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# Surprise and design creativity: investigating the drivers of unexpectedness

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**ABSTRACT**

Scholars argue about the role played by surprise in making new products creative. Different perspectives evaluate surprise as a nuance of novelty, an independent dimension, or an emotional reaction to new products. The paper proposes a framework of factors supposedly characterizing the emergence of surprise in terms of individuals' interpretations and/or modifications of products' behavior and structure. Moreover, it illustrates the outcomes of a preliminary empirical investigation about the manifestation of unexpectedness according to such a framework: the proposed factors have been checked by interpreting the motivations leading to the presence of surprise in 12 new lamps described in the literature. The experiment states the reasonability of the described factors and, as a consequence, the paper provides a contribution to better articulate the debate in the research arena.

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Creativity; surprise; novelty; diversity; emotion

## 1. Introduction

Creativity in engineering design is a complex phenomenon that regards, but is not limited to, people, procedures, products, environments (Thompson & Lordan, 1999). According to the study conducted by Demirkan and Hasirci (2009), products hold the highest importance among all the elements that characterize the creativity of design processes. From this viewpoint, the design community is currently paying significant efforts to establish terms and formalities to assess the creativity of new products or services. Recent proposals suggest some metrics (Borgianni, Cascini, & Rotini, 2013; Sarkar & Chakrabarti, 2011) and discuss the multidimensional nature of the task. However, these approaches base creativity assessments essentially on two terms: novelty and usefulness. Said dimensions are undoubtedly the most acknowledged aspects pertaining to product creativity. Nonetheless, criticism is starting to spread in the literature with respect to the exhaustiveness and the significance of these two factors. For instance, recent studies claim the major relevance of novelty in the evaluation of creativity (Diedrich, Benedek, Jauk, & Neubauer, 2015), also because of the possibly biased interpretation of usefulness in engineering design. This means addressing it with a strictly functional or practical sense, rather than referring to the fulfillment of all kinds of need depicted in Maslow's pyramid, thus including emotional aspects. At the same time, additional factors are supposed to affect the assessment

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of creativity. Gero (2011) points out how surprise is sometimes included within qualitative evaluations, while Brown (2012) urges to investigate such a factor more accurately.

The unresolved conflicts concerning the concept of surprise within creativity are likely to jeopardize any attempt to formalize its computation and subsequent employment. This is especially true within engineering design, while a major understanding has been achieved in other fields. For instance, the emergence of surprise during the design process and the means to generate deliverables arousing unexpectedness are investigated by Dorst and Cross (2001) and Rodríguez Ramírez (2014), by obtaining insights about approaches and tactics of outstanding industrial designers.

Focusing on the open issues about the role played by surprise within the creativity of new products, the present paper aims at better characterizing this concept with a particular emphasis on engineering design. Section 2 documents the debate about the phenomena that enable the display of people's surprise, the influence of such a perception to the extent of creativity, the mutual relationships between unexpectedness and novelty. Section 3 discusses the meaning of acknowledged factors influencing design creativity (Product, Process, Person, Press) within situations in which surprise is perceived by an external evaluator. A set of dimensions are proposed in Section 4 that are claimed to characterize surprising artifacts, emerging from empiric observations of available examples gathered from the Internet. Products considered surprising in literature sources are subsequently analyzed with respect to such dimensions (Section 5); the outcomes of this task show that characteristics typifying novelty are insufficient to describe phenomena of unexpectedness. The final remarks are drawn in Section 6.

## 2. Related art

The present Section illustrates how the literature about creativity and design has discussed the theme of surprise. Reference definitions are provided at first and, then, the review outlines different views with respect to the supposed prerequisite of creative products to arouse surprise.

### 2.1. Surprise: definitions and fundamental concepts in creativity literature

In Section 1, the words "surprise" and "unexpectedness" have been employed with the same meaning. The possibility to interchange the terms is somehow supported by the literature, whereas the most common definition of surprise consists in the violation of expectations. Brown (2008) and O'Quin and Besemer (2006) explain how surprising products present unexpected information to the evaluator. In other terms, they seem implausible or even impossible to be embodied and developed according to current knowledge, generating a sense of astonishment and bewilderment (Boden, 1996). In this perspective, it is worth noticing that surprise does not arise just when expectations have been contravened, but also in those events for which no clear expectation has been formulated (Ortony & Partridge, 1987). At the same time, the extent of surprise is qualitatively linked with the degree to which a transformed aspect of the product is deemed usual, typical, or even immutable (Brown, 2012). Major insights about the kinds of violated expectations are described in (Grace, Maher, Fisher, & Brady, 2014) with the aim of assessing surprise on the basis of the likelihood of infringing habits. Although rooted in the creativity field, the above explanations do not clarify how the emergence of surprise affects the perception of creativity. It is clear that radically new products or unprecedented proposals can lead to surprise. In other words, surprise can take place when novelty is ensured, i.e. whereas one of the most acknowledged dimensions of creativity is manifestly displayed. Hence, with respect to the supposed overlapping of the concepts undermining "surprise" and "novelty," two diffused different visions can be extrapolated from the literature:

- surprise is a particular characterization of novelty, or even a well-identified level of the same dimension (see Subsection 2.2);
- surprise is an independent factor, which can however take place when the product is novel in a certain context and according to a definite background (see Subsection 2.3).

Other perspectives are documented in Subsection 2.4. Subsequently, Subsection 2.5 points out the specific objectives of the work.

### 2.2. Surprise as a characteristic of novel products

As already remarked, novelty and usefulness (sometimes indicated as quality, meaningfulness, or value with similar meanings) are the most diffused terms to evaluate or rank creative ideas and products (Oman & Tumer, 2009). When the concept of surprise has been firstly introduced, it has been typically considered as a nuance of the former. Hoffmann, Cropley, Cropley, Nguyen, and Swatman (2007) report how, in the seminal studies performed by Bruner (1962), the concepts of novelty and surprise even overlap.

More diffusedly, surprise is considered as a degree or a particular cluster of novelty (Chiu & Shu, 2012). This assumption is made also in formalized procedures to evaluate creativity, such as Creative Product Analysis Model, in which surprising solutions are a particular category of novel products (Besemer, 2000). According to this model, novel products are indeed grouped into surprising and original artifacts. According to (Besemer & O'Quin, 1999) original ideas are unusual or infrequently seen in a universe of products, while the surprise component is related to reactions to unexpected or unanticipated information. Additional characterizations are added in later publications, consisting in style (Horn & Salvendy, 2006), i.e. the degree to which a product combines unlike elements into a coherent whole, and germinability, i.e. the driver for suggesting future creative products (O'Quin & Besemer, 2006).

### 2.3. Surprise as a separate dimension

Boden (1996) points out that creative ideas are surprising in essence. However, few studies include surprise as a prerequisite to obtain creative products or a separate dimension to assess them. According to Maher (2011), the difference between novelty and surprise stands in the reference artifacts or concepts against which to compare. While the former emerges when the new product differs from the existing descriptions of artifacts, the latter ensues when deviations are observed from the expected projection of design values and features that belong to a definite conceptual space (Maher, Brady, & Fisher, 2013). In other words, novel deliverables are essentially unprecedented, while surprising ones deviate from the trajectory drawn by a family of products. On the same wavelength, the scholars introduce a binary scale to distinguish surprising and predictable products, by including in the former:

- the ones showing new attributes if compared with the items known in the recent past (Maher, 2010);
- the ones whose performances represent outliers in a time-dependant function, obtained through a statistical regression analysis (Maher & Fisher, 2012).

Nevertheless, the proposed approach can be currently considered as a preliminary proposal to include surprise in the relevant dimensions of creativity, because of the lack of an appropriate validation activity. Besides, other scholars individuate surprise as an independent factor of design creativity, but their purpose is limited to the building of a theoretical framework (Nguyen & Shanks, 2009) or to qualitative evaluations extrapolated from testers' reactions to new artifacts (Goodwin et al., 2013). The assessment of surprise is further complicated by the issue raised by Bruner (1962), who observes the temporary nature of unexpectedness, which quickly ceases after the initial so called "Aha! moment."

### 2.4. Other interpretations of surprise within product creativity

According to different views, surprise does not pertain to the product level of creativity, being it considered as an emotional reaction to different phenomena. Wiggins (2006) explicitly denies the

unexpected dimension of creative artifacts, by considering surprise an emotional reaction of people as a consequence of novelty or outstanding value. Similarly, Silva and Read (2010) focus on the display of surprise as a resultant of products' creativity, but, from their viewpoint, novelty is the unique source of the phenomenon. This vision is partially shared by Burns (2015), who describes, however, a more tangled interplay between surprise, novelty, usefulness and esthetics.

In a different context with respect to engineering design (Information systems), Dean, Hender, Rodgers, and Santanen (2006) individuate surprise as a dimension that, together with rarity, enables the display of original concepts. The link between surprise and rarity refers to (Horvitz, Apacible, Sarin, & Liao, 2005) too.

Eventually, Im, Bhat, and Lee (2015) take into account novelty and usefulness as constituents of artifacts' creativity, but argue that such dimensions are ineffective to ensure future market success. Indeed, the scholars show the relevance of an additional factor, i.e. coolness, to make products attractive or exciting. Coolness is contextually meant as the capability to arouse positive surprise, whereas the mere presence of novelty can lead to the design of absurd deliverables. Recent studies, still in the market field, emphasize the search for surprise as an attracting factor to get people's attention and achieve market success; Hutter and Hoffmann (2014) discuss unexpectedness of advertising ambiences.

### 2.5. Open issues and objectives of the work

The proposed overview elucidates how the concept of surprise is intrinsically connected with design creativity, but several aspects are not shared by the scientific community. In essence, surprise can be interpreted as a characteristic of novel artifacts, a fundamental facet of creative products or an emotional reaction to original and valuable designs. A deeper knowledge about surprise is hence required, especially with regard to engineering design and within the perspective of evaluating the creativity of new ideas and products. The possibility to recognize and assess the determining factors of creative design outputs is a prerequisite for establishing the contribution of these measures to achieve market success.

According to the above open issues, the objectives of the present paper are thus:

- identifying and verifying the existence of distinguishing traits of surprise that are overlooked by most of the schemes of product creativity, which limit their scopes to novelty and usefulness;
- provide a major understanding about phenomena related to the perception of surprise, in order to enhance the available models for assessing design creativity and, in the long term, predicting the potential of new products in terms of market appraisal.

## 3. Rhodes's 4Ps of creativity and their meaning in surprise emergence

### 3.1. Original formulation of Rhodes' 4Ps

Consistently with the different contributions highlighted in Section 2, it clearly comes out that the emergence of surprise can be also characterized by the 4Ps of Rhodes' dimensions of creativity. The scientist collected several definitions of creativity that

> are not mutually exclusive. They overlap and intertwine. When analysed as through a prism, the content of the definitions forms four strands […]. One of these strands pertains essentially to the Person as a human being. Another strand pertains to the mental Processes that are operative in creative ideas. A third strand pertains to the influence of the ecological Press on the person and on his mental processes. And the fourth strand pertains to ideas. Ideas are always expressed in the forms of either language or craft and this is what we call Products (Rhodes, 1961).

More in detail, the different definitions he analyzed and that support the emergence of the Person strand deal with the traits of the individual who is deemed to be creative. Very different factors are mentioned, such as personality, intellect, temperament, behavior, habits, attitude, and some that may even sound unexpected, as physique and traits. The Person is here considered as the actor who is creative, hence the designer, or the problem solver, in the perspective of design creativity. In other terms, the Person is represented by the individual who is asked to provide novel ideas to attain a target goal.

**Table 1.** Essential comparison between the original 4Ps Rhodes' model and the authors' interpretation in the perspective of surprise evaluation.

| 4 Ps | Rhodes' perspective | Authors' perspective |
|---|---|---|
| Product | The final outcome of the design process (as a target for the designer) | The final outcome of the design process (as an object/idea to be evaluated) |
| Press | The environment and the seeded knowledge in which the design process takes place | The environment and the seeded knowledge in which the evaluation process takes place |
| Person | The designer | The evaluator (e.g. the user) |
| Process | The cognitive process leading from a problem to a solution | The cognitive process through which surprise arises (not considered in this study) |

The Process strand concerns the different activities the Person carries out when she/he is creative. Process deals with very different actions, such as motivation, learning, thinking, communicating, problem solving, etc.

The Press is the "relationship between human beings and their environment." Rhodes wrote that there are forces that push novel needs both inside and outside the Person. Sensations and perceptions, for instance, can come from both internal and external sources. Besides, the Person is exposed to external sources of knowledge and information, including sensory ones, which influence her/his behavior and cognition. For instance, an overload of information may reduce the capability to memorize concepts, as well as to recall and shape idea. On the other hand, Rhodes borrows the words of Gilfillan to clarify that the Press acts as a positive trigger to creativity due to the information and knowledge it produces: "Inventions are not just accidents, nor the inscrutable products of sporadic genius, but have abundant and clear causes in prior scientific and technological development."

The Product to Rhodes is the tangible form of an idea. Products can assume very different forms, such as drawings, words, but also artifacts composed by different materials. Yet, whatever their appearance is, they reflect an idea that has been initially generated as an abstract concept. The idea itself has to be considered as the Product of the creative Process.

### 3.2. Interpretation of Rhodes' 4Ps in the perspective of evaluating surprising artifacts

From the description of these four strands, it emerges that the definition of Rhodes pertains to the designing part of creativity. From his perspective, creativity can manifest into a Product, which has been designed by a Person that followed a thinking Process to generate the idea behind it, under the influence of the Press(ure) for satisfying novel demands due to environmental changes.

The authors share this vision of creativity from the perspective of designing. However, the same four strands appear relevant also from the viewpoint of surprise emergence, even if their meaning needs to be adapted according to the perspective of the individual who senses and evaluates an idea or its embodiment.

This means that the Person to be considered in surprise emergence is not the designing agent, but the evaluating subject (e.g. a user or a stakeholder), whose perception and interpretation of the product (or the idea) might result in a surprised reaction. In this perspective, it is the individual who can be surprised and not the creator of the product. Despite this different angle, the Press exactly reflects the same concept pointed out by Rhodes, since it is the environment by which everyone, even if in different ways, is influenced.

The Product, as well, keeps the same meaning as for Rhodes' description. Indeed, in surprise emergence, the idea that one comes in touch with is the embodied form of the concepts originated by a designer's mind, whatever its form or appearance is.

A significant difference appears on the viewpoint from which the Process can be considered: the creative Process is the one that leads to creative ideas; scholars are still conducting research on effective, efficient, and robust methods and tools to produce such an outcome. As a result, there are just few contributions about heuristics to make this process also capable of coming up with ideas that elicit surprise to the eyes of an evaluator. This kind of creative process still reflects Rhodes' definition.

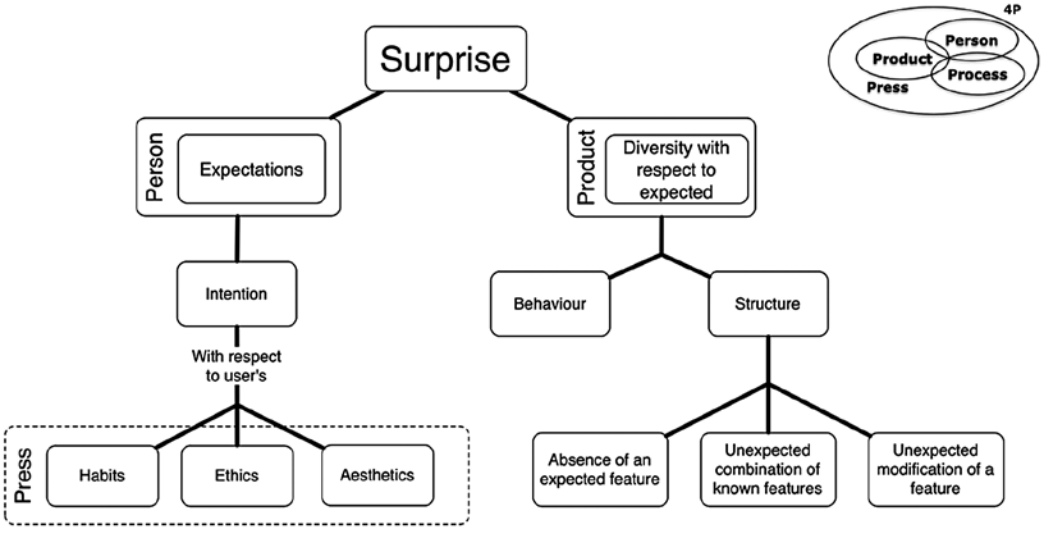


**Figure 1.** The authors' vision about the characteristics potentially triggering the emergence of surprise.

However, it does not pertain to the domain of surprise emergence. The Process concept needs to be redefined here as the cognitive and emotional activities the evaluating subject, more or less consciously, carries out when it perceives a Product and surprise emerges.

The Process will not be considered in the next section, but a preliminary contribution to the characterization of the cognitive processes behind surprise emergence is available in Becattini, Borgianni, Cascini, and Rotini (2015).

For the sake of clarity, the different meanings of 4Ps are summarized in Table 1.

## 4. A model to point out the characteristics of surprising products

Figure 1 proposes the authors' understanding of the potential dimensions triggering surprise. By arising from a deductive process, the model represents a scheme to be tested and further verified, rather than a reference theoretical framework summarizing all the relevant literature contributions.

Indeed, the model depicted in the Figure joins individuated relevant factors, which have been collected by the authors by means of their understanding about the phenomena supposedly determining surprise for a series of original products randomly picked up through the Internet. The articulation of the model clearly reflects the Function – Behavior – Structure ontology (FBS, e.g. Gero & Kannengiesser, 2004), which is well known in the engineering design field and has influenced authors' comprehension of the categories of factors enabling unexpectedness. However, differences can be highlighted with respect to FBS constructs.

On the one hand, the Behavior and the Structure comply with the corresponding ontological entities of the FBS ontology, by potentially dictating the perception of surprise through the display of unexpected peculiarities. More specifically, according to the described adaptation of the Rhodes' 4Ps, there cannot be any surprise if there is no sensorial interaction between a Product (or the idea behind it) and a Person judging it. This implies, on the other hand, that the consideration of the Function deviates from its meaning in the FBS framework, i.e. designers' objective. Indeed, what plays a role in the evaluation of, supposedly surprising, products is the interpretation of the objective set during the design process, mediated through senses and individual perceptions. Still according to authors' understanding, said perceptions can likewise drive toward phenomena of surprise, as a result of mismatches with expectations that evaluators have shaped in light of the Press in which they are

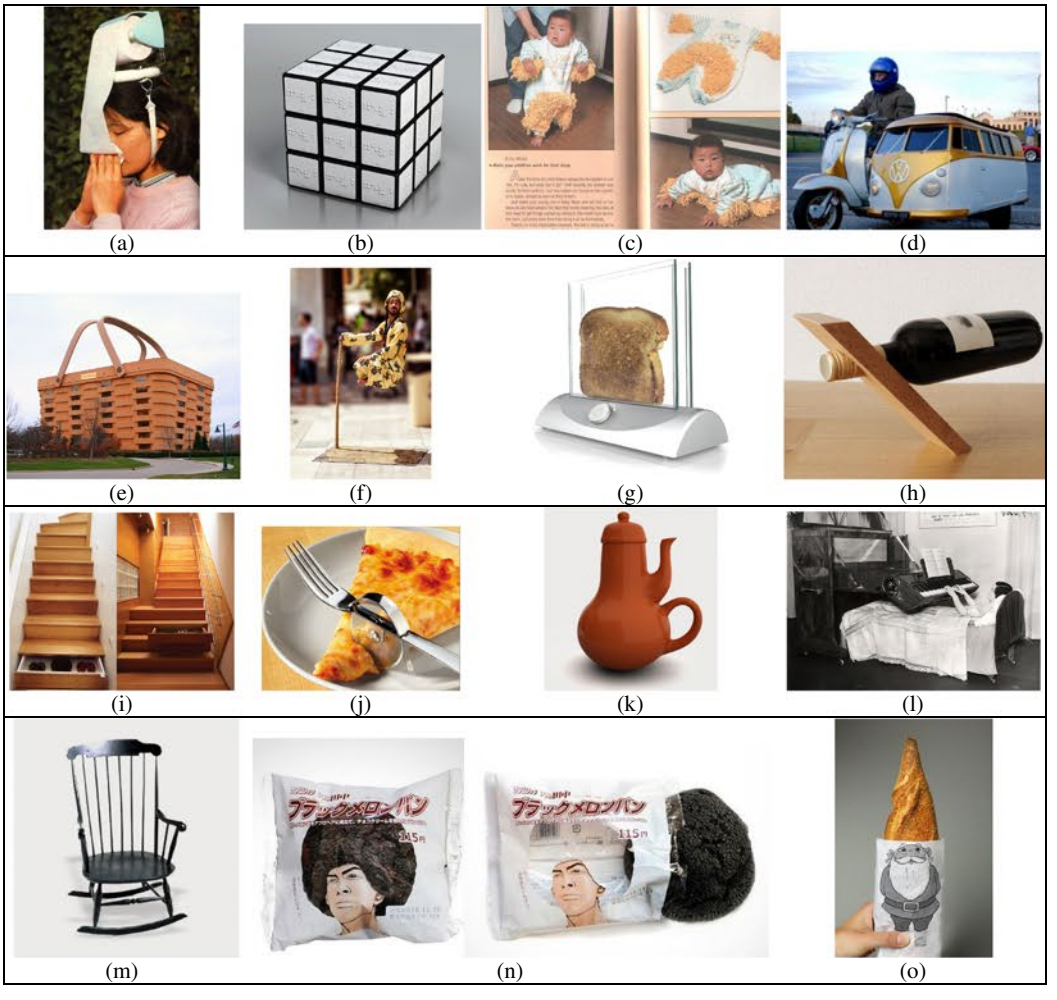


**Figure 2.** Examples of products presenting features directly triggering surprise or inducing surprise by understanding the intentions of the designer.

immersed. Therefore, the Press is constituted by any factor, distinct from the inherent characteristics of the Product, which is capable of dictating the building of an expectation. Ultimately, we can refer to the Press as what exerts social and cultural forces, including individual knowledge, experience, and systems of value.

In coherence with FBS articulation and the required adaptations, the proposed scheme specifies which dimensions mostly pertain to the product itself (here seen as a carrier of surprise by one or more of its features) or to interpretation mechanisms. Examples (pictures collected in Figure 2(a)–(n)), which clarify the meaning of surprise drivers as described at the end of each branch, will be discussed in the following subsections. The left branch of Figure 1 deals with personal interpretations that trigger an unexpected reaction by violating the set of values owned by the individual (Person) that judges according to the mindset of the context (Press). Conversely, the right branch of Figure 1 represents tangible or, more in general, sensible features embedded into the product. It does not mean that the product by itself can be considered as surprising. The personal interpretation of which product features do not match the expectations is still necessary by an observer/evaluator. However, such surprising features are peculiarly embodied into the product.

In these terms, the two main factors characterizing the emergence of surprise are, specifically, the person's expectations and the different features the product owns and that may result unexpected. The former are related to individual- or environment-induced system of values, while the surprised reaction depends on the person's mindset. More gladly such a reaction will be perceived, the higher the matching of surprise with values and beliefs, beyond the degree of mismatching with expectations.

### 4.1. Surprising intention as perceived by the person

This dimension of surprise deals with the interpretation of the intentions underlying a "proposal," as perceived by people. More precisely, a person might get surprised by the mismatch between his interpretation of the motivation behind a certain product or feature and his expectations in the specific context the product in which it is immersed.

Such mismatching may deal with, at least, three main domains:

#### 4.1.1. Habits

Match/Mismatch with social routine, with what is familiar/unfamiliar in a given context or, as well, with events that are more/less frequent to the eyes of the evaluator. Such a specific factor mirrors the findings of the above-mentioned probabilistic approach to evaluate the extent of surprise (Grace et al., 2014). An essential component of the surprise that the toilet roll hat (Figure 2(a)) might provoke is certainly linked with the unexpectedness to show the use of a toilet device in public. It may happen, as well, that something conventional, such as embedding Braille characters to aid visually impaired people, appears as surprising on a certain product (such as Rubik's Cube, Figure 2(b)), due to the lack of specific habits.

#### 4.1.2. Ethics

Match/Mismatch with the concept of "morally right and wrong" in a given context. The suite that makes a baby a mop (Figure 2(c)) generates surprise also because it contrasts what people might consider fair. Besides, despite it being considered right to provide support to impaired people, the above-mentioned example of the Braille Rubik's Cube might generate surprise at first sight. Is such surprise diminished, or at least vanishes more quickly due to the alignment with the ethical expectations?

#### 4.1.3. Esthetics

Match/Mismatch with the perception of beauty, with what is considered nice or ugly. Surprise can be provoked by acting on esthetic standards, as witnessed by examples such as the sidecar in Figure 2(d) and the Longaberger headquarter building in Figure 2(e). In both cases, something with a well-known and appreciated look is proposed out of context, but with opposite outcomes. Indeed, as far as most people describe the former as nice, the latter appears in the top positions of several rankings on the ugliest buildings ever. Such out-of-context proposition of esthetic features can bring surprise to people, but it is required to investigate further to which extent unexpectedness is influenced by the personal perception of beauty.

### 4.2. Surprise deriving from product features diversity

The mismatch between the product features and the related expectations may also depend on intentionally designed product characteristics. These specific characteristics are articulated as shown in the right branch of Figure 1.

Such features can occur at two different levels: the way the system works (Behavior) and what the system is made of (Structure). It is worth noticing that these two aspects can be also mutually tangled, since a change occurring at a structural level may impact on the behavior and vice versa. For instance, an invisible (to the interacting people) structural change may result in a sensibly different behavior for an existing and known product. The floating man (Figure 2(f)) surprises at a first glance because it seems to behave against the laws of physics (or in popular terms, he is not affected by gravity) and

intuition suggests that some structural element is missing. On the other hand, one cannot even imagine at first what the transparent toaster (Figure 2(g)) is used for, since the structure does not resemble any domestic appliance. Then, while it is working, surprise might arise because of the difficulty to imagine how it toasts bread.

Structural changes can be also characterized into further details. Surprise, indeed, can be triggered by structural rearrangements of different types, as proposed hereinafter.

#### 4.2.1. Absence of an expected feature

A typical source of surprise is the lack of a component or a feature that is definitely expected in a certain product. In addition to the above-mentioned floating man (Figure 2(f)), another well-known example is the wine hold that leverages the mass of the wine bottle to stand (Figure 2(h)). The absence of an expected feature is likely to trigger also a wrong interpretation of the system behavior.

#### 4.2.2. Unexpected combination of existing features

A product feature is matched with another one coming from a different system or context and such a combination is unexpected. The stairs with hidden drawers (Figure 2(i)) and the cutting fork for pizza (Figure 2(j)) are two examples of this category. It is interesting to notice that, in the former, the feature combination emerges only when the added (surprising) feature is used, while, in the latter, it is visible at first sight.

#### 4.2.3. Unexpected modification of a feature

A feature is modified (Change) and its specific change is unexpected. More in detail, the unexpected change of a feature may deal with the followings:

- Its aspect or aspect ratio within the product, as for the already mentioned sidecar in Figure 2(d) and Longaberger building in Figure 2(e);
- Its absolute or relative position within the product, as for the well-known "Coffeepot for masochists" (Figure 2(k)), where the surprising placement of the handle and the spout appears as without any logic. Besides, a logical arrangement of features can also result surprising, if non-conventional and unexpected. An example is the piano in Figure 2(l), conceived for those who cannot get out of bed, but difficult to contextualize if seen in a living room with no beds. Also the laterally rocking chair (Figure 2(m)) belongs to this category and it is likely to deliver surprise, especially if an absent-minded user sits on it without noticing the difference and starts rocking. In turn, it is interesting to notice that this surprising features rearrangement may bring to the impossibility to use the object (the Coffeepot for masochists), to the use of the object also by people who would be normally unable, or just to an unconventional usage mode (the laterally rocking chair);
- The perceived meaning of structural characteristics, thus shifting the usage of the product itself to something different, as for the Japanese Pastry Packaging in Figure 2(n). In this case, the dark hair of the character on the package is actually the chocolate pastry itself and, therefore, the surprise emerges when the pastry is pulled out. Another example is the Gnome Bread Packaging (Figure 2(o)), where the bread tip sticking out of the package is surprisingly interpreted as the gnome hat.

## 5. Preliminary verification of the model and discussion of the results

The combination of concepts extracted from literature and empirical evidences about surprising products enabled the identification of surprise arising factors. However, the research approach followed by authors did not ensure the completeness of outcomes in terms of representing all the relevant triggers determining surprise. This issue is deemed important by authors since the exhaustiveness of the proposed framework strongly affects its reliability and future usability to codify users' reactions in front of supposedly surprising or creative products. Therefore, a verification has been carried out to provide preliminary answers to the following questions:

(1) Are the factors encompassed by the model consistent and really capable of mapping the aspects characterizing surprise manifestation?
(2) Besides the already considered ones, does the framework neglect other potentially relevant aspects?

### 5.1. Organization of the questionnaire

The verification was performed through a test planned as follows:

- a sample of odd and potentially surprising products has been identified;
- a respondents sample has been asked to judge and assess the "suprising" products by answering to a specifically developed questionnaire.

Hereinafter, further details are given about the above-summarized activity and collected results.

#### 5.1.1. Respondents sample

The sample is constituted by a total of 23 Ph.D. Students, Researchers and Assistant Researchers coming from Politecnico di Milano, Free University of Bozen/Bolzano, and University of Florence, whose expertise belongs to the field of engineering and design. No information about the framework presented in Section 4 has been shared with respondents before the test.

#### 5.1.2. Products sample

The products sample is constituted by 12 items from the lighting industry, and more specifically lamps. The authors chose this sector for the large availability of examples widely acknowledged as uncanny and bizarre. In order to clarify the peculiar features constituting each lamp, a textual description has been provided to respondents together with some pictures. The whole products sample is reported in Appendix 1 as submitted to respondents, including descriptions and pictures matching the artifacts. The sources for the illustrated surprising lamps and descriptions are (Grimaldi, 2008; Ludden, Schifferstein, & Hekkert, 2008; Rodríguez Ramírez, 2014).

#### 5.1.3. Administered questionnaire

The questionnaire consists of two parts administered in two different steps. The first set of questions aims to perform the screening of proposed lamps according to the respondents' knowledge and their perception of surprise. The questions constituting the first part are the following:

(a) Do you know this lighting device? If Yes, go to question (b), otherwise go to question (c).
(b) Were you surprised when you got in touch with this lighting device for the first time? Answer with Yes or No. If Yes, go to question (d). If No, move to the following product.
(c) Do you believe that this kind of lighting device is surprising or does it present unexpected properties? Answer with Yes or No. If Yes, go to question (d). If No, move to the following product.
(d) If Yes, describe why

The second part of questions leads the surprised respondent to explain personal reasons behind surprise emergence, according to the influencing factors already highlighted by the suggested framework. In addition, a final open question asks to address further reasons triggering surprise. In such a way, the questionnaire helps discover surprise-impacting factors that are not taken into account by the framework.

Furthermore, as remarked in Section 4, some product features might be perceived as negative or positive by people, so generating surprise. This evidence seems particularly relevant for characteristics that belong to Habits, Ethics, and Esthetics categories. Therefore, the questions investigating these aspects have been performed by considering the dual kind of perception that determines surprise.

Eventually, the questions have been administered in a random order to avoid any possible bias effect. Table 2 shows the second part of the questionnaire.

**Table 2.** Second part of the questionnaire: questions investigating surprise triggering factors.

| Factors triggering surprise | Question: I find/found it surprising because it does |
|---|---|
| Habits | (1) Focus on current people's habits and attempt to take them to the extreme |
| | (2) Infringe seeded habits |
| Ethics | (3) Emphasize ethical values |
| | (4) Violate ethical values |
| Esthetics | (5) Stress current esthetical tastes or look extremely good |
| | (6) Mismatch with diffused esthetical tastes or look particularly ugly |
| Behavior | (7) Work or behave in an unexpected way |
| Absence of an expected features | (8) Not include something in its structure I'm used to see or perceive |
| Unexpected combination of known features | (9) Combine something in its structure I'm not used to find together |
| Unexpected modification of a feature | (10) Change something of the structure in a way I wouldn't expect |
| *Other reasons* | (11) Write here |

**Table 3.** Results of the screening: number of surprised respondents for each assessed product.

| Product | Number of respondents |
|---|---|
| On edge lamp | 17 |
| Lamp on/off | 8 |
| Fisherman's tears | 14 |
| Euro-condom | 7 |
| Fly lamp | 6 |
| Titania lamp | 8 |
| Levitating lamp | 21 |
| Leaf lamp | 8 |
| WS/lamp angel | 8 |
| Porca miseria | 11 |
| Flex lamp | 10 |
| Konko | 6 |

#### *5.1.4. Results*

The results of the test are shown in Tables 3 and 4. More precisely:

- Table 3 summarizes the number of surprised respondents for each product;
- Table 4 presents the following outcomes:

- The number of factors that determined respondents' surprise for each product, already considered by the framework (rows from 1 to 10 of Table 2, which are reported in corresponding columns in Table 4);
- The number of surprising aspects addressed by respondents that seem neglected by the proposed model (column "OTHER").

### *5.2. Discussion on the preliminary results*

Despite the sample of people invited to respond to the questionnaire being still limited, the results of this first survey show that the proposed model seems suitable to represent the dimensions characterizing the emergence of surprise.

At first, it should be noticed that:

- all the lamps were considered surprising by at least 6 of the 23 respondents, meaning that they all trigger surprise to a certain number of people;
- surprise is motivated by the respondents through several complementary factors that fall into the list of dimensions proposed by the authors in large majority;
- none of the proposed factors have been considered irrelevant by all the respondents, meaning that all of them appear as influential for triggering surprise in some circumstances;
- some respondents indicated other factors, not included in the proposed list as relevant for inducing surprise.

**Table 4.** Number of answers to the second part of the questionnaire. The numeration of surprising factors and related questions refers to Table 2.

| Surprising factor | Habits | | Ethics | | Esthetics | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Question | (1) Emphasise | (2) Violate | (3) Emphasise | (4) Violate | (5) Emphasise | (6) Mismatch | (7) Unexpeced behavior | (8) Absence of an expected features | (9) Unexpected combination of known features | (10) Unexpected modification of a feature | Other factors |
| On edge lamp | 9 | 13 | 0 | 2 | 1 | 0 | 17 | 14 | 9 | 4 | 1 |
| Lamp on/off | 4 | 4 | 0 | 0 | 2 | 0 | 8 | 8 | 5 | 3 | 0 |
| Fisherman's tears | 0 | 1 | 1 | 0 | 13 | 1 | 3 | 9 | 7 | 8 | 4 |
| Euro-Condom | 1 | 1 | 2 | 0 | 2 | 1 | 4 | 5 | 0 | 7 | 0 |
| Fly lamp | 1 | 0 | 0 | 0 | 4 | 2 | 0 | 3 | 1 | 4 | 1 |
| Titania lamp | 2 | 1 | 0 | 0 | 2 | 3 | 6 | 5 | 2 | 5 | 1 |
| Levitating lamp | 5 | 10 | 0 | 1 | 10 | 0 | 21 | 19 | 15 | 3 | 1 |
| Leaf lamp | 1 | 2 | 0 | 0 | 2 | 1 | 7 | 6 | 6 | 2 | 0 |
| WS/lamp Angel | 3 | 1 | 1 | 0 | 1 | 2 | 6 | 6 | 1 | 6 | 1 |
| Porca Miseria | 2 | 2 | 0 | 0 | 9 | 1 | 0 | 3 | 3 | 5 | 3 |
| FlexLamp | 0 | 4 | 0 | 0 | 1 | 0 | 6 | 10 | 0 | 4 | 1 |
| Konko | 2 | 2 | 1 | 0 | 5 | 1 | 2 | 3 | 1 | 2 | 0 |
| Total answers | 30 | 41 | 5 | 3 | 52 | 12 | 80 | 91 | 50 | 53 | 13 |

The last point would imply that the proposed model misses to represent some aspects that can produce surprise in an observer. Nevertheless, in all the 13 cases registered in this survey, the explanation provided by the respondents seems not related to a factor inducing surprise, but rather to further considerations or judgements expressed by testers. Indeed, exemplary replies to the question "What are the other reasons that surprised you?" are:

- "The atmosphere it produces is wonderful," or "(It) Recall(s) fascinating memory," which seem another way to express what is proposed in factor (5) (see Tables 2 and 4);
- "(It) Changes lighting features continuously," or "it gives a sensation that is not true," which deal with unexpected behavior, i.e. factor (7) (actually, many of the "other factors" appointed by the respondents are definitely explainable in terms of unexpected behavior);
- "It is the only one of these lamps that I would eventually buy," which argues about the outcome of the surprise, rather than about the motivation behind it.
- "When I was 8, I decided that is the lamp that I would like to have in my bedroom. I was searching for colored lights, my parents were not clearly of the same advice. So we found in this lamp the perfect compromise: white light, but with the possibility to change the color of the lamp itself when I wanted to," which points out something that does not deal, at least explicitly, with the factors triggering surprise; it rather provides the rationale behind purchasing choices.

According to the above considerations, the proposed model appears as comprehensive and not oversized, i.e. not referring to irrelevant factors. In fact, Table 4 shows that the answers have been mostly concentrated on specific dimensions while some categories collected just a small amount of records. More specifically, it is worth noticing that both the unexpected behavior and the absence of a feature are often recognized as triggers of surprise (80 and 91 answers, respectively). On the contrary, Ethics has been poorly identified as a critical factor in triggering surprise, even if eight answers witness that some of the lamps represent a surprising violation or reinforcement of respondents' systems of values.

With reference to the validity of the proposed model and its capability to capture the relevant factors triggering surprise, the above two extremes provide significant elements to be discussed. First, the abundance of answers addressing specific factors may lead to consider the existence of sub-dimensions that have not been noticed yet. Second, the model is sufficiently comprehensive to capture also surprising factors which are uncommon, yet existing.

Indeed, especially with reference to the category of Ethics, it is important to notice that the small amount of answers should not be considered as an evidence of poor relevance. On the contrary, the authors believe that this is one of the most significant results of the investigation. Lampsare poorly related to ethical issues intrinsically and, in turn, one's ethics is usually not forged or affected by lamps. Then, if respondents to the questionnaire find a lamp surprising because it violates or reinforce their ethical values, this represents an evidence that the model is comprehensive and capable of capturing the relevant factors, even in a domain in which one should not expect that they are particularly relevant. Moreover, it is worth noticing that the 23 respondents represent a quite homogeneous group in terms of cultural values, being they involved with similar roles in academic institutions; a more heterogenous group could help reduce the effects of cultural biases related to ethical issues. From this perspective, still with reference to Table 4, it is important to notice that zeros in some cells show that none of the respondents find a specific lamp surprising according to the some specific factors of the proposed model. Conversely, it is also worth underlining that none of the above lamps can be considered surprising because of a single factor: the respondents pointed out that at least six factors (Fly lamp) contextually contribute to generate surprise to the eyes of an evaluator. Further studies are necessary to determine if some factors are more relevant than others in determining the emergence of surprise. The analyzed set of objects (lamps) though cannot be considered sufficient to draw any conclusion about the distribution frequency of factors triggering surprise, despite the proposed classification appearing as appropriate to launch an experimental campaign with this objective.

On the other hand, for what concerns the factors that collected the largest number of answers, the authors have not identified more detailed triggers concerning the unexpectedness of products. With

regard to the correlations among different FBS ontological domains, the authors have qualitatively observed that a certain degree of correlation exists between the unexpected behavior and the absence of expected features, which should be considered as a structural characteristic according to the proposed model. However, this correlation needs further investigation, because the missing feature of a specific object is not necessarily sufficient to determine a cause-effect relationship triggering the emergence of surprise as due to an unexpected behavior.

Eventually, the answer reported in the last bullet of the above list suggests a potential correlation between surprise and usefulness. The capability of changing light colors through a screen (Titania lamp) is a novel feature that is not just purely related to esthetics. The function of the lamp generates useful outcomes for its user that, by its own word, was positively surprised. This recorded evidence contributes to the debate about surprise and creativity. Besides, from the same answer, it seems that being surprised by the usefulness of an object produces a persistent effect of surprise, which potentially contradicts the sudden nature of surprise as opposed to the supposed persistent nature of novelty. The latter is considered as persistent if referred to something novel for the whole human kind, but it refers to a subjective phenomenon if the evaluation is taken into account of a user that comes in touch for the first time with an object, consistently with the definition of H-novelty and P-novelty by Boden (1996).

## 6. Conclusions and future activities

The paper proposes a set of triggers that are deemed capable of enabling the manifestation of surprise, whose dimensions and causes hold particular relevance in the field of creativity assessment. These drivers of surprise include evident modifications of product characteristics with respect to existing systems in any reference industrial domain. However, said shifts do not seem to justify the display of surprise by themselves. Indeed, the not negligible role played by human interpretation of creative products contrasts with the vision of scholars that see surprise as a mere dimension or measure of novelty.

The experimental results, obtained through a survey on surprise to which 23 respondents answered, do not provide significant evidence about the existence of any unidentified trait triggering surprise that has been not included in the proposed framework. However, experiments with a wider set of respondents and with questionnaires focusing on different types of products will help make this conclusion more robust. Beyond the extended testing activity, the authors aim at addressing the issues that remain unexplored at the end of this research, such as:

- What are the surprising factors designers should leverage, so that a product or a concept can trigger a surprised reaction in an observer more easily?
- Are these factors independent from each other? Are they intertwined?
- Is there any correlation between surprise and other dimensions of design creativity (e.g. novelty, usefulness, etc.)?
- Is there any relationship between the factors characterizing surprise and the customer's perceived value of innovative products?
- What are the effects of cultural biases in the emergence of creativity?
- Is it possible to describe the patterns of surprising products' evaluation from a cognitive point of view?
- How cognitive factors and emotional statuses of the evaluator interplay?

Larger the set of respondents participating the future testing activities, more precise and statistically significant the results of the above-mentioned investigation activities will be.

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No potential conflict of interest was reported by the authors.

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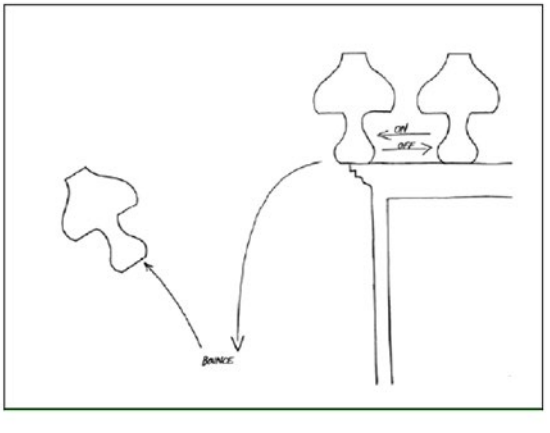
## Appendix 1. The lamps constituting the sample of surprising products for the questionnaire

**On edge lamp**

What is feared of a lamp is that it will fall on the ground and break, and possibly be dangerous because of the glass and electricity involved. To reinforce this fear, the lamp is only on when it is placed on the edge of the table. This creates a sense of suspense, by staging the future fall, and also tends to stimulate people's gut reaction to try to move it to the center of the table. Anyone with children or pets will recognize the tendency to move fragile objects farther from the edge of the table. By moving the lamp onto the table, the user is not only going to touch the lamp, and therefore feel the rubber and realize it will not break, but will also discover that the lamp can only be turned on when on the edge.




The pictures are courtesy of Silvia Grimaldi. For additional information please refer to Grimaldi (2008).

**Lamp On/Off for Luceplan**
The lamp is turned on or off by shifting its weight from one side to the other. The design of the lamp originated as a response to accidentally knocking over the bedside lamp when falling asleep and trying to turn it off. The same kind of gesture can turn the lamp on or off, without knocking it over. For illustrations of the lamp, search images through the string "Lamp On/Off Luceplan" or refer to Rodriguez Ramírez (2014).

**Lacrime del Pescatore (Fisherman's tears)**
A senior lighting designer mentions that in 1975, he saw a fisherman hauling in a net full of fish, and the drops of water falling from the net looked like tears. There was a strong light from the morning sun reflected on the drops. He kept this observation for 35 years and designed the "Lacrime del pescatore" (Fisherman's tears) installation . The design consists of a series of layered nylon nets with 350 crystals representing tears illuminated by a halogen lightbulb.

**Euro-Condom**
A famous designer judges the incandescent lightbulb as 'the most wonderful object made by human beings.' The law introduced in Europe in 2009, which banned frosted incandescent lightbulbs, irritated the designer. His team designed the Euro Condom in response. The design involves a silicon cover that diffuses light just as the frosted incandescent bulbs do.

**Fly lamp**
The designers of this lamp put different animals to the task of affecting their material environment. They also mapped the movement of a fly around a lightbulb in order to design a lamp. For illustrations of the lamp, search images through the string "Fly Lamp Front Design" or refer to Rodriguez Ramírez (2014).

**Titania lamp**
The lamp Titania by a senior designer changes color when the user changes a filter. The designer mentions that the initial intention in designing Titania was to explore the form of a plane's wing. They discovered the property of changing the light's color by experimenting with different materials to decide which colors of plastic the lamp should be offered in. They found that including only one colored sheet of plastic was enough to change the color of the whole lamp, which was an unexpected finding. This was surprising to the designers, who assumed that their customers could be surprised by the same effect too. For illustrations of the lamp, search images through the string "Titania Luceplan" or refer to Rodriguez Ramírez (2014).

**Levitating lamp**
The design is created with what would seem an impossible characteristic that defies the laws of nature. The result is a lamp that levitates. For illustrations of the lamp, lamp search images through the string "Levitating Lamp Front Design" or refer to Rodriguez Ramírez (2014).

**Leaf lamp**
The Leaf lamp features a touch-sensitive area on which it is necessary to run one's finger along the surface of the base to dim the light up or down. There is no visible moving switch. For illustrations of the lamp, search images through the string "Leaf Lamp Fuseproject" or refer to Rodriguez Ramírez (2014).

**Workstation/lamp Angel**
The workstation/lamp Angel uses the form of an archetypal bedside table lamp on a much bigger scale. For illustrations of the lamp, search images through the string "Naos Angel Desk Lamp" or refer to Rodriguez Ramírez (2014).

**Porca Miseria!**
The lamp "Porca Miseria!" consists of broken pieces of expensive porcelain tableware, making it a lamp with a unique shape. Pictures of the lamps "Lacrime del Pescatore", "Euro-Condom" and "Porca Miseria!" are courtesy of Ingo Maurer, www.ingo-maurer.com. Credit: © Ingo Maurer GmbH, Munich, Germany.

**Flexlamp**

The material of the lamp seems a familiar material, but, actually, it is a new material and someone touching it feels different than what he/she was thinking. Indeed, the lamp looks like it is made out of matt glass. Again, it resembles typical glass lamps in shape and surface texture. This lamp is actually made out of flexible polyurethane rubber, and it feels much more flexible than a lamp made out of glass. The pictures of Flexlamp are courtesy of Industrial Facility: www.industrialfacility.co.uk. Design: Industrial Facility / Sam Hecht. Photography: Copyright Industrial Facility.

**Konko**

Alternative or new production techniques can be used to create new shapes for known materials. The lamp is made using a 3D printing technique, creating a new shape for a lamp and for the material, a polyamide. The lamp looks like it is made out of cloth or paper, and may be expected to feel light and flexible. However, it feels solid, heavy, and unflexible. The picture of Konko lamp is courtesy of its designers Willeke Evenhuis and Alex Gabriel.