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

Lorenzo Fiorineschi[1], Rocco Furferi[2], Marco Melani[3] and Federico Rotini[4]

[1]University of Florence, lorenzo.fiorineschi@unifi.it
[2]University of Florence, rocco.furferi@unifi.it
[3]University of Florence, marco.melani@unifi.it
[3]University of Florence, federico.rotini@unifi.it

Corresponding author: Marco Melani, marco.melani@unifi.it

Abstract. The systematic use of stimuli by designers in the early stages of product development represents a methodology extensively explored in scientific literature, acknowledged for its advantages in terms of broader exploration of solutions and reduction in development time and costs. In an era where the importance of environmental aspects, such as the reduction of resource consumption, is also growing in the industry, it becomes crucial to assess the potential benefits of such tools in achieving these specific goals, an area so far scarcely explored in research. This study is positioned within this context, with the intent of preliminarily investigating the presence and nature of benefits deriving from the use of textual stimuli drawn from cooperative patent classifications (CPCs) to generate ideas on possible alternative applications for end-of-life products. To this end, an experiment was conducted with volunteers, divided into groups, and submitted to two different case studies. Only some of the participants were given additional textual material to assess the differences in results between those who received the stimuli and those who did not. The indicative results do not show consistency across the two products analyzed, with variability in terms of originality, volume of ideas produced, application sectors, and related functionalities. Statistical analyses, however, more clearly highlight the absence of significant beneficial effects in generating new application areas and in terms of the originality of the ideas. As for the generation of new functions, the study does not provide definitive conclusions, necessitating further research. Therefore, the findings of this investigation could influence the use of Computer-Aided design tools in the early stages of new product development.

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1 INTRODUCTION

In the face of escalating climate change, the industrial sector finds itself at a critical turning point. As a significant contributor to global emissions, it brings an important responsibility and, at the same time, a significant chance to guide the direction towards sustainability. A crucial element of this transition involves the adoption of the 3R strategy, which centers around the principles of reducing, reusing, and recycling pre-existing commodities [18]. This method aims to not only reduce the environmental impact by efficiently managing waste and resources, but also to supervises the entire lifespan of products, starting from the initial design phase and ending with their final disposal, known as the cradle-to-grave approach [21].

In particular, the process of reusing products and materials offers a compelling chance to conserve resources and reduce the demand for raw materials in several businesses. This strategy effectively guarantees that things are utilized for their maximum lifespan, so extracting their greatest value and minimizing their ecological impact.

An effective strategy that exemplifies this approach involves analyzing different uses for the product from the very beginning of the product cycle, particularly during the product design phase. This requires a level of insight beyond conventional design considerations, necessitating designers to think about future applications and multiple lives of the product or its components [23]. Nevertheless, this is not lacking obstacles. To identify potential alternative uses, one must have an in-depth understanding of the product's capabilities and limitations when it arrives to the end of life, as well as the ability to anticipate future market demands and environmental factors.

At the base of this strategy lies creativity. In the domain of product design, creativity is not merely a valuable quality but an essential requirement, having the ability to convert conventional ideas into innovative solutions. Therefore, stimulating the creative faculties of designers becomes of paramount importance, as well as measuring the impacts of the stimulation means [11-12]. This is where creative stimuli play a key role.

Such stimuli might be of different types and originate from many sources [4-5],[9],[16],[19-20],[25-28]. International patent databases (IPD) are widely recognized as a primary source of design inspiration, as noted by numerous authors in the field [7],[9],[17],[29],[31]. Many studies have suggested strategies for extracting inventive stimuli from patents, frequently by utilizing natural language processing algorithms to examine the documents based on different scopes and metrics [25-26],[31]. Additional types of stimuli can also be obtained from the descriptions of International Patent Classifications (IPC) [30].

The present research specifically examines this last type of stimulus and its ability to improve the exploration of alternative applications for a product or its components. As a result, it has the potential to impact the early design stages and the prospective use of Computer-Aided Design systems in this process.

More precisely, the authors aim to answer three distinct research questions. Firstly, the study seeks to determine whether the detailed descriptions offered by these patent classifications can aid in identifying alternative functions for a product that diverge from their original ones. Additionally, the investigation explores the possibility that these textual definitions might facilitate the discovery of new application sectors for the same product. Lastly, the proposed investigation tries to understand the contribution of patent classification definitions in enhancing the ideas' originality.

Specifically, the study examines whether these definitions can act as triggers in generating novel uses for an existing product, therefore promoting innovation and creativity. The outcomes of the proposed study can provide a first reference for developing Computer-Aided systems aimed at stimulating ideas for identifying applications of "exhausted" products in alternative applications' fields with respect the original one. Overall, the objective of the paper is to provide preliminary answers to these questions, which at least could represent a useful starting point for further research on the topic.

2 BACKGROUND ON INTERNATIONAL PATENT CLASSIFICATION

As widely recognized, the IPC is a system with global application, developed and upheld by the World Intellectual Property Organization (WIPO), serving to categorize and organize patents based on the technical content they reveal [30]. This standardized framework plays a vital role in facilitating the retrieval of patent information, offering a structured approach for patent offices, inventors, and researchers to systematically organize and search for patents within specific technological domains. At its core, the IPC is structured hierarchically, featuring codes that represent specific technical aspects of inventions, ensuring a detailed classification that reflects the increasing levels of detail regarding the technical features of patents.

The IPC is comprised of sections, classes, subclasses, groups, and subgroups, with sections representing broad categorizations covering major technological fields (for instance, "A" for human necessities or "B" for performing operations and transporting). These sections are further divided into classes, subclasses, groups, and subgroups, creating a comprehensive and evolving classification system. To stay relevant with technological advancements, the IPC undergoes periodic updates and revisions. This dynamic nature enables patent examiners and professionals globally to conduct effective patent searches, examine applications, and maintain consistency in classification.

Beyond its application within patent offices, the IPC serves as a valuable tool for a broader audience, including inventors, businesses, and researchers. By providing a standardized language for describing technical concepts, it facilitates global communication and collaboration in the innovation ecosystem. Stakeholders can utilize the IPC to identify relevant prior art, assess the state of the art in specific fields, and make informed decisions concerning patentability and freedom to operate.

A distinctive feature of the IPC is its multilingual nature, ensuring accessibility on a global scale. Available in multiple languages, this characteristic promotes inclusivity, enabling users from diverse linguistic backgrounds to navigate and contribute to the classification system.

2.1 Rationale Behind the Proposed Investigation

The textual definitions within the IPC could act potentially as stimuli for identifying new product applications for several reasons. Firstly, the IPC employs a precise technical language, aiding in the clear understanding of the features and components of existing patented technologies. Textual definitions provide detailed descriptions of various technical concepts, offering depth and insights into specific technological areas.

Analyzing the IPC allows for the identification of gaps and opportunities in technological coverage. It reveals concentrations of patents or areas with fewer patents, highlighting opportunities for new product applications or innovations. The hierarchical organization of the IPC provides cross-disciplinary insights, fostering innovation at the intersection of different technologies.

Moreover, reading textual definitions of patents inspires individuals to consider improvements or combinations of existing technologies, potentially leading to the development of innovative products. IPC analysis helps in understanding market trends and aligning new product development with current and future demands. Patent landscape analysis, facilitated by the IPC, allows for a comprehensive examination of technological domains, revealing areas of saturation or unexplored territories.

The IPC, being an international classification system, offers a global perspective on technological advancements. Innovators can gain insights into developments across countries and industries, encouraging them to think beyond regional boundaries. Studying existing patents through the IPC aids in assessing the risk of potential infringement, ensuring freedom to operate in specific technological spaces.

Lastly, the standardized language in the IPC facilitates effective communication with experts in the field. Innovators can use IPC definitions to engage in meaningful discussions with researchers, patent examiners, and other professionals.

2.2 Stimuli as Triggers for Creativity: a Literature Analysis

The integration of stimuli into the design process, especially through Computer-Aided systems [1],[3], is a crucial task for guiding designers through complex problem-solving spaces and fostering creativity. Individual preferences for stimulation methods vary, including pictures, videos, or text, [5] necessitating flexible approaches to address the advantages and drawbacks of different modalities [14]. Despite recognizing the benefits of diverse stimuli, designers often struggle to efficiently select and navigate them, leading to suboptimal exploration outcomes [15]. To address this, personalized and articulated stimulation activities aligned with designers' preferences are recommended. Many studies have been conducted in the literature on creativity stimulation methods and their impact on the design process and related outcomes, with a comprehensive review presented in [4].

About the use of information contained in patents, and more specifically, about patent classification as a creative stimulus, some recent contributions exist in the literature, which face the research questions from different perspectives.

For instance, [25] proposes a method that explores the role of product patents as sources of design inspiration. They emphasize the potential of patents to stimulate creativity and innovation in product design. The study introduces a process for extracting creative inspiration from patents, discussing the categorization of design knowledge within patents and the influence of patent knowledge on three layers of innovation. The authors present a natural language processing approach to extract inspiration stimuli from patent knowledge, emphasizing the relationship between innovation layers and these stimuli. They also provide a practical process to help designers draw inspiration from diverse patents.

In a study by [16], the elements influencing creativity in the design process are evaluated. The analysis involves studying knowledge, knowledge relationships, and innovative strategies using representations obtained from the International Patent Classification (IPC). The experiment features 40 undergraduate students proposing designs for a coin-sorting device. The findings indicate that verb knowledge within the IPC significantly boosts creative inspiration. For less-experienced students, innovative strategies negatively impact originality, but this is mitigated by knowledge relationships, facilitating innovation. The research provides valuable insights into the effects of knowledge and innovative strategies on design inspiration, particularly for individuals lacking expertise.

Authors in [20] present a method for conceptual design driven by data, utilizing a "knowledge-based expert system to stimulate human ideation for novel design concepts". The system provides design stimuli across semantic, document, and field levels from all engineering and technology fields, aligning with creativity theories. A network of technology fields in the patent classification system organizes global technological knowledge, facilitating the exploration and retrieval of inspirational stimuli. Two case studies demonstrate the system's effectiveness in exploring and retrieving multilevel stimuli for problem-solving and open-ended innovation.

In [26] the need for swift and effective forecasting of new product generations for market competitiveness is addressed. They propose an integrated method "combining technological evolution laws with a back propagation neural network, IPC knowledge, and the company's technological distance". The method searches for the optimal evolution law and accesses potential solutions based on IPC functional verbs and technological distance. Applied to a steel pipe-cutting machine, the method reduces reliance on designer experience and provides a systematic approach for innovative product design, showcasing its effectiveness through case studies.

Despite the numerous contributions available in the literature, there are no specific studies aimed at verifying the use of textual definitions of patent classification as stimulation means to

find alternative applications for existing technologies/products. Therefore, the study described in this paper provides further knowledge to define Computer-Aided Design systems aimed at supporting design activities oriented towards the reuse of products in contexts different from the original one.

3 RESEARCH APPROACH

The preliminary research questions introduced in the first section have been answered through an experimental activity, specifically tailored on the identification of alternative ideas and applications of two distinct products used as objects of the investigation. The adopted approach is structured as follows: a series of null hypotheses are formulated, and metrics to be observed through the chosen experimental activity are defined. The results obtained are then analyzed using appropriate statistical tests to either reject or not the initial hypotheses.

A sample of students attending the first year of a master's degree course in mechanical engineering at the University of Florence (Italy) has been involved in the test. The product selection has been based on two actual case studies, specifically focusing on a mosquito net product and a wine barrel. The choice of two completely different products was performed to make the study's results independent from the type of product analyzed, thus drawing conclusions that have more general validity.

The participants were divided into two groups: a control group, which was asked to identify ideas and alternative applications for the first product based solely on a textual/visual description as input, and a treated group, which received the same textual/visual description of the product along with a set of textual stimuli to perform the same task. These textual stimuli were the definitions of the considered patent classes. Subsequently, the procedure was replicated using the second product, reversing the roles of the two groups: the group that had not previously been exposed to the additional textual hints was then given them, whereas the other group was not. The textual descriptions and images that were presented to both groups are reported in the appendix. The additional stimuli consisted of three Cooperative Patent Classification (CPC) descriptions per product. For the sake of clarity, CPC is based on the IPC system, but it is more detailed as it considers more clusters in the classification levels of the patents [8]. The chosen descriptors are reported in Table 1 and Table 2 respectively for the mosquito net and the wine barrel.

CPC	*Description*
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.

Table 1: CPC descriptions are employed as additional stimuli for mosquito net products.

CPC	*Description*
A23L	foods, foodstuffs, or non-alcoholic beverages; their preparation or treatment, e.g., cooking; modification of nutritive qualities; physical treatment (shaping or working); preservation of foods or foodstuffs, in general.
A24B	manufacture or preparation of tobacco for smoking or chewing; tobacco; snuff.
A61H	physical therapy apparatus, e.g., devices for locating or stimulating reflex points in the body; artificial respiration; massage; bathing devices for special therapeutic or hygienic purposes or specific parts of the body (electrotherapy,

	magnetotherapy, radiation therapy, ultrasound therapy).

Table 2: CPC descriptions are employed as additional stimuli for wine barrel products.

The selection of these classes was based on a prior study [22], where the method described in [9] was employed to identify novel product application domains. Specifically, these classes were identified as the most helpful by a panel of experts upon conducting the study. In fact, they have been used as triggers to enhance design activities performed by industrial experts, which were focused on the identification of alternative uses of barrels and mosquito nets [9],[22]. Since the outcomes were judged interesting and potentially relevant, these classes were deemed effective triggers for enhancing creativity, and thus, they have been selected for this experiment.

The overall participant count was 37, consisting of 2 girls and 35 males. The participants were randomly distributed, leading to the formation of two groups:

- Group A: 18 participants, with 17 males and 1 female.
- Group B: 19 participants, with 18 males and 1 female.

Thus, the individual gender distribution is optimized to maximize equality. The study assessed any variations in age and prior knowledge to be unimportant, provided all individuals had the same engineering academic backgrounds. The allocation of stimuli to the two groups in relation to the products is presented in Table 3. From this point forward, the barrel will be directly referred to as product 1 and the mosquito net as product 2.

	Group A	*Group B*
Product 1 – wine barrel	With CPC description assigned	No Stimuli
Product 2 – mosquito net	No stimuli	With CPC descriptions assigned

Table 3: CPC describes the assignment scheme in relation to products and work groups.

The participants were assigned the task of identifying the highest possible number of alternative application fields for the end-of-life phase of the products. An evaluation of the technical feasibility of the solutions found was not required to limit the idea-generation process because this feature was not deemed relevant to answering the research questions. The individuals were asked to explain each concept with a brief textual description concisely and, if desired, by including rough illustrations, sketches, etc. Besides, participants were explicitly told to refrain from any form of communication with one another and from the use of electronic devices for the whole course of the test.

The experiment duration was set to 30 minutes for each product since this time frame represents a good balance between the requirement of maintaining high levels of focus of the participants and of promoting creativity while also considering the necessities of organization and analysis [6]. Individual participants' personal information was not recorded in accordance with the general regulations on ethics. Consequently, none of the participants was exposed to any comparative or individual evaluation during or after the experimentation. In addition, participation was entirely voluntary. Three examples of collected outcomes have been reported in the appendix.

3.1 Metric 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 [13]. 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. Consequently, a unique ID letter was given to each generated idea, following the rule

that two different ideas would share the same ID only if they possessed the same set of functions and application fields. This evaluation methodology was collectively agreed upon by the authors in order to achieve the least subjective outcomes possible. 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 for both products. The metric of quantity involves different parameters: the selected ones are numbered from 1 to 5 in the following list, based on the available data. Originality metric follows in the last point:

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

For what concerns originality, it can be assessed "a priori" or "a posteriori". The first option involves comparisons of the ideas obtained with already known and existing solutions, while the latter one only observes the outcomes, categorizing them in terms of frequency of appearance [5]. The less recurring ideas are therefore considered the most original ones, according to the fact that they are more unexpected from a psychological point of view [12]. As stated in [10],[12], both the approaches are commonly used in the literature, as it has been demonstrated that they are not correlated.

In this study, since the primary interest is to evaluate the relative performance differences between the test and control groups, irrespective of comparisons to reference solutions, only "a posteriori" evaluations have been conducted.

3.2 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.

In conclusion, the metrics, and hypotheses above defined were used to answer the three research questions summarized in the introductive section as shown in Table 4. Metrics and hypotheses numbers refer respectively to the lists of sections 3.1 and 3.2.

Research question	*Metrics*	*Hypotheses*
Patent classifications can aid in identifying alternative functions for a product that diverge from their original ones.	1; 2; 3.	1. (H01a); 2. (H01b); 3. (H01c).
Patent classifications might facilitate the discovery of new application sectors for the same product.	1; 4; 5.	1. (H01a); 4. (H01d); 5. (H01e).
Patent classification definitions enhance ideas' originality.	6.	6. (H01f).

Table 4: Summary of the formulated research questions, observed metrics and related hypotheses involved.

4 RESULTS

The outcomes in terms of the different metrics of quantity, functions, application fields and originality are reported in this chapter.

4.1 Quantity Results

The ideas generated during the experimental test have been collected and analyzed according to the criteria enounced in the previous section. The total number of outcomes is reported in Table 5.

	Product 1	*Product 2*
Test group	45	78
Control group	54	57

Table 5: Total numbers of ideas generated by the two groups for product 1 and product 2.

After a first screening, the non-compliant ideas were discarded, arriving at the final numbers reported in Table 6.

	Product 1	*Product 2*
Test group	44	71
Control group	49	57

Table 6: Total numbers of valid ideas generated by the two groups for product 1 and product 2.

4.2 Ideas Generated by Participants

The t-student statistical test has been employed to evaluate the collected data, specifically focusing on the validation or rejection of the formulated null hypothesis. Mean values, standard deviations, and skewness are reported in Table 7 for products 1 and Table 8 for product 2. The p-value results are instead reported in Table 9.

Metric	*Test Group (A)*			*Control Group (B)*		
	Mean	*S.D.*	*Skewness*	*Mean*	*S.D.*	*Skewness*

Quantity – ideas/participants	2.444	1.504	0.0615	2.579	1.895	0.630

Table 7: Mean, standard deviation, and skewness values of the "ideas per participant" metric for product 1.

Metric	*Test Group (B)*			*Control Group (A)*		
	Mean	*S.D.*	*Skewness*	*Mean*	*S.D.*	*Skewness*
Quantity – ideas/participants	3.737	2.621	0.796	3.167	1.689	-0.128

Table 8: Mean, standard deviation, and skewness values of the "ideas per participant" metric for product 2.

Metric	*Hypothesis test*	*Type of test*	*p-value Product 1*	*p-value Product 2*
Quantity – ideas/participants	H01a	t-student	0.812	0.435

Table 9: Results of the t-student statistical tests performed for the "ideas per participant" metric of product 1 and product 2.

As it can be observed, the p-values are far from the alpha threshold level commonly established at 0.05 [24], indicating that there is no statistically significant difference between the number of ideas obtained by the participants with and without external stimuli.

4.3 Functions Results

Regarding the functions, the total quantity obtained by the two groups is provided in Table 10. As it can be observed, the overall trends are in opposition to each other, with a greater number of functions generated with stimuli in product 2 and without stimuli in product 1.

	Product 1	*Product 2*
Test group	86	168
Control group	102	141

Table 10: Total numbers of valid functions obtained by the two groups for product 1 and product 2.

The functions distribution among participants is reported in Table 11 for products 1 and Table 12 for product 2.

Function	*Test Group (A)*	*Control Group (B)*
Support	29	34
Contain	16	21
Beautify	16	26
Flavor	3	4
Season	3	1
Dry	1	0
Smoke	3	2
Refrigerate	2	1
Insulate	5	7
Cook	2	0
Entertain	1	2

Treat (physically)	3	1
Amplify	1	1
Generate	0	1
Degrade	1	0
Separate	0	1

Table 11: Functions distribution obtained for product 1.

Function	*Test Group (B)*	*Control Group (A)*
Protect	28	16
Beautify	7	8
Block	29	34
Collect	9	2
Support	32	22
Darken	5	3
Filter	13	20
Separate	11	18
Dampen	1	1
Contain	25	14
Remove	3	3
Isolate	3	0
Cool	1	0
Mix	1	0

Table 12: Functions distribution obtained for product 2.

As can be observed, the total amount of retrieved functions follows an opposite trend for the two products, with a greater number of functions obtained in the control group for product 1 and in the test group for product 2. However, trivial functions related to the original application fields of fly screens and wine barrels can be both retrieved. These come from previous decompositions of the staring products performed in [22]. In particular, they are the following:

- sustain, contain, flavor, and season for wine barrel;
- protect, block, filter, and separate for mosquito net.

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 Table 13 are therefore obtained.

	Product 1		*Product 2*	
	Test Group (A)	*Control Group (B)*	*Test Group (B)*	*Control Group (A)*
Trivial Functions	35	60	81	88
New Functions	51	42	87	53

Table 13: The total number of functions obtained from the two work groups for product 1 and product 2 are categorized into new functions and trivial functions, the latter being attributable to the application sector from which the two products originate.

Despite the opposite trends observed in Table 10, the number of new functions turns out to be greater in the test group compared to the control group for both products. The statistical

significance of the results has been analysed in this case with a chi-squared test, as it aims to examine the frequencies of function occurrences in the two groups. Table 14 reports the results.

Metric	*Hypothesis test*	*Type of test*	*p-value Product 1*	*p-value Product 2*
Quantity – functions	H01b	chi-squared	0.715	0.105
Quantity – cumulative functions	H01c	chi-squared	1.000	0.013

Table 14: Results of the chi-squared statistical tests performed to verify H01b and H01c hypotheses. The p-value of H01c for product 1 has been corrected according to Yates formulation because of the limited numerosity of the sample.

While it is possible to observe that the H01b hypothesis cannot be rejected for both cases, the occurrence percentages of new functions with respect to trivial ones show contrasting results in the two products. Indeed, it is possible to reject the hypothesis H01c only in product 2.

4.4 Application Fields Results

With regards to the application fields, the total quantities obtained are reported in Table 15. It is possible to observe an opposite trend in the two products, similar to what has already been highlighted for the functions in Table 10.

	Product 1	*Product 2*
Test group	44	71
Control group	49	57

Table 15: Total number of valid application fields obtained by the two groups for product 1 and product 2 in terms of CPCs.

The complete results are reported in Table 16 for the wine barrel and Table 17 for the fly screen. It is important to remember that in this study, the categorization of application fields is based on the system provided by the Cooperative Patent Classification.

CPC	*Test Group (A)*	*Control Group (B)*
A47B	7	10
A47F	2	1
A47C	3	2
A47G	5	5
A47J	1	1
A47K	1	0
A63G	1	0
A99Z	1	0
F21V	1	2
B65H	1	0
C11B	2	3
A24B	3	0
A23L	4	3
A01G	3	7
B65D	2	3
A61H	3	1
E04B	1	1

E04F	1	0
C11D	1	0
G10K	1	0
A01K	0	2
G10D	0	1
E04H	0	1
B63B	0	1
A63J	0	1
C12J	0	1
F24S	0	1
F03B	0	1
B32K	0	1

Table 16: CPC distribution obtained for product 1.

CPC	*Test Group (B)*	*Control Group (A)*
A41B	1	0
A42B	6	3
A41D	6	3
A45C	1	1
A01G	12	3
A01D	6	1
A01K	4	6
F21V	1	0
B29D	4	1
E04F	2	1
A45B	1	1
B01D	2	3
E03C	1	1
D07B	1	1
A63B	2	3
E01F	2	2
F01M	1	3
G10H	1	1
B33Y	1	1
B60H	1	4
B65D	3	3
B08B	3	1
A23L	1	0
F24S	1	0
F25D	1	0
A47J	4	2
B01F	1	0
H01B	1	0
D05C	0	1
A43B	0	1
F21S	0	1
E03F	0	1
B09B	0	2
A22C	0	1

A47C	0	1
A01M	0	1
F41H	0	1
A44C	0	1
A47G	0	1

Table 17: CPC distribution obtained for product 2.

It is observable that, as one might expect, some of the Cooperative Patent Classification (CPC) codes retrieved in the test group were also present among those provided as stimuli. Concerning category A01G for fly screens and all three categories (A24B, A23L, and A61H) for the barrel, The cumulative results in Table 18 are grouped based on whether the CPCs were included in the stimuli or not.

	Product 1		*Product 2*	
	Test Group (A)	*Control Group (B)*	*Test Group (B)*	*Control Group (A)*
CPCs from stimuli	10	4	12	3
Other CPCs	34	45	59	54

Table 18: The total number of CPCs obtained from the two work groups for product 1 and product 2 were categorized into CPCs coming from additional stimuli and others.

As one might expect, the quantity of CPCs obtained that belong to those provided as stimuli is greater in the test groups compared to the control groups for both products.

The statistical tests performed to reject hypotheses H01d and H01e are, respectively, the chi-squared test and the Fisher exact test. The latter was chosen due to the small sample size, with the number of occurrences in each cell being less than 5. The results of the p-values are reported in Table 19.

Metric	*Hypothesis test*	*Type of test*	*p-value Product 1*	*p-value Product 2*
Quantity – application fields	H01d	chi-squared	0.663	0.549
Quantity – cumulative application fields	H01e	Fisher	0.0795	0.0787

Table 19: Results of the chi-squared and Fisher statistical tests performed to verify H01d and H01e hypotheses.

It can be concluded that the null hypotheses cannot be rejected. Therefore, the given textual stimuli do not influence the occurrence percentages of each application field, and their use does not focus the research on applications in the patent areas from which the definitions originate.

4.5 Originality Results

The originality metric was calculated using the previously known total and distinct numbers of valid ideas. Consequently, the frequency of occurrence for each idea is the primary variable of interest for the third research question of this study. Mean values, standard deviations, and measures of skewness for the two groups are presented in Table 20 for product 1 and Table 21 for product 2.

Metric	*Test Group (A)*	*Control Group (B)*

	Mean	*S.D.*	*Skewness*	*Mean*	*S.D.*	*Skewness*
Originality	1.375	0.660	2.290	1.885	1.728	2.510

Table 20: Mean, standard deviation, and skewness values of the originality metric for product 1.

Metric	*Test Group (B)*			*Control Group (A)*		
	Mean	*S.D.*	*Skewness*	*Mean*	*S.D.*	*Skewness*
Originality	1.972	1.594	2.198	1.677	0.976	1.131

Table 21: Mean, standard deviation, and skewness values of the originality metric for product 2.

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 outcomes of the statistical analyses conducted for the validation of the null hypothesis is reported in Table 22. Notably, the skewness value exceeding 2 necessitated an alternative approach to the analysis; hence, the Mann-Whitney test was utilized instead of the t-student test for both products.

Metric	*Hypothesis test*	*Type of test*	*p-value Product 1*	*p-value Product 2*
Originality	H01f	Mann-Whitney	0.521	0.670

Table 22: Results of the Mann-Whitney statistical test performed to verify H01f hypothesis.

These p-values are well above the conventional levels of statistical significance, which indicates that there is no difference between employing or not such textual stimuli for generating more original ideas. Therefore, the null hypothesis cannot be rejected.

5 DISCUSSIONS

As observed in the previous chapter, the preliminary study conducted has revealed contrasting outcomes for the various parameters evaluated when comparing the two products under investigation. Specifically, with respect to the mosquito net, the aggregate trend data of the metrics assessed suggest that the test group outperformed the control group. This was evident in the ability to generate a higher quantity of ideas characterized by a broader diversity in functionality, application fields, and innovation. In contrast, for the wine barrel case, the textual hints provided did not yield any notable advantageous effects. All the parameters involved in the study are here analyzed singularly.

Regarding the average number of ideas generated per participant, the mosquito net product has recorded a value of 3.737 in the test group and 3.167 in the control group, indicating a potential, although modest, influence of the textual stimuli on the volume of idea generation. Conversely, for the wine barrel, the test and control group averages were 2.444 and 2.579, respectively, suggesting no benefit from the use of such textual descriptions.

For the metric related to the generation of the function, the test group associated with product 2 exhibited a more extensive array of functions and a greater cumulative count of novel functions, suggesting that the textual stimuli may have fostered a more expansive exploration of functional possibilities among participants. Conversely, the total number of functions formulated by the test group for product 1 was lower than that of the control group (86 versus 102). Nevertheless, it is noteworthy that also in this case there was a relative increase in the proportion of non-obvious

functions within the group exposed to the stimuli, as opposed to functions that were directly tied to the original domain of application, suggesting a potentially beneficial influence of the textual descriptions even in this context.

The analysis of potential application sectors once again suggests, as evidenced by the larger number of application fields identified by the test group for product 2 (71 versus 57), that CPC descriptions may facilitate this objective. However, the results for product 1 do not exhibit a similar trend. From the standpoint of application sectors that are different from or similar to the descriptive stimuli, it is observed instead that these stimuli have influenced the number of ideas associated with them for both products, as could reasonably be expected.

Despite these observed trends, statistical analyses revealed a more uniform reality. While the generation of functions and application fields matched expectations from an indicative point of view only for one of the two products, statistical tests have shown that in no case will these differences result in significant, with p-values well above the threshold of 0.05. The sole exception lies in the cumulative number of new functions, which seems to be notably influenced by the CPC's textual stimuli, but only for product 2. This was manifested in the significantly greater number of novel functions produced by the test group, leading to the rejection of the null hypothesis in this regard (with a p-value of 0.013). Considering these observations, the preliminary investigation does not provide a clear answer to the initial research question of the study, given that the statistical outcomes differ between the two products.

For what concerns the hypothesis that textual definitions from patent classifications facilitate the discovery of new application sectors, the p-values obtained do not support this outcome. Indeed, the test groups did not demonstrate a statistically relevant ability to identify a wider range of application fields for both products compared to the control groups. Therefore, the answer to the second research question is negative.

Lastly, in examining whether the originality of ideas is enhanced by the use of CPC descriptions, the study provides a negative response. Specifically, the test group of product 2 also exhibited a slight rise in the frequency of repeating ideas, indicating a fixation problem caused by the stimuli. However, this observation lacks statistical significance, as indicated by p-values of 0.521 and 0.670, respectively, for products 1 and 2. This result implies that any differences in idea originality between the test and control groups could be attributed to random variation, and the answer to the third research question cannot be positive.

It is worth noting that several factors may have influenced the results. First and foremost, the specific descriptions used: for the purposes of the study, descriptions corresponding to the 4-digit CPCs were indeed chosen. This decision was intentionally made to strike a balance between offering hints that were not overly abstract and vague and avoiding those that were excessively detailed and descriptive of the technologies. However, this choice certainly influenced the process of generating ideas, thereby affecting the type of outcomes produced.

Furthermore, the intentional restriction to just three descriptions has been taken to prevent overwhelming participants, although this decision may also have consequences for the range and variety of ideas generated. Moreover, the choice of mosquito nets and wine barrels as the subjects of analysis was significant, suggesting that the findings might be product-specific.

Another important aspect is related to the characteristics of the participants. For the purposes of the study, they were divided randomly into two groups, considering that they had the same type of background and that any more talented individuals were equally distributed. In accordance with the university's ethical regulations, participants were not asked for any personal information. Therefore, these aspects could not be checked. However, it was considered that, as they all belonged to the same university course and were all around the same age, they could be regarded as a homogeneous group. A more critical characteristic is that of numerosity. In order to carry out statistical analyses, the larger the sample available, the more reliable the results will be. Compared to other studies in the literature [5], in this case the sample available was smaller, with a total number of participants between the two groups of 37.

Another source of potential influence on the results lies in the assumptions made in the assignment of functions and CPCs descriptions to the various ideas, which was carried out by the authors as rigorously as possible, but still without any comparison with a broader group of experts. Furthermore, the choice of how these ideas were grouped to obtain a set without repetitions can certainly be reconsidered. In this case, all ideas with the same functions and the same field of application were considered to belong to the same idea. However, other parameters, such as the only application fields, could also have been considered, thus modifying the results. Lastly, it is necessary to note that the textual and visual descriptions provided to both groups for the two products might themselves have created an underlying fixation problem for the ideas generated, similar to what has been observed because of the CPCs.

Table 23 and Table 24 summarize the considerations discussed above, presenting the answers to the three research questions based on the indicative outcomes and the results of the statistical tests, respectively.

Research question	*Answer*
Patent classifications can aid in identifying alternative functions for a product that diverge from their original ones.	The absolute quantity of functions obtained is not clearly influenced by the provided textual stimuli, with opposing results between the two products. However, in percentage terms, the new product functions generated compared to the obvious initial ones are greater in the test groups for both products.
Patent classifications might facilitate the discovery of new application sectors for the same product.	The absolute quantity of application sectors obtained is not clearly influenced by the provided textual stimuli, with opposing results between the two products. However, in both cases, a fixation phenomenon generated by the CPC stimuli is observed, with more ideas related to the provided patent classes retrieved in the test groups.
Patent classification definitions enhance ideas' originality.	The originality of the generated ideas is not clearly influenced by the provided textual stimuli, with opposing results between the two products.

Table 23: Answers to the research questions of the study based on the indicative outcomes.

Research question	*Answer*
Patent classifications can aid in identifying alternative functions for a product, that diverge from their original ones.	The preliminary study does not provide a clear-cut answer to this research question, with conflicting results for the two products. Further investigations are necessary.
Patent classifications 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 CPC descriptors as textual stimuli.
Patent classification definitions enhance ideas' originality.	A posteriori originality level is not statistically influenced by the use of CPC descriptors as textual stimuli.

Table 24: Answers to the research questions of the study based on the statistical tests performed.

6 CONCLUSIONS

In the present study, a preliminary investigation was conducted to explore the impact of textual stimuli derived from CPC descriptions for the identification of alternative application fields of a specified product. This inquiry was particularly focused on evaluating the extent to which these CPC-derived descriptions could potentially enhance the creative process. In particular, the objectives of the study were to assess the influence of such textual stimuli on specific metrics of the ideation phase. Firstly, the quantitative increase in the number of functions and the range of Cooperative Patent Classifications associated with the ideas generated. Secondly, the enhancement in the originality of ideas. This was carried out through a controlled experiment, which involved a group of students from the University of Florence, Italy. The exercise consisted in the generation of the maximum number of ideas for the reuse of two given products at their end of life. Students were divided in two groups: a control group and a test group. A series of stimuli derived from selected CPCs descriptions has been provided only to the test group and the results have been compared. Then, the same procedure has been repeated for the second product, switching the two groups. While the indicative research's findings have shown opposite trends for the two products under investigation, statistical tests have revealed more coherent results. In fact, quite surprisingly, none of the formulated null hypotheses can be rejected since all p-values from the statistical tests exceed the threshold for significance. The sole exception is represented by the hypothesis related to the identification of new functions, which appears to be effectively enhanced by CPCs descriptions only for product 2, indicating the necessity of further investigations.

In conclusion, this study aimed to increase our understanding of how CPC descriptions contribute to the identification of alternative application fields for end-of-life products in an uncovered manner with respect to existing literature. It also provides valuable insights into the potential use of CPC descriptions in promoting innovative thinking in product development and design, particularly in combining them with Computer-Aided Design tools.

However, the preliminary nature of the study must be emphasized, remembering that various factors inherent to the experiment may have influenced the results. These include the limited set of products proposed, the specific CPCs provided, and the characteristics of the participants. For these reasons, further studies would be required to generalize the results obtained. In particular, involving a larger sample of participants to represent the population better would reduce the uncertainty regarding these parameters. Furthermore, by analyzing the same products with different stimuli in several groups, it is possible to see if there is variability in this case as well.

Lorenzo Fiorineschi, https://orcid.org/0000-0002-8458-2794
Rocco Furferi, https://orcid.org/0000-0001-6771-5981
Marco Melani, https://orcid.org/0000-0002-9451-9625
Federico Rotini, https://orcid.org/0000-0002-1676-0835

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APPENDIX

The textual descriptions provided to the test and control groups are reported in this appendix, together with the corresponding images of Figure 1 and Figure 2. Wine barrel description follows:

The barrel-shaped, biodegradable wooden barrel plays an indispensable role in the preservation and enhancement of wine. Its solid structure provides effective protection, creating a barrier against external environmental influences. The barrel shape, besides evoking tradition and grandeur, supports the proper development of the wine inside, allowing for a harmonious and gradual aromatization. During aging, the wood interacts with the wine, contributing delicate layers of aromatic complexity, such as hints of vanilla, spicy notes, and a subtle toastiness.

Figure 1: The wine barrel image is shown to the test and control groups.

The mosquito net description follows:

The mosquito netting is an essential element for protecting indoor environments from unwanted insects, such as mosquitoes, flies, and other flying insects. Various types are available, but the most commonly used are made of polypropylene or a fiberglass compound coated with PVC. The mesh is designed to allow the passage of air and sunlight while keeping insects out. Depending on the material and thickness, it can also partially screen out sunlight. The mosquito

net can be installed on windows, doors, and openings, both inside and outside of buildings. It is easy to cut and adjust to the desired size, allowing for simple do-it-yourself installation.

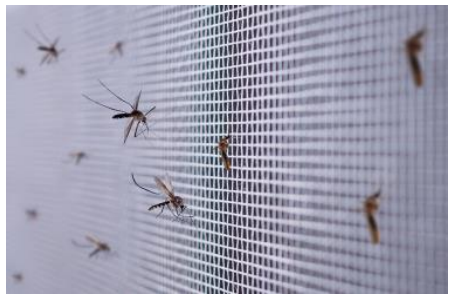

Figure 2: Mosquito net image shown to the test and control groups.

Three examples of collected outcomes are reported in
Figure **3** for both mosquito net and wine barrel.

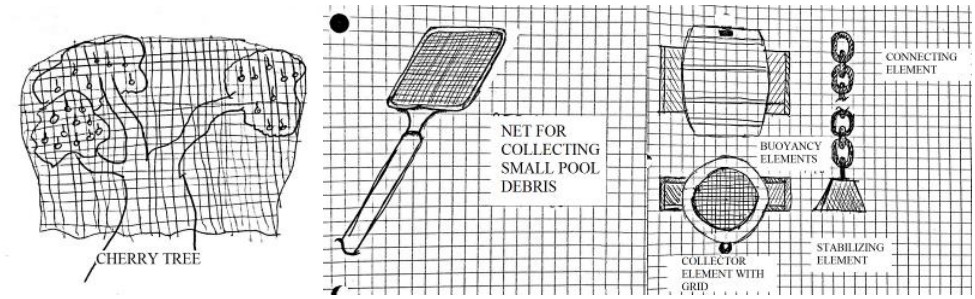

Figure 3: Examples of generated alternative product applications for fly screen (a,b) and wine barrel (c). (a) Protecting device for fruit trees. (b) Net for collecting pool debris. (c) Device for collection of river and sea garbage.