Title:
Does the Patent Classification Help Creativity in Generating New Product Applications? Some Preliminary Answers

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Introduction:
In the face of escalating climate change, the industrial sector finds itself at a critical turning point, bearing the responsibility and opportunity to guide the direction towards sustainability. Central to this shift is the adoption of the 3R strategy (reduce, reuse, and recycle) [5], which aims to not only reduce the environmental impact by efficiently managing waste and resources but also to supervise the entire lifespan of products. The reusing strategy is particularly remarkable since it presents a significant chance to preserve resources and reduce the need for raw materials, especially if it is considered from the beginning of the product design phase. Creativity plays a paramount role in this context, as it allows us to convert conventional ideas into innovative solutions.

The objective of the study is to explore the potential of Cooperative Patent Classification (CPC) as a source of creative inspiration. It investigates whether CPC descriptions can facilitate the discovery of new functions and application sectors for products with respect to their original intended uses. Additionally, the study aims to understand the extent to which CPC descriptors can influence the originality of the generated ideas. Despite the numerous contributions available in the literature that discuss different forms of stimuli as triggers for creativity [1-3], there are no specific studies aimed at verifying the use of textual definitions in patent classification as a stimulation means to find alternative applications for existing technologies/products. Therefore, the study described in this paper provides further knowledge on how to define Computer-Aided Design systems aimed at supporting design activities oriented towards the reuse of products in contexts different from the original one.

Research Approach:
The mentioned research questions were addressed through an experimental activity tailored to identify alternative application fields of a given product, specifically a mosquito net. First-year mechanical engineering master's students from the University of Florence (Italy) participated. They were split into two groups: a control group tasked with independent idea generation and a treated group provided with additional textual stimuli from CPC descriptions. In total, 37 participants took part, with a gender distribution of 2 girls and 35 males, randomly divided into Group A (18 participants: 17 male and 1 female) and Group B (19 participants: 18 male and 1 female). The chosen descriptors were the following:

- D06C: finishing, dressing, tentering, or stretching textile fabrics.

- A01G: horticulture; cultivation of vegetables, flowers, rice, fruit, vines, hops, or seaweed; forestry; watering (picking of fruits, vegetables, hops, or the like; propagating unicellular algae).
- B32B: layered products, i.e., products built up of strata of flat or non-flat, e.g., cellular or honeycomb form.

The selection of these classes was based on a prior study [6], where the method described in [3] was employed to identify novel application domains for a mosquito net. The participants were assigned the task of identifying the highest possible number of alternative application fields for the end-of-life phase of the product. An evaluation of the technical feasibility of the found solutions was not required to limit the idea-generation process. The individuals were asked to explain each concept with a brief textual description concisely and, if desired, by including rough illustrations, sketches, etc. Two examples of collected outcomes have been reported in Fig. 1(a). and Fig. 1(b). Individual participants' personal information was not recorded in accordance with the general regulations on ethics.

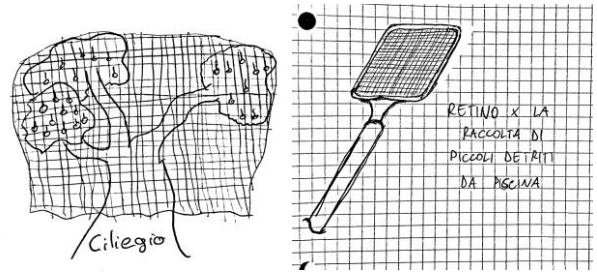

Fig. 1: Examples of generated alternative product applications for the fly screen. The outcomes are in the Italian language, and the translation is provided here: (a) cherry tree, (b) net for collecting small swimming pool debris.

Metrics Definition and Post-Processing:
Every idea obtained by the participants is classified and subsequently analyzed in terms of its functions and field of application. The functions align with the S-A-O definition proposed by [4]. A maximum of four functions has been assigned to each idea, while the field of application is always unique. The categorization of the application fields corresponds to that provided by the CPC subdivision. It's important to note that only the ideas meeting the following criteria were considered:

- It was possible to assign a single CPC without ambiguity (non-vagueness).
- The application field was distinct from the original one.

Consequently, the valid ideas obtained have been analyzed according to different metrics of quantity and originality, comparing the results of the control group with those of the treated group. The investigated parameters are the following:

1. Quantity of ideas per participant.
2. Quantity of different functions.
3. Quantity of alternative functions with respect to the ones pertaining to the original product application.
4. Quantity of different application fields, referring to them as the ones described by CPC.
5. Quantity of alternative application fields with respect to the ones provided as stimuli in the experiment.
6. Originality level of the ideas obtained, based on their frequency of appearance [2].

Hypotheses Formulation:
Consequently, the following null hypotheses have been formulated, which are subject to verification and potential rejection through statistical testing:

1. H01a: the average value of ideas generated by each participant is not dependent on whether textual stimuli are used in the ideation process.
2. H01b: the occurrence percentage of each function obtained out of the total occurrences of all functions is independent of whether textual stimuli are used in the ideation process. In other words, the number of functions and their distribution do not depend on the use of stimuli.
3. H01c: the cumulative occurrence percentage of alternative functions with respect to the ones related to the original field of application is not dependent on whether stimuli were or were not employed.
4. H01d: the occurrence percentage of each application field obtained out of the total occurrences of all application fields is independent of whether textual stimuli are used in the ideation process. In other words, the quantity of application fields and how they are distributed is not dependent on whether stimuli were employed or not.
5. H01e: the cumulative occurrence percentage of alternative application fields with respect to the ones provided as stimuli in the experiment is not dependent on whether stimuli were employed or not.
6. H01f: the originality of the ideas obtained is not dependent on whether the stimuli are used or not during the ideation process.

Ideas Generated by Participants:
After a first screening, the non-compliant ideas were discarded, arriving to the following final numbers:

- Control group (A): 57 valid ideas out of 57 (34 distinct valid ideas).
- Test group (B): 71 valid ideas out of 78 (36 distinct valid ideas).

The distribution of the quantities of ideas generated by the participants led to an average of 3.737 for the test group (S.D. = 2.621) and 2.621 for the control group (S.D. = 1.689). The p-value result from t-student statistical test is instead reported in Tab. 1.

Metric	*Hypothesis test*	*Type of test*	*p-value*
Quantity – ideas/participants	H01a	t-student	0.435

Tab. 1: Result of the t-student statistical test performed to verify H01a hypothesis.

As it can be observed, the p-value is far from the alpha threshold level commonly established at 0.05, indicating that there is no statistically significant difference between the number of ideas obtained by the participants with and without external stimuli.

Functions Results:
The total quantity of functions obtained by the two groups is as follows: the control group (A) achieved 141 functions, while the test group (B) achieved 168 functions. Trivial functions related to the original application field of the fly screens – coming from a previous decomposition of the staring product [6] – has been detected as well. They are the following: protect, block, filter, and separate.

Based on this criterion, the functions can be further divided and analyzed to determine whether textual stimuli can promote the discovery of new functions that were not present in the product's original intended use. The data in Tab. 2. are therefore obtained, while p-value results of the statistical tests performed are reported in Tab. 3. Despite the lower p-values with respect to the first metric introduced, only the H01c null hypothesis can be rejected.

	Test Group (B)	*Control Group (A)*
Trivial Functions	81	88
New Functions	87	53

Tab. 2: Total numbers of trivial and new functions generated by groups A and B.

Metric	*Hypothesis test*	*Type of test*	*p-value*
Quantity – functions	H01b	Chi-squared	0.105
Quantity – cumulative functions	H01c	Chi-squared	0.013

Tab. 3: Result of the Chi-squared statistical tests performed to verify H01b and H01c hypotheses.

Application Fields Results:
Concerning application fields, the control group (A) achieved 57, while the test group (B) reached 71. Notably, the categorization relies on the Cooperative Patent Classification system.

It's noteworthy that – as one could expect – some CPC codes found in the test group were also present among the provided stimuli. The cumulative results in Tab. 4. are grouped based on whether the CPCs were included in the stimuli or not. The statistical tests results are instead reported in Tab. 5. It can be concluded that the null hypotheses cannot be rejected. Therefore, the occurrence percentages of each application field are not influenced by the given textual stimuli.

	Test Group (B)	*Control Group (A)*
CPCs from stimuli	12	3
Other CPCs	59	54

Tab. 4: Total number of CPCs from stimuli and other CPCs generated by groups A and B.

Metric	*Hypothesis test*	*Type of test*	*p-value*
Quantity – application fields	H01d	Chi-squared	0.549
Quantity – cumulative application fields	H01e	Yates-corrected Chi-squared	0.0787

Tab. 5: Result of the statistical tests performed to verify H01d and H01e hypotheses.

Originality Results:
The originality metric was calculated using the previously known total and distinct numbers of valid ideas. Consequently, the occurrence frequency for each idea is the primary variable of interest for the third research question of this study. Test group achieved a mean score of 1.972 (S.D. = 1.594; skw = 2.198), while the control group a mean value of 1.677 (S.D. = 0.976; skw = 1.131) with regard to this parameter.

Within the scope of this analysis, it is observed that elevated mean values signify a higher incidence of recurring ideas. This recurrence suggests a diminished level of originality, as it indicates a tendency towards the repetition of similar concepts rather than the introduction of unique ones. The outcome of the statistical test is reported in Tab. 6.

Metric	*Hypothesis test*	*Type of test*	*p-value*
Originality	H01f	Mann-Whitney	0.670

Tab. 6: Result of the Mann-Whitney statistical test performed to verify H01f hypothesis.

This p-value is well above the conventional level of statistical significance. Therefore, the use of textual stimuli does not influence the originality of the ideas obtained, and the null hypothesis cannot be rejected.

Tab. 7. summarizes the above performed considerations in terms of answers to the considered research questions.

Research question	*Answer*
CPCs can aid in identifying alternative	Although CPCs appear effective in generating

functions for a product that diverge from their original ones.	alternative functions from the single product shown, further experiments are needed to lend greater validity to the results.
CPCs might facilitate the discovery of new application sectors for the same product.	The identification of new application fields is not statistically enhanced by the use of CPCs as textual stimuli.
CPCs enhance ideas' originality.	A posteriori originality level is not statistically influenced by the use of CPCs as textual stimuli.

Tab. 7: Summary of the responses identified for the three research questions of the study.

Conclusions:
In this study, a preliminary investigation has been performed about the impact of textual stimuli derived from Cooperative Patent Classifications (CPC) on identifying alternative application fields for the reuse of a specific product at the end of its life. The study aimed to assess the potential of CPC descriptions to enhance the creative process, focusing on three key aspects: the increase in the number and diversity of functions, the range of CPCs associated with the generated ideas, and the enhancement in idea originality. A controlled experiment involving students from the University of Florence (Italy) was conducted, where they were tasked with generating ideas for reusing a given product at its end of life, with and without the employment of a given set of CPCs descriptions as stimuli. Indicative findings appeared consistent with the expected outcomes; however, further statistical analysis was brought to the rejection of all formulated null hypotheses, except for the one related to the identification of new functions. Nonetheless, even in this latter case, further experiments are necessary to provide greater validity to the result. The study sheds light on the use of CPC descriptions in innovative thinking for product development, especially when integrated with Computer-Aided Design tools.

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