INFORMATION EXTRACTED FROM PATENTS AS CREATIVE STIMULI FOR PRODUCT INNOVATION

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Abstract

This paper investigates the impact of information extracted from patents on the creative performance of R&D engineers involved in new product design tasks. The creative stimuli originated by domain specific patent sources are proposed in the form of problem-solutions maps possibly enriched with TRIZ contradiction models related to the challenges addressed by the patents. The effectiveness of this kind of creative stimuli has been checked with a two-phase experiment that involved 56 professional engineers as testers subdivided into design teams of 2 people each. The teams were initially asked to brainstorm and generate innovative ideas in the field of devices for walking support (walkers). The 28 teams were, then, exposed to 4 different treatments (7 teams each): simple brainstorming as control group, problem-solution maps with and without related TRIZ contradiction models, patent-text used as far-field sources of analogy. The results of the experiment show that the problem-solution maps alone enhance variety of generated solutions, while enriched by the TRIZ contradiction models have a higher impact on novelty despite with a smaller variety.

Keywords: Creativity, Early design phases, Conceptual design, Patents, TRIZ

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1   INTRODUCTION

Making analogies is a natural cognitive mechanism that involves mental association of ideas, which differ from each other by one or more of its characteristics. Sources of inspiration that generate meaningful analogies are crucial for the effectiveness of design tools that aim at improving the generativity during the idea generation process. Therefore, their effectiveness in design is a relevant topic studied from different angles. The effect of analogical distance on design outcomes is still controversial, as some experiments recorded a positive relationship between the source-target domains distance and the novelty of generated ideas (Chan et al., 2011). However, a recent study from the same authors questioned the advantages of distant analogy as it presents opposite results (Chan et al., 2015). The nature/domain of sources is also among the studied traits of creative stimuli. Technology models and diagrams, trends in technology (e.g. TRIZ trends), single words, pictures and text, biological solutions, patents, patent drawings… this variety of creative stimuli also witnesses that the way to deliver them and, among the others, their representation can be different: textual, graphical or mixed. The exposition to mixed contents allows mitigating the fixation effects due to the provided graphical stimulus and reduces the need of interpretation of purely textual ones (Gonçalves et al., 2016).

R&D engineers in the industrial context still scarcely adopt these design support tools in real operational environment, except for some companies, while creativity stimulation is more typically addressed through a more inspiring working environment or with incentives enhancing the motivation of employees. The barriers preventing a larger adoption of creative design supporting tools can be searched both in the abovementioned controversial evidence, as well as in potential communication barriers that complicate the interpretation of the stimuli.

Among the creative stimuli proposed in literature, patents represent a suitable option for R&D engineers, since they are supposed to be acquainted with this kind of documents, and they are not expected to be as sceptic as for other documents of non-technical origin. Patents as stimuli, even if recalled from the same domain, can be meaningful for these target users since also incremental innovations might allow the exploitation of a fruitful business for the patenting subjects.

According to these premises, this research aims at providing further experimental evidence about the effect of patents as stimuli in idea generation processes, as the result of recent studies shows their effectiveness for such purpose. The target group used for the experiment is a set of expected users of the patent-based stimuli in real operational environment.

The following section presents the background of the study discussing what, of the patent content, can be used as a source of inspiration and what might be relevant especially during the earliest phase of a design activity. Such discussion helps to refine sharper research questions. Section 3 presents an original map to be used as a design tool for creative stimulation, which describes technical problems addressed by patents as TRIZ technical contradictions models. Then, it describes the methodological approach proposed to answer the research questions, based on the comparison of the design performance of 3 patent-based design tools against brainstorming (as quantity, novelty, and variety of the generated ideas). The results are presented and discussed before the concluding section.

2   BACKGROUND

As mentioned in the introduction, recent studies have demonstrated that patents can serve as sources of inspiration in ideational processes (e.g. Fu et al., 2015). A patent describes an inventive solution and aims at protecting the intellectual property behind it. To be patentable, a solution has to be novel, useful and should demonstrate an inventive step. Large patent sets require a long time to process and extract information, and this especially affects unstructured information, which usually contains technical knowledge. To reduce the effort for reading patents textual content, several text mining approaches have been proposed (e.g. NLP and neural networks, semantic processing…) for extracting relevant elements of knowledge. Their description is out of the scope of this paper. Whatever the approach is, the extracted information (and, in case, their relationship) requires a map to describe this knowledge explicitly. There exist several alternatives for knowledge mapping. Word clouds and mind/conceptual maps (e.g. Reymond and Quoniam, 2016) are two different examples of knowledge representation. Word clouds summarize the extracted contents consistently with word frequency. In a cloud of words, recurring words takes bigger size and vice versa, the words appearing just rarely are not shown. Mind and conceptual maps combine textual and graphical content and their structure of nodes and links allows for a versatile

use. Nodes and links can describe almost everything, depending on the meaning and the degree of differentiation one assigns to these items. Among technically relevant conceptual maps, functional models and citation maps are of particular interest to map knowledge from patents. Citation maps, which use structured data, allow to link patents (nodes) using forward and backward citation (links) in order to show, for instance, milestone patents in technology evolution (Madani and Weber, 2016). Functional models, on the contrary, provide information extracted from the textual corpus. These models describe the essential components of inventions (nodes) and the functions they carry out in order to solve the problem (links) (i.e. Cascini et al., 2004). This representation, however, does not allow to clearly describe technical problems, as the model just presents a graphical description of what are the functional relationships between components to make the invention working.

Matrix maps (Suzuki, 2011) present patent characteristics on a XY set of orthogonal axes, which can describe a versatile set of concepts, as for conceptual maps. For patent mapping, structured data is commonly used to show the analysis of competition by comparing patent classifications, assignees, priority years, etc. In a problem-solution map, the X-axis shows clusters of problems addressed by a patent set and the Y-axis the corresponding solution strategies. The radius of bubbles at XY crosses corresponds to the number of patents that address the cluster of problems X with the strategy of solution Y (Figure 1). Its construction is a time-consuming activity, as text mining approaches are (still?) not capable of identifying and clustering problems and solutions. However, these two concepts appear to be critical during idea generation in conceptual design, which is the one where patentable solutions should appear. Keeping problems as stimuli is consistent from the cognitive perspective, as a designer periodically shifts between the problem and the solution space (Dorst and Cross, 2004)
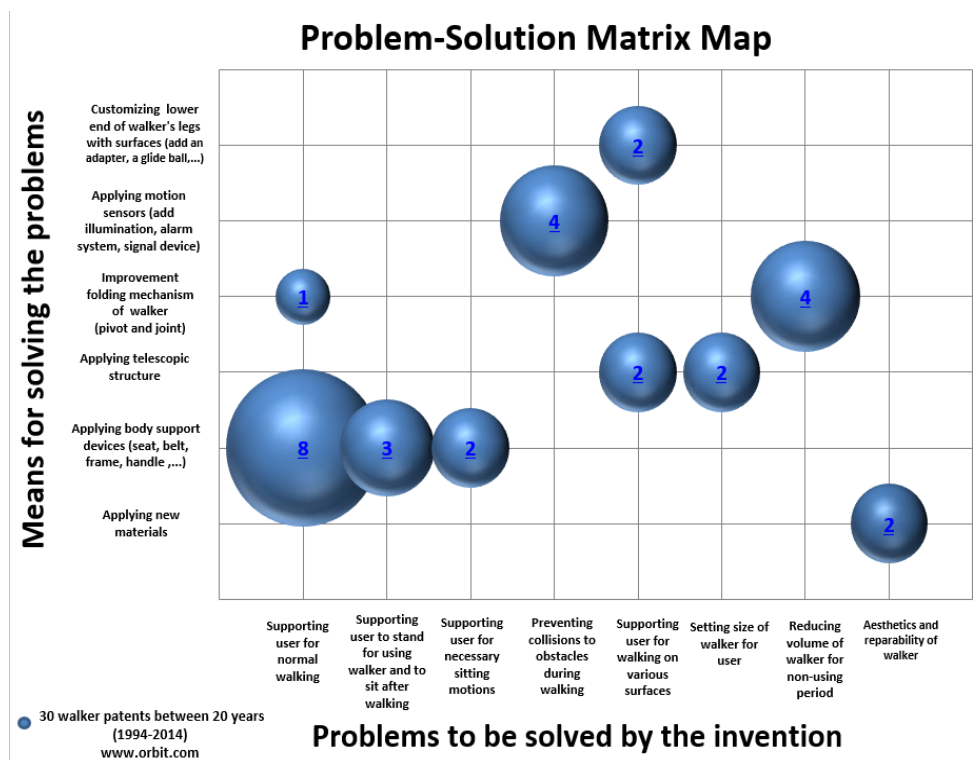

Figure 1. A patent map showing problem, solutions and patent frequency

Problem-Solution patent maps can be used as a design inspiration tool since they easily light up neglected directions of development, thus enlarging the exploration of the design space. On the other hand, it can also create initial constraints in the exploration of the design space, because the listed problems and solutions trigger a fixation effect, which reflects on the boundaries considered for the generation of ideas.

However, this kind of patent map appears to be poorly figurative, thus also less effective in creative stimulation (Gonçalves et al., 2016). On the other hand, it might just represent elements whose textual description remain far from the technical side of the implementation of solutions, thus creating a potential barrier before the interpretation of its content.

The next section presents an original patent map working as a source of creative inspiration to be used in combination with the above patent map of problems and solution strategies. The objective of this design tool is to provide R&D engineers with information inputs that are expected to stimulate the generation of more potentially patentable solutions.

Then, this research aims at answering the following research questions:

- Does the representation of patents content affect ideation performance of R&D engineers?
- Does patent-based stimuli, characterized by diverse content representations, differently affect the ideation performance of R&D engineers?

3   A CONTRADICTION MAP BASED ON PATENT CONTENTS

Consistently with the above-stated research question, the development of a patent-based content map, aims at enriching the description of problems and solutions with more informational representations. The assumption behind the research is that different patent-based contents can improve idea generation in different ways, as our cognition interprets and associates information using different schemes depending on the media (Gonçalves et al., 2016). The combined use of a problems/solutions patent map with other information extracted from patents allows exploring the effect on creativity in idea generation of different modalities of stimulation, from the perspective of the provided content nature and representation.

The development of the map requires exploring models that are suitable to enrich the description of problems and solutions with meaningful and relevant design content. The TRIZ contradiction model (Becattini and Cascini, 2013), among the evaluated alternatives (fishbone diagrams, fault-tree diagrams, IBIS notation) showed a marked difference from the others, as it focuses on problems and solution using design parameters, corresponding respectively to design variables (what the designer can change) and design requirements (targets to be achieved, problems to be satisfied). This is considered as a positive factor for the interpretation of problems from the familiar design-based perspective of R&D departments.

The TRIZ contradiction model leverages the cause-and-effect relationship between design variables and requirements. It represents problems in terms of two statements describing two opposite design conditions. Condition 1: the design variable of element X should assume value1 in order to satisfy the requirement A of Element Y, but this makes the requirement B of Element Z not satisfied anymore. Condition 2: the design variable of element X should assume value2 (logically opposite to value1) in order to satisfy the requirement B of Element Z, but this makes the requirement A of Element Y not satisfied anymore. Each of the two sentences highlights a direction to solve a problem that triggers a new problem. These two problems and the related solutions, playing on the value of the same design variable, characterize a design conflict, as depicted in Figure 2.
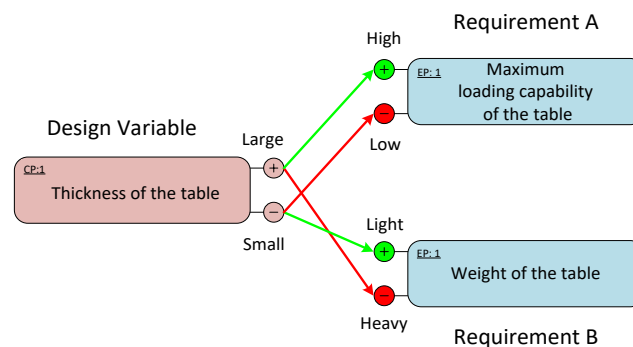

Figure 2. An example of design conflict through the TRIZ contradiction model

Consequently, it was decided to extract contradictions from patents, as a means to enrich the information provided by problem-solution maps. The following 3-step procedure can be used to build a map of contradictions from patents, also linked to a map of problems and solutions.

The first step (preparation of the patent corpus) has two main stages: 1) patents retrieval (through queries with relevant keywords and CPC classes); 2) classification and selection of patents (through time clustering and the elimination of redundancies by similarity).

The second step (extraction of problems, solutions, and related design parameters) has four main stages: 1) definition of the problem solved by the invention; 2) identification of the solution strategy of the invention; 3) identification of the other problem that, before the invention, required the solution to be solved by a design trade-off; 4) identification of requirements (from problems) and design variables (from solution strategies) and formalization of cause-and-effect links.

The third step (building the map has two main stages: 1) clustering of the contents extracted from patents (in order to create maps capable to stimulate creativity without overloading cognition); 2) creation of the diagrams (definition of links between problem and solution with the number of related patents for the patent map and models of design conflicts for the contradiction map). As Figure 1 is a patent map of problems and solutions, Figure 3 is a TRIZ contradiction map consistent with the above concept and procedure.
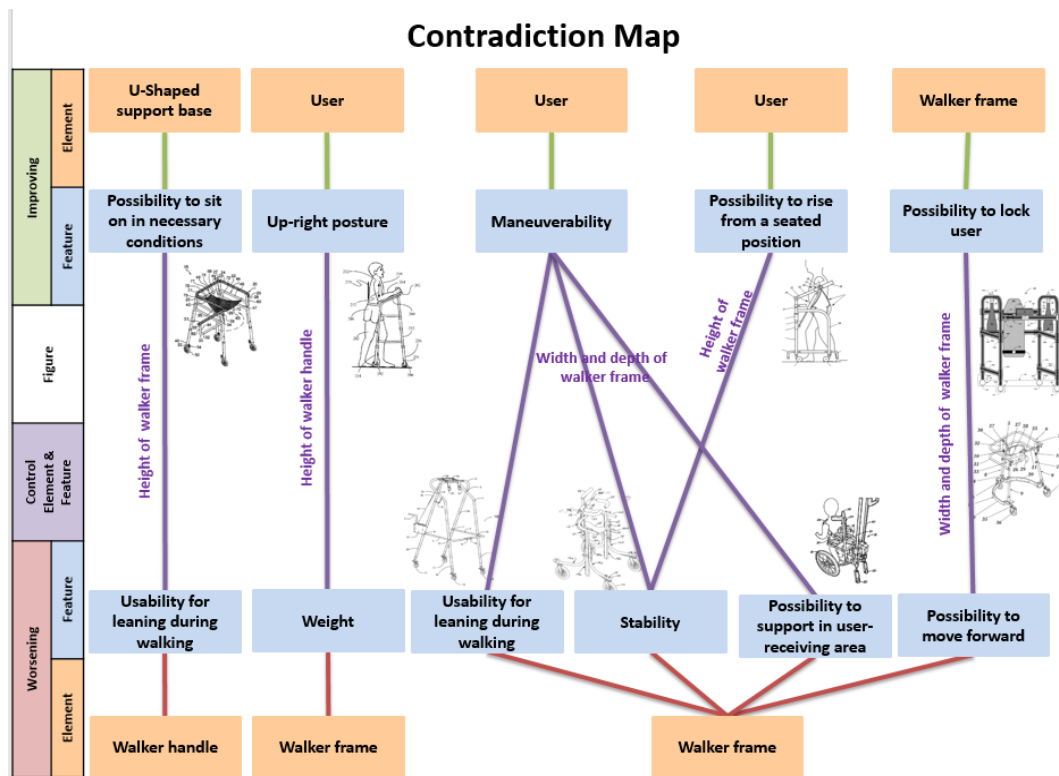

Figure 3. A map of TRIZ contradiction models from patent-based content

This map will be used in the experimental activity to evaluate the effect of different ways of presenting patent content as creative stimuli on the outcomes of the design process.

4 EXPERIMENT AND RESULTS EVALUATION PLANNING

To study the effect of different patent content representation as creative stimulation in ideation processes, the investigation requires comparing the outcomes of alternative approaches using patents. Since analogies have witnessed to be effective for increasing the novelty and the quantity of ideas (Chan et al., 2011), and patents as sources of analogies demonstrated effectiveness in idea generation (Fu et al, 2015), their simplest representation (Patent Full-Text - PT) has been chosen as one of the stimuli for the comparison of treatments. Besides, the Problem-Solution Matrix (PS) Map has been selected as the second patent-based approach to stimulate ideation. It represents the basis to develop the TRIZ Contradiction (TC) map, thus the results obtained through this approach help highlighting differences when used together with the TC map. This experiment focuses only on the differences emerging when presenting the same information in different forms as it overlooks the impact of the patents retrieval step. To gather evidence about the benefits each of the information approaches possibly provide, a control group that freely brainstorms with no external information support is also necessary. Therefore, 4 different treatments were adopted for this experiment: Brainstorming (Control Group - BS Group); the TRIZ Contradiction map (PS+TC group); the Problem-Solution Matrix Map (PS group), and Patent Full-Text (PT group). The last three sets of stimuli were built out of the same patent corpus.

Fifty-six (56) R&D engineers (45 M; 11 F), with an average working experience of 9,2 years (Std. deviation 1.5) and different backgrounds (mechanical/industrial, chemical, electronics, computer science…), were involved and randomly subdivided into 4 groups, one per each of the abovementioned treatments. Further, the 14 people in each group were randomly organized into 7 teams of 2 engineers each. This enables gathering a sufficient amount of experimental data for each treatment (7 data points) and have real-like design conditions for the team (2 people sharing and generating ideas on the design task).

The experiment was organized into two rounds. During the first round (duration 30 minutes), the 28 teams of R&D engineers were free to brainstorm without any methodological tool and asked to generate inventive ideas they consider worth of patenting. The duration of 30 minutes is consistent with the findings of Howard et al. (2010) on the saturation of generativity. After a break of 15 minutes, the second round (30 minutes) started and the 4 groups received a different treatment each. PS group received Fig. 1, PS + TC group received Fig. 1 and a map as the one in Figure 3 for each of the PS map's XY intersections; PT group received 5 randomly selected patents and BS Group did not receive anything. The 7 teams composing each group were, then, asked to get inspired from the received stimuli, if any, and generate further ideas they considered worth of patenting.

To avoid biases due to misinterpretations, the design task regarded the generation of inventive ideas for a walker (or walking frame), a device for disabled or elderly people who need additional support to maintain balance or stability while walking. Its intrinsic simplicity released the testers from having specific competencies to understand its current functions and related working principles.

Quantity, Novelty, and Variety are the metrics used for results assessment as they proved to be effective for ideation processes (Shah et al., 2003). Every team contributed with its score for the above three metrics. Each of these entries is a data point for the related population, corresponding to a specific treatment. Quantity measures idea by counting different ideas one-by-one. The measure of quantity accounts for the concept that the chances of finding a good idea in a large set of ideas are higher, larger the set is. The above statement might be questionable and, for large sets of ideas, the evaluation process can be so time-consuming to pulverize the benefits of a fast and fluent idea generation process. With industrially manageable set of ideas (tenths), quantity becomes a relevant index, as also the generation of solution concepts helps focusing on requirements (identification or redefinition) (Cascini et al, 2013). Novelty also represents one of the requirements for an invention to be patentable. Thus, it is relevant to the purpose of generating ideas that were worth, at least to the eyes of the inventor, of patenting. These categories, determined with an ex-post approach for weighting attributes, characterized the attributes to evaluate the novelty of ideas, weights in brackets: User balance (0,25); Walker balance (0,25); Storage & Transport (0,15); User support in non-ergonomic conditions (0,15); Support routine activities (0,1); Propulsion (0,1). An a-posteriori approach also determines S coefficients.

Variety measures how broadly the engineers explored the alternatives in the design space. Tools showing effective results on variety can provide better support in inventing activities, where it is necessary to generate an umbrella of patent around a technological solution. S coefficients for variety got evaluated by functions and further classified into Physical principle, Working Principles, Embodiment, Detail (respectively scoring S=10, 6, 3, 1). The following functions are considered, weights in brackets: Support user to Transport (0,1); Support walking in any surfaces (0,2); Support user to sit and stand (0,1); Support normal walking (0,2); Prevent user collision & falling (0,2); Ergonomics balance (0,1); Accessories holder (0,05); Information support (0,05).

The detail level of the described ideas did not always allow for the evaluation of Quality of the ideas, and therefore this investigation does not consider it, due to the extreme uncertainties the interpretation of ideas might bring.

Mean values and standard deviations described the population corresponding to each treatment, according to Quantity, Novelty and Variety. T-tests for two samples (on the mean values) check statistically significant differences through Group-X vs. Group-Y comparisons.

To make the test effective and free from the influences of group compositions, the first round had to verify that the random procedure for building groups was effective (substantial homogeneity between groups). If groups are homogenous, the second round, after the administration of the four treatments, aimed at checking the differences in design performance between different patent-based stimuli. Table 1 summarizes H0 and Ha and the expected results for each round.

If the results of the second round show significant differences between the different treatments, the descriptive statistics of the four groups allows mean values to help answer the research question.

Table 1. Summary of the hypotheses tests

Null-hypothesis	Alternative Hypothesis	Round	Differences in creative stimulation	Target p-value
The mean for metrics Z of group X IS the same of Group Y	The mean for metrics Z of group X IS NOT the same of Group Y	1	No (Brainstorming)	p >> 0,05
		2	Yes (Brainstorming + 3 patent-based sources of inspiration)	p < 0,05

5   RESULTS

Table 2 shows the results of the idea generation accomplished by the 56 participants to the experiment.

Table 2. Results of the test by team and group (rows) and round and metrics (in columns)

	Team Id	1st round			2nd round		
		Quantity	Novelty	Variety	Quantity	Novelty	Variety
PS Group	A_1	16	13	68	7	5	70
	A_2	8	6	29	4	4	80
	A_3	12	9	28	5	4	50
	A_4	17	13	60	5	5	43
	A_5	7	6	61	4	3	41
	A_6	22	18	77	11	10	67
	A_7	6	6	51	3	3	60
	Mean	**12,57**	**10,14**	**53,43**	**5,57**	**4,86**	**58,71**
	StDev	**6,00**	**4,67**	**18,79**	**2,70**	**2,41**	**14,65**
PS + TC Group	B_1	10	7	65	8	8,7	34
	B_2	17	14	49	11	12,1	58
	B_3	11	9	67	4	3	80
	B_4	17	16	55	10	7,9	46
	B_5	5	5	26	5	6,1	51
	B_6	9	6	35	7	6,2	68
	B_7	19	17	49	9	8,2	28
	Mean	**12,57**	**10,57**	**49,43**	**7,71**	**7,46**	**52,14**
	StDev	**5,16**	**5,00**	**14,94**	**2,56**	**2,80**	**18,32**
PT Group	C_1	10	8,3	49,3	3	2	30,5
	C_2	10	9,5	49	8	6,4	70,5
	C_3	10	8,6	39,3	2	2,1	40
	C_4	18	13,4	35,3	6	4,5	34
	C_5	5	4,6	31	4	3,3	31,5
	C_6	15	13,5	56,5	6	8	21,3
	C_7	11	8,9	42,3	5	7,5	50,5
	Mean	**11,29**	**9,54**	**43,24**	**4,86**	**4,83**	**39,76**
	StDev	**4,15**	**3,10**	**8,90**	**2,04**	**2,50**	**16,27**
BS Group	D_1	5	3,4	21	4	4,1	40,5
	D_2	17	13,7	49	3	2,4	30
	D_3	8	7,4	47,3	3	2,8	30,5
	D_4	12	10	64	3	4	60
	D_5	10	8,1	61,3	4	3,4	40,5
	D_6	16	14,5	59,8	3	2,1	30,5
	D_7	12	9,3	62	2	2	10,5
	Mean	**11,43**	**9,49**	**52,06**	**3,14**	**2,97**	**34,64**
	StDev	**4,24**	**3,80**	**15,18**	**0,69**	**0,87**	**15,00**

5.1 Analysis of the results after the first round

Teams working without any ideation tool and left free to brainstorm generated approximately 12 ideas each, after the first round. The mean values for quantity span just a gap of 1,28. A similar behaviour characterizes the novelty of ideas between groups: the mean is approximately 10, and it covers an interval of 1,08. Variety mean values say that the teams explored the design space a little less homogenously: the mean is approximately 50, but the difference between the max and the min is 10,19. The test of hypotheses for round one aims at checking the homogenous composition of groups. The distributions of these results show that, for what concerns the quantity of ideas, they are sufficiently homogenous (p-value max=1 for PS vs TC; p-value min=0,62 for TC vs PT). The p-values for the novelty of ideas also support the hypothesis of random composition (p-value max=0,98 for PT vs BS; p-value min=0,65 for TC vs BS). Homogeneity for the variety of ideas is satisfactory, however, questionable for the following comparisons: PT vs BS (p=0,22), PT vs PS (p=0,23); TC vs PT (p=0,37).

5.2 Analysis of the results after the second round

To verify differences and identifying best candidates for patent-based design tools to improve ideation effectiveness, the results of the second round (Table 2, right part) provide numerical results to verify if such differences are also statistically significant. As differences are expected to be marked and groups should behave differently, H0 has to be rejected (implicitly verifying Ha) with p-values higher than 0,05. Table 3 collects p-values for cross-comparisons between groups.

Table 3. P-values for the three metrics along group vs. group comparisons (PS = Problem-Solution patent map, TC = TRIZ Contradiction map, PT=Patent Full-Text, BS=Brainstorming)

		PS Group			PS + TC Group			PT Group			BS Group		
		Qty	Nov	Var	Qty	Nov	Var	Qty	Nov	Var	Qty	Nov	Var
PS	Quantity				0,16			0,59			0,06		
	Novelty					0,09			0,98			0,09	
	Variety						0,47			0,04			0,01
PS + TC	Quantity	0,16						0,04			0,004		
	Novelty		0,09						0,09			0,005	
	Variety			0,47						0,21			0,08
PT	Quantity	0,59			0,04						0,07		
	Novelty		0,98			0,09						0,11	
	Variety			0,04			0,21						0,55
BS	Quantity	0,06			0,004			0,07					
	Novelty		0,09			0,005			0,11				
	Variety			0,01			0,08			0,55			

For what concerns the quantity of ideas, these results show that the patent-based creative stimulation is effective. All the tools (Patent Map per se, Patent Map and Contradiction Map, Patents' Full-Text), if compared against idea generation through brainstorming, trigger significantly different results. Considering the mean values for quantity (approximately 3), BS group members demonstrated they had almost completely exhausted their capability to generate new concepts (ideas they considered worth of patenting) after the first round.

Considering the treatments, the performance of R&D engineers using the patent maps (either PS map alone, or PS and TC maps together) are significantly different from the ones of PT group, which got inspiration from the Full-Text of five randomly proposed patents (p=0,04), and BS group that brainstormed without any specific design tool (p=0,004).

The mean value for quantity is close to 8 if the PS and the TC maps are used in combination, which is more than 2 units higher than its best competitor (PS map per se), around 3 and 4,5 with respect to patents full-text and free brainstorming. These gaps and the results of hypothesis testing display that the PS and the TC maps are more effective than the other proposed approaches. Despite a quite large

difference between the two means of PS and PS + TC, the dispersion of data in each population is similar in extension, and approximately in between 1/3 of 1/2 of the average values, which results in a partial overlapping of the two distributions. Therefore, the comparison PS+TC against PS still presents a low p-value that is not sufficient to consider the results as statistically different.

The results of the patent-based ideation tools against brainstorming, for what concerns the novelty of ideas, behave a little differently from what was discussed above and it is not always possible to state that the difference between treatments is statistically significant. The combined use of the PS map with the TC map is the only treatment showing that groups are mutually different (p=0,005). The p-values for the comparison of BS with PS and PT are, respectively, 0,093 and 0,106. These relatively small values suggest a potential effect that deserves further investigation with tests on a larger scale. A similar situation occurs comparing the results of PS+TC with the outcomes of PS and PT. Both the comparison PS vs PS+TC and PS+TC vs PT have p-values around a small interval close to 0,1.

The mean values for novelty (Table 2) for each group show a similar behaviour to what highlighted for the quantity of ideas. The introduction of the PS+TC maps as a source of creative stimulation yields a mean novelty value for the generated ideas of 7,46. It is 2,5 units higher than the related mean values for the PS and the PT, 3,5 units higher than BS. Except for the comparison with brainstorming, in the other two cases, the quite large dispersion of results does not allow to substantiate this evidence provided by mean values with statistical significance. This suggests the need for repeating the test with a larger number of participants, in order to confirm or deny the results of this test.

For both the metrics of quantity and novelty, the results of BS did not differ from those of PT.

Still, with reference to Table 3, the variety of ideas shows contradictory results concerning what discussed above. The only two meaningful statistical differences between groups concern PS with PT (p=0,043) and BS (p=0,011). The p values are higher than 0,05 in the other two comparisons between design tools and brainstorming. However, the comparison against the combined use of maps gets a p-value of 0,076 that is close to the chosen level of significance. The mean value of variety for PS+TC is 52,14, and it is not anymore the highest against its competitors, as the mean for PS is 58,71.Yet, it is still 17,5 units higher than the mean novelty of BS (34,64). Considering the mean values, PS has also produced the highest variety of ideas with meaningful statistical differences against PT and BS, showing that PS has an effect on improving the exploration of the design space. On the other hand, the comparison between PS and PS+TC does not show that the two treatments differently support ideation. The two treatments differ only from the use of the TC map, which undoubtedly reflects in a higher effort (at least in terms of time) for the interpretation of two maps instead of one. From this perspective, it would be interesting to investigate whether these discrepancies between the treatments depend on time, on cognitive load or chance. This can also trigger the opportunity to organize the combined use of the design tool in sequence rather than in parallel.

6   CONCLUSIONS

The paper presents a research that aims at testing the effectiveness of design tools characterized by different representations for patent-based contents in idea generation processes. The results of this research should support R&D engineers, which need to generate patentable ideas, in the selection of appropriate design tools to improve their design performance as quantity, quality, and variety of generated ideas. An experiment involving 56 R&D engineers checked the effectiveness of three different patent-based tools (Patent map with problems and solution strategies; the patent map in combination with an originally developed TRIZ contradiction map; 5 full-text patents) against simple brainstorming and themselves. The results measured for quantity, novelty, and variety of ideas substantiate the following conclusions:

- Patent-based design tools trigger better performances than brainstorming;
- there is no statistically significant difference between the use of the patent map per se and with the contradiction map for none of the three metrics, despite the results suggest potential advantages regarding enhanced novelty;
- the combined use of the problem-solution and contradiction maps increases, with statistical significance, the quantity of ideas, compared to full-text patent stimuli and simple brainstorming;
- the combined use of the problem-solution patent map and contradiction map increases, with statistical significance, the novelty of ideas, compared to simple brainstorming;

- the use of the problem-solution patent map per se increases, with statistical significance, the variety of ideas, compared to full-text stimuli and simple brainstorming.

With reference to the research questions mentioned at the end of Section 2, the above-listed outcomes support the following conclusions.

The representation of patent content leveraging different channels, meanings, and detail level affects the idea generation process since different representations of patent content used as creative stimuli generated statistically different results for quantity, novelty and variety. Patent maps (with or without contradictions) performed better than patents' full-text for mean quantity, variety and novelty but for novelty the results do not ensure this difference is statistically significant. This, however, means that a more various description of the design space, compared to the text of 5 randomly proposed patent, provides a sufficient amount of information to stimulate idea generation. As this is statistically significant also for quantity, the structured and dense set of information provided by pictorial diagrams as maps result in a more fluent and broad exploration of the design space.

The results analysed after the experiment suggest running a test on a larger scale to confirm or deny the results that remained partially uncertain because of the large dispersion of data for some groups. The proposed experimental setting and approach for data analysis allows the repeatability with further experiments that aims at comparing patent content representations to be used as creative stimuli. The set of these results also allows taking into account the differences occurring between the first and the second round, after the administration of the different treatments. Therefore, among the future research step on this topic, the authors aim at extending the investigation of patent-based design stimuli by two main directions. First, benchmarking design tools using different representations of knowledge, as for instance problem-solution maps that present the design rationale. Second, checking the effects of the design tools by comparing the results between the first creatively unsupported design round with the outcomes after a potential saturation of idea generation in rebooting generativity.

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