in [Bacciotti et al. 2016]; a brainstorming session guided by the SPF and students' own creativity otherwise;
- if "Group" is 1, more people together (2 or 3) have cooperated in the ideation task; otherwise, individuals have worked alone.

An additional column clarifies the number of participants, so as to disclose the size of groups.
The quantity of ideas represents the number of new benefits or original product attributes that have shown no precedence in the reference market of the investigated product, i.e. the camera or the coffee machine. The lists of reported ideas has been checked by the authors, who have then counted the numbers of actually new product characteristics. It is worth noting that the testing campaign has been conducted with samples of convenience, but some conditions have been fully addressed:

- no one has worked on the same topic with two different idea generation tools;
- groups were not altered from the first to the second ideation session in the second testing year.

Table 1. Summary of the testing campaign and number of generated ideas

Test ID	Camera	iDea	Group	Number of participants	Quantity of new ideas
1	1	0	0	1	3
2	1	0	0	1	2
3	1	0	0	1	6
4	1	0	0	1	3
5	1	0	0	1	5

6	1	0	0	1	3
7	1	0	0	1	7
8	1	0	0	1	2
9	1	0	0	1	3
10	1	0	0	1	1
11	1	0	0	1	5
12	1	0	0	1	8
13	0	0	0	1	3
14	0	0	0	1	5
15	0	0	0	1	3
16	0	0	0	1	4
17	0	0	0	1	5
18	0	0	0	1	5
19	0	0	0	1	3
20	0	0	0	1	7
21	0	0	0	1	10
22	0	0	0	1	7
23	0	0	0	1	5
24	0	0	0	1	3
25	0	1	0	1	20
26	0	1	0	1	21
27	0	1	0	1	31
28	0	1	0	1	12
29	0	1	0	1	14
30	0	1	0	1	20
31	0	1	0	1	28
32	0	1	0	1	8
33	0	1	0	1	16
34	0	1	0	1	7
35	0	1	0	1	21
36	0	1	0	1	39
37	1	1	0	1	28
38	1	1	0	1	17
39	1	1	0	1	15
40	1	1	0	1	13
41	1	1	0	1	19
42	1	1	0	1	13
43	1	1	0	1	27
44	1	1	0	1	34
45	1	1	0	1	20
46	1	1	0	1	18
47	1	1	0	1	14
48	1	1	0	1	30
49	1	0	1	2	6
50	0	0	1	3	22
51	0	0	1	3	4
52	0	0	1	3	9
53	0	0	1	3	8

54	1	0	1	3	8
55	1	0	1	3	5
56	1	0	1	3	22
57	1	0	1	3	9
58	1	1	1	3	47
59	0	1	1	3	39
60	1	1	1	3	29
61	0	1	1	3	33
62	0	1	1	3	20
63	1	1	1	2	23
64	1	1	1	3	27
65	1	1	1	3	34

4.2 Effect of ideation groups on the quantity of new product attributes

The available data have been exploited in order to extrapolate statistical evidences. In particular, the influence of the topic, the kind of stimuli and the creation of groups were firstly investigated within the overall testing campaign. Subsequently the effect of working in groups has been estimated for the specific stimulation modes.

Linear regression models have been built to perform the above evaluations by means of the software Stata 13.0. Such a statistical model has been chosen as the simplest function capable of remarking the magnitude of the effect of multiple factors operating contextually, although no linear relationship was hypotesized a priori and the scope of the activity was not the construction of a previsional model. For this reason, the intercept has been calculated in each statistical function, but it will not be discussed in the followings. For each regression, the results are reported in terms of regression coefficients and p-values; the lower the value of such an index, the higher the likelihood of the associated factor to influence the results of the session. As a common rule of thumb, regression factors are considered impacting when the connected p-value is lower than 0.05. In the tables that follow, one star is used for p-values lower than 0.05; two stars for indexes minor than 0.01; three stars for values lower than 0.001. In other words, the number of stars reveals whether the probability of the influence of each regressor is higher than 95%, 99% and 99.9%, respectively.

Table 2 shows the impact of each regression factor on the quantity of generated ideas. The regression coefficients indicate (here and in the followings) the number of additional new ideas that the kinds of treatments produce when they hold the value 1 (see the meaning of the dummy variables reported in the previous paragraph).

Table 2. Results of the linear regression analysis on the overall testing campaign: impact of regressors on the quantity of generated ideas

Regressor	Regression coefficient	p-value
Camera	0.09	0.955
iDea	17.13	0.000***
Group	8.44	0.000***

Table 2 clearly highlights that the topic does not influence the quantity of generated ideas. In this perspective, the authors will not consider this factor in further statistical models. This does not mean that the role played by the topic is irrelevant in any case, but we can assess with very good reliability that the discussion on cameras or coffee machines has not impacted on creativity in the described tests. Conversely, both the stimulation mode and the teamwork have undoubtedly affected the outcomes.

However, it emerges that the kind of administered stimuli holds the highest importance if we observe the data about regression coefficients. In this sense, further observations have been performed to assess the influence of groups for both the stimulation means. The results are reported in Table 3.

Table 3. Role played by the organization of groups in different stimulation modes on the quantity of generated ideas

Stimulation mode	Regression coefficient for Group	p-value for the regressor Group
Six Path Framework	5.83	0.001**
iDea	11.29	0.002**

The outcomes highlight that the work in teams is effective for both the ideation means on single creative sessions in terms of the number of generated ideas. The organization of groups allows to increment the average number of generated ideas especially when working with iDea. Supposedly, this does not seem to be related to the complexity of the instrument, as the idea generation flow is considerable also in individual tasks. Nevertheless, the positive effect of workgroups is even more remarkable in sessions guided by the SPF, as the p-value is minor for this kind of stimulation mode.
In order to get a complete outlook of the full spectrum of ideation ways included in the testing campaign, Table 4 uses regressors that combine the stimulation mode and the work performed by individuals or groups. The combination of the SPF and individual tasks has been chosen as a baseline for the statistical model; in other words, the regression coefficients that follow indicate the expected increase of generated ideas when applying different conditions.

Table 4. Influence of the different testing conditions on the number of generated ideas: increase of quantity with respect to individual tasks exploiting the Six Path Framework

Working condition	Regression coefficient	p-value
Six Path Framework - groups	5.83	0.025*
iDea - individuals	15.71	0.000***
iDea - groups	27.00	0.000***

Also from this prospect, we can deduce the positive role of groups, but it emerges how providing a rich collection of stimuli boosts the capability of identifying new product attributes to a greater extent.

4.3 Insights into nominal groups

The literature argues about the effectiveness of brainstorming sessions for the scope of generating ideas and solutions. Many authors claim that individuals working alone outperform groups constituted by the same number of people. Several sources indicate with the term "nominal groups" samples of individuals that perform brainstorming activities in parallel without exchanging ideas and information.
The same kind of study can be performed for what concerns the present investigation, as nominal groups can be simulated by any samples of students that have participated to tests as individuals. However, the quantity of produced ideas cannot be computed by trivially summing up the numbers of new product attributes emerging by each individual test. Indeed, it can happen that identical potential benefits have been individuated by more testers. Thus, the real quantity of ideas emerging by nominal groups should take into account redundancies, to be subtracted from the total number of new product attributes.
In order to obtain data about the performance of nominal groups, the authors have carried out the following steps:

- one of the two topics has been chosen as a reference to conduct the study of redundancies (cameras);
- individual tests treating the above topic have been split into those using the SPF and the ones exploiting iDea;
- for both the stimulation modes, the ideas generated by each individual have been compared and redundancies have been pointed out, by individuating akin benefits reported by more individuals;
- all possible permutations among students (2 and 3 people) have been performed, by determining the number of generated ideas for each permutation;
- average numbers of generated ideas have been calculated for each stimulation mode and for each size of the nominal groups (duos or trios).

The above procedure allows to compare the results of nominal groups and the outcomes emerging from real Brainstorming groups, which have been already exploited for the considerations reported in Subsection 4.2.
Table 5 illustrates the redundancy scores for each kind of treatment. The reported percentages stand for the fraction of ideas that should be omitted from the hypothetic sum of product attributes generated by the individuals participating in nominal groups. In other words, if the sum of ideas of each individual is 100 and the redundancy score is 10%, the average number of not overlapping ideas is 90.

Table 5. Redundancy for stimulation modes and size of nominal groups (duos or trios)

Stimulation mode	Size of the Nominal group	Redundancy score
Six Path Framework	2	2,2%
Six Path Framework	3	4,5%
iDea	2	6,6%
iDea	3	12,2%

The presented indexes, besides being useful to compare nominal and real groups, allow to infer whether the stimulation means tend to guide testers towards similar or various ideas. Not surprisingly, greater redundancy scores refer to iDea, which has been chosen as a reference for a set of punctual indications of value aspects to be taken into account. Table 6 reports the mean values of ideas' quantity for nominal and real Brainstorming groups. Especially for what concerns ideation driven by iDea, grouping the outcomes produced by individuals gives rise to a bigger quantity of produced concepts.

Table 6. Performance of nominal and real groups, in terms of identifying new benefits for a digital camera

Stimulation mode	Size of the group	Mean number of ideas for real groups	Mean number of ideas for nominal groups
Six Path Framework	2	6	7.8
Six Path Framework	3	11	11.4
iDea	2	23	38.5
iDea	3	34.2	54.3

5. Discussions and conclusions

The present paper has illustrated a multi-stage experiment to gain knowledge about individuals' and groups' capability of performing effective ideation sessions when submitted to specific stimuli in Product Planning. Previous literature contributions have stressed the differences between group Brainstorming and individual generation activities, without specific indications about the phase of New Product Development cycles for which creative efforts were paid. In this sense, the original contribution of the manuscript consists in verifying the suitability of findings for the generation of new product benefits that are capable of guiding the development of original products. A further contribution is the comparison between stimulation modes. On the one hand, the Six Path Framework, which represents the generative tool within Blue Ocean Strategy, has been chosen as a reference for collections of "loose" stimuli and indications of trends that intersect multiple industries. On the other hand, a recently developed system has been employed within the experiment that attempts to investigate all the possible product development directions by providing a very large number of hints. This framework was already evaluated as particularly well-performing in terms of increasing the quantity of generated ideas with respect to vague stimuli or unsupported Brainstorming sessions [Bacciotti et al. 2016].

5.1 Summary of findings

According to the results illustrated in Section 4, the following conclusions can be drawn with regard to the number of generated ideas in the Product Planning:

- engineering students, regardless of their working procedure as individuals or groups, carry out more effective creative sessions if guided by rich samples of stimuli, which they use to make analogies;

- the organization of groups favours the generation of ideas if we compare identical time intervals to perform the creative sessions; this statement is valid for both "loose" and very focused stimuli;
- the kind of stimulation mode that is exploited to derive analogies results as the most relevant administering condition in terms of increasing the number of generated ideas;
- when exploiting large collections of stimuli, the work in groups does not hinder the flow of ideas between participants, but, at the same time, does not allow to outperform nominal groups, despite the presence of not negligible redundancies; the same statement cannot be made for less focused stimuli, as the differences between Brainstorming and nominal groups are not particularly relevant;
- despite allowing a good exploration of product development opportunities, the employed procedure with large sets of stimuli shows limitations in terms of its utility with nominal groups, as the generated ideas of more participants overlap considerably; this can be thought as a side effect of a stimulation system that tends to provide precise definitions of new benefits and leverages designers' creativity and imagination to a smaller extent.

5.2 Limitations and future work

The main limitations of this study refer to the specific stimulation alternatives that have been chosen as a reference. Different results could be obtained by exploiting dissimilar procedures to support analogical thinking. The presented experiment has made use of extremely different techniques: the former illustrates vague and business-oriented directions, while the latter allows to turn abstract definitions of benefits into new product attributes that are appropriate for a specific artefact. Further stimulation tools should be tested in order to verify whether the increasing volume and formalization of stimuli linearly corresponds to growing numbers of generated ideas.
A further limitation is represented by the set of testers. The authors cannot conclude with certainty if the results observed with Engineering students apply also to engineers, designers and industrial R&D teams. Indeed, also recent studies point out how the experience of individuals and the kind of expertise heavily affect the choice of the preferred instruments to provide inspiration during design activities [Gonçalves et al. 2014]. In addition, we can remark that all the students constituting the groups were entrusted of the same role within the creative sessions and no moderator or facilitator participated. This condition is deemed particularly relevant in Brainstorming sessions [Isaksen and Gaulin 2005], but this kind of treatment could not be applied. The number of tests carried out by individuals is largely greater than the quantity of experiments performed by groups; however, despite of the latter, the statistical functions provide clear indications, if the very low p-values are considered.
For what concerns the topics of the investigation, it was in the authors' intention to propose products to be investigated that were supposed to play a limited role in the display of new ideas. This measure was effective (see Table 2) and the study could concentrate on other factors, such as groups and stimulation modes. However, this condition could not be met in industrial settings and different ideation conditions could result more suitable than those judged as the most productive in the present study, i.e. focused stimuli and nominal groups. Moreover, it is worth noting that the present study limited its scope to ideation volume, which is the most popular performance index of Brainstorming techniques. Other factors such as variety, novelty and quality of ideas should be appropriately tested, as they form the reference parameters for creative activities within engineering design. In this sense, it is considered particularly relevant to investigate whether groups are capable of outperforming individuals in terms of producing ideas that are potentially beneficial for the sake of developing successful products. The full spectrum of results produced within the testing campaign could be exploited to the purpose, although subjective evaluations are required in this sense. The discussed issues represent the core of future authors' activities. A further kind of test is deemed relevant in order to overcome focused stimuli's limitations in terms of redundancy. As three-hours sessions resulted insufficient to complete the investigation of the stimuli proposed by iDea, nominal groups could be organized differently, by entrusting individuals to work only on specific subsets of stimuli.

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