



WHAT SURPRISED YOU? A QUESTIONNAIRE TO MAP UNEXPECTEDNESS THROUGH FBS VARIABLES

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Abstract: The paper presents the analysis of an original online survey that aims at checking the factors triggering surprise in randomly chosen evaluators who were submitted a set of surprising products. The authors use the answers to check the capability of a situated FBS-based model to help catch the main factors triggering surprise in products, here seen as a mismatch between what is interpreted and previously conceived expectations. The survey questionnaire shows to be effective in grabbing surprising factors and the results demonstrate that the model allows a strong ex-post convergence in the investigation of surprising factors.

Keywords: *surprising products, cognitive processes, Function-Behaviour-Structure*

1. Introduction and background

According to literature sources from different fields, creativity does not ensure the delivery of successful designs and products. Among influential factors, various forms of surprise and emotional attractiveness are supposed to play a relevant role in the achievement of success for what concerns physical products (Im et al., 2015) and beyond (Gross and Bürglen, 2014; Hutter and Hoffmann, 2014). With respect to surprise in product design, the overlap with the main creativity dimensions (novelty in particular) is illustrated by several works, including recent authors' contributions. This can be claimed despite the disagreement of scholars with respect to the role of surprise within design creativity. Differences are particularly evident if cognitive aspects are taken into account.

On the one hand, the cognitive nature of the creative process in design has been largely discussed in the literature, leading to the definition of approaches and procedures that maximise the display of designers' innovativeness and talent (Howard et al., 2008). On the other hand, cognition studies about surprise in design are not diffused. It is worth noting that this lack hinders the definition of strategies to design surprising artefacts. At the same time, whereas the fundamental locus of creativity lies in the design act, the manifestation of surprise happens when the artefact is observed and evaluated (Wiggings, 2008). In this

sense, the authors decided to investigate this peculiar phenomenon and hypothesized which cognitive processes could be relevant in the evaluation of products considered surprising (Becattini et al., 2015-b). The problem was preliminarily approached through the identification of processes classified according to the situated Function-Behaviour-Structure model, by applying a shift from the designer's to the evaluator's perspective. At the same time, the authors focused on those actions that are more directly connected with mismatches leading to surprise.

Indeed, literature acknowledges a link between surprise and concepts like unexpectedness with respect to individual knowledge and beliefs (e.g. O'Quin and Besemer, 2006). Certain works relate surprise with unfamiliar combinations (Van Rompay & Ludden, 2015) or with the introduction of infrequent events, thus linking it with rarity (Horvitz et al., 2005; Dean et al., 2006). In several studies, the effect of unexpected or uncommon phenomena is observed insightfully. For instance, Ludden et al. (2012) conducted articulated experiments by leveraging sensory inconsistencies, i.e. visual and tactile. However, those studies do not allow to define a general model for surprise cognition tailored to engineering and product design.

In order to fulfil this objective, the authors recall the proposed model and highlight those processes at the climax of surprise manifestation (Section 2). Section 3 describes the development of a test strategy to confirm the validity of authors' assumptions, i.e. the presence of fundamental well-distinguishable processes in the display of surprise and corollary processes that contribute in terms of fostering intuitiveness, recalling existing and building new knowledge. Section 4 discusses the findings of the paper and describes future work.

2. Proposed model for monitoring the emergence of evaluators' surprise

Previous works have already tackled the issue of identifying the design factors involved in the emergence of surprise to the eyes of evaluators (Becattini et al., 2015-a). Even if considered from the perspective of an evaluator and not a designer, those factors deal with three of the facets characterizing creativity, namely the product, the person and the press (Rhodes, 1961). On this basis, the authors also proposed a model that is potentially capable of describing the cognitive process behind the emergence of surprise (Becattini et al., 2015-b). This model, represented in Figure 2, adopts the same ontological variables (Function, Behaviour and Structure) of the situated-FBS model by Gero and Kannengiesser (2004) and its three worlds characterizing situatedness (where the reference subject is shifted from the designer to the evaluator):

- “The *external world* is the world that is composed of representations outside the subject”;
- “The *interpreted world* is the world that is built up inside the subject in terms of sensory experiences, perceptions and concepts”;
- “The *expected world* is the world that the imagined actions of the subject will produce” (it is part of the interpreted world).

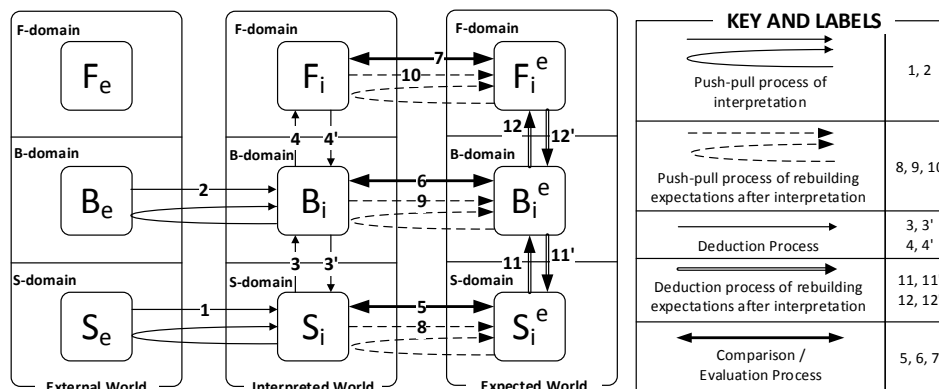


Figure 1. The model of cognition describing the emergence of surprise (processes #5, 6 and 7)

Surprise emerges when the interpreted representation of product features (being related to functional, behavioural or structural variables) does not match the existing expectations that one builds through previous experiences (processes labeled 5, 6 and 7). The other processes the model aims at describing go beyond the purpose of this paper, their complete description is available in (Becattini et al., 2015-b).

3. Description of the survey and of the preliminary results

3.1 Aim of the experiment and selection of the experimental approach

This section presents the experimental activity the authors have carried out to check, with external observers, the applicability of the proposed model to describe cognition within the emergence of surprise. Through the experiment, the authors aim at checking what happens at the cognitive level, beyond the observers' senses, when they have to evaluate an object that they consider surprising. Cognitive analysis in design is usually carried out through behavioural studies allowing for the ex-post reconstruction of protocols (Gero and McNeill, 1998), their segmentation and coding with appropriate schemes (Dekoninck et al., 2010). The FBS model presented in Section 2 has been adopted as one of such coding schemes too (Kan and Gero, 2009; McNeill et al, 1998) both for protocols of groups and single designers, either in thinking aloud when designing or in ex-post descriptions of their thread of thought during design.

Considering the shift of perspective from the designer to the user/observer, the researchers carrying out such studies should have poor or no contact with the thinking subject during their activity in order not to influence their cognition. To this purpose, the authors considered the implications of carrying out a protocol study with a large number of testing subjects who individually carry out their evaluation of the proposed surprising objects. The involvement of a large number of testing subjects would allow to draw conclusions supported with higher statistical significance, but, at the same time, it would increase the time required for the transcription, the segmentation, the coding and the analysis of the protocols (the duration ratio protocol: protocol analysis typically ranges between 1:10 and 1:100).

The authors also considered procedures to capture the opinion of product evaluators in the marketing domain, where it is critical to gather the Voice of the Customer (Griffin and Hauser, 1993). Those approaches leveraging live interaction in focus groups are not suitable for the purposes of the current investigation because of both the individual nature of surprise emergence and the testing mechanisms, which would require a protocol analysis-like approach for the investigation of the results. Interviews, in turn, allow to reduce the time needed for the analysis, but might affect the interviewees' cognition, given their direct contact with the interviewer. The administration of questionnaires apparently presents similar limitations with the interviews, because questions, even if written, surely affect the cognition of the reader, at least by triggering reflections on the meaning of the question and about the required answer. On the other hand, questionnaires provide a structured way to gather and process data to speed up the analysis (i.e. the interviewer is not present), also with a large number of participants. Considering the above presented strengths and weaknesses, the authors opted to carry out the experiment through the administration of a questionnaire. In order to deal with the potential bias on results through questions that trigger cognition towards model-dependent paths, the authors took care of both the formulation of questions and their sequence. The development of the questionnaire is described in the next subsection.

3.2 Development of the questionnaire

The development of the questionnaire occurred with a three-step process, in order to check its effectiveness both in terms of the ease of comprehending the questions and their robustness beyond language and knowledge barriers, as shown in Figure 2. The Figure indicates the overall structure of the questionnaire, the number of responses provided in the first two development steps and the planned final investigation for the latest version. The involvement of 100 anonymous evaluators concerns an ongoing process; the positive results, which will be presented in Section 3.3 and refer to the first five respondents, have encouraged the authors to carry out a large-scale investigation.

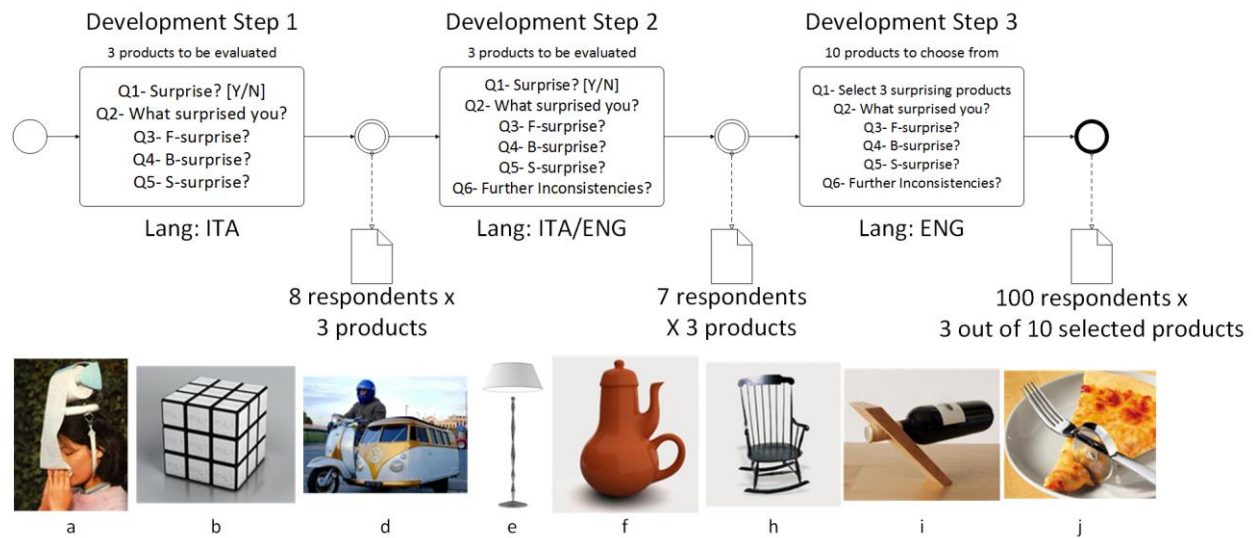


Figure 2. The 3-step development process of the questionnaire (top) and the 8 out of the 10 products presented in the last version of the questionnaire (those mentioned in Table 2, down).

All the different versions of the questionnaire presented an open question at the beginning, followed by other questions (Q3, 4, 5): each of them is specifically focused on inconsistencies about a given FBS variable, i.e. “Can you clearly understand how the product works?...” concerns behavioural aspects. The terminology included in the questions allows respondents, according to authors’ intention, to express their feelings and considerations without being knowledgeable of Gero’s framework. This overall structure is intended to minimise the biasing of respondents’ cognition and to check if the answers to questions Q3, 4, 5 are consistent with what declared through Q2. Although biasing phenomena are not excluded a priori, the sequence of questions allows to discard the questionnaires with no reference between the answer to the open question and the more focused ones, which is considered as an evidence of FBS-related question bias. For the sake of brevity, the final version of the questionnaire, together with the 10 potentially surprising products to choose from, is fully available at <https://goo.gl/83aTR5>. The introduction of a selection process made by respondents, who were asked to pick up the three most surprising products, is motivated by the need of getting evaluations about artefacts that were presumably not known before.

3.3 Experiment setting and criteria for data analysis

The questionnaire was designed in order to facilitate its administration to a large number of people, so that the results can be also used in the future to draw further conclusions beyond the ones concerning the applicability of the proposed model, as for the aim of current study.

For this first round, five randomly selected users (which provided answers for three surprising products each) electronically accessed the questionnaire via the website <http://www.microworkers.com>. In order to minimise the language biases, respondents have been restricted to users registered to the web service in English speaking countries (US, GB, CA, AU, and NZ). The questionnaire could be completed in 45 minutes or less, but longer durations were allowed. The web service collects the input data as text. Results come as comma-separated values and each row corresponds to the answers of a single respondent. The web service provides instruments to avoid the same respondent to access the questionnaire twice. The limited number of completed questionnaires, besides insufficient for statistical purposes, overcomes the quantity of tests carried out in previous studies having a similar purpose (Cascini et al, 2012; Gero and Kannengiesser, 2004) and it is deemed sufficient for the viability of the procedure to monitor cognitive processes concerning surprise emergence.

As in a standard protocol study in design, answers require to be coded according to the model proposed as a coding scheme. To this purpose, the authors processed the results by interpreting them and identifying clear, despite unaware, references to the FBS ontological variables and the world they belong to, by stressing which ones resulted mainly responsible for surprise. Otherwise said, the interpretation and coding of the answers should identify:

- The FBS ontological variables playing an evident role in determining the emergence of surprise;
- The mismatches between FBS variables of the same kind in the comparison between the interpreted and the expected world.

Moreover, the coding might help highlight the potential emergence of deduction processes showing links between FBS variables within the same world ($S \leftarrow \rightarrow B$ or $B \leftarrow \rightarrow F$).

It is evident that interpretation of results may introduce a further (communication) bias, beyond the one that already occurs between the observer's cognition and what is made explicit in a written form. In order to check the impact of such a bias, the four authors individually carried out the analysis of the answers, with no access to the coding of the others. In the present contribution, the authors intend to demonstrate the non-randomness of unexpected FBS variables' designations according to respondents' answers with the aim of verifying the robustness of the employed procedure. The following hypothesis H0 should be therefore investigated by means of statistical tools:

H0: the coherence of judgments between knowledgeable analysers is random when individuating unexpected FBS variables with reference to respondents' declarations based on the proposed questionnaire and concerning their reaction towards surprising products.

3.4 Analysis of the results

In order to provide readers with insights into the given respondents' statements, Table 1 presents the answers of the first respondent about product 1 (a – toilet paper hat), together with the consistent interpretation of the four authors with regards to involved FBS variables.

Within the example of Table 1, the first answer to the questionnaire clearly points the attention to structural features that are reconsidered also in fourth answer. Table 2 presents the summary of the variables involved in the emergence of surprise, as interpreted by each author similarly to the above Table 1, for the whole set of fifteen products.

Table 1. An example of answers to the questionnaire (second column) for each query (identified through the first column) and the related interpretation of FBS variables as carried out by the four authors.

ID	Answer	Author's comments
1	I found the toilet tissue being attached to the woman's headgear surprising. This is a location I've never seen toilet tissue held before.	Author 1: S-related characteristics interpreted as not matching the expectations; Author 2: Structural features interpreted as not fitting the expectations; Author 3: Structure, attribute (location of element) is different from expectation; Author 4: A structural part of the system (toilet tissue) is not in the expected location.
2	It is clear that the head gear is used like regular toilet tissue -- to wipe and clean up, particularly the nose/face (that's why it's attached to the head, for convenient access to the face).	Author 3: Function correctly interpreted and not considered surprising
3	Yes, I can understand how the product works. When a person feels they need to wipe up or clean something, they can easily reach up to the headgear and take some toilet tissue from it.	Author 3: Mode of use (Behavioural variable) correctly interpreted and not considered surprising

4	Yes, I was not expecting the head attachment to be there. Usually, toilet tissue is in rooms and not attached to the body.	Author 1: Structural feature (position of the toilet paper) not consistent with the value it gets (head of the holder); Author 2: Structural features interpreted as not fitting the expectations; Author 3: Structure, attribute (location of element) is different from expectation; Author 4: The triggering factor is not the presence or the absence of a feature but the unusual position of a part of the system
5	No, I did not find any inconsistencies between the product features, the way they work, and their purpose. It is clear that the headgear provides easy access to the toilet paper to wipe and clean anytime a person needs it.	

Table 2. Summary of the variables triggering surprise according to the interpretation of the questionnaire.

Resp.-Prod.	A-a	A-b	A-e	B-i	B-f	B-d	C-a	C-j	C-h	D-f	D-h	D-b	E-j	E-b	E-d
Author 1	S	S	S	B	S	S	S	S	B	S	S	S	-	F	S
Author 2	S	F	S	B	S	S	S	S	B	S	B	S	-	F	S
Author 3	S	S	S	B	S	S	S	S	B	S	B	S	?	F	S
Author 4	S	S	B	B	S	S	S	S	B	S	B	F	F	F	S
Agreement	4/4	3/4	3/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	3/4	3/4	NO	4/4	4/4

Just in one case out of fifteen (respondent: E, object: j – fork/pizza cutter) the authors denoted difficulties in interpreting with a sufficient degree of confidence the ontological domain in which surprise emerges. This lack of clarity is evident since the first answer:

Answer E-j to question #1: “I think the product is very inventive. It would make eating pizza much easier. Cheese falling off is always a problem for me, so this would solve it”.

It is possible to infer from the above answer that the combination of two elements that are usually not connected to each other (S, attribute) seems to be a novelty for this respondent. However, it is not crystal clear whether this novelty is also surprising. The respondent seems to appreciate the intent as well (F), even if the advantages they are convinced to gain with the novel way of working (B) are not univocally understandable. The statement in italic, however, does not clearly mention which is the ontological domain involved in surprise emergence, even if one of the authors recognized it as a functional variable.

This hypothesis, however, is not fully confirmed by the answer concerning the purpose of the object.

Answer E-j to question #2: It is very clear how the product works and what it is used for. I think this would be a huge success among the as seen on TV products. It is unique and has a really useful purpose.

Considering the potentially emerging lacks in the interpretation from the authors, the absence of clear reasons explaining what the product is for, as requested by question #2, and because of the lack of coherence between answer #1 and answer #2, the test labelled E-j is the only one discarded from the analysis.

The investigation of the above-formulated hypothesis H0 is performed as follows.

3.4.1. Non-randomness of the designation procedure for unexpected FBS variables

The designation made by each of the four authors could lead to the following circumstances with reference to the most frequently identified FBS variable:

- it appears twice (54 out of 81 possible combinations);
- it appears 3 times (24 out of 81 possible combinations);
- it appears 4 times (3 out of 81 possible combinations), i.e. there is a complete agreement.

With reference to the above events and their corresponding probabilities, under the initial hypothesis that F, B and S variable are equivalently probable (as in a random setting), Table 3 illustrates the difference between expected and observed situations, as described the above bullet list and taking into account 14 independent experiments (the designations of all the 4 authors).

Table 3. Number of expected and observed situations in terms of the highest frequency of FBS variables' designation out of 14 independent observations.

Frequency of most designated variable	2	3	4
Expected cases	9.33	4.15	0.52
Observed cases	0	4	10

The data reported in Table 3 allow to calculate the χ^2 statistic for the two distributions: the Yates correction is necessary in this case, because of the low probability of a particular event and the limited number of experiments. The variable χ^2 assumes the value of roughly 166 in a situation with 2 degrees of freedom. These values enable the determination of the corresponding p-value for the hypothesis formulated in Section 3.3, which approximates to 0 (order of magnitude 10^{-39}), thus leading to reject the H0 undeniably. In the other terms, the randomness of the authors' convergence towards unexpected FBS variables is ruled out definitively.

In truth, the assumption of an equal frequency of FBS variables in authors' indications seems questionable in light of the majority of S designations, whose potential causes are investigated in the next subsection. However, the strong confidence about the H0 allows authors not to conduct further data analysis to demonstrate the non-randomness of the convergence process, although the outcomes could result inexact.

3.4.2. *Insightful analysis of the results and further comments*

The further analysis of the outcomes that is included in this subsection takes into account the designation of the majority of the authors, which clearly emerges in all valid 14 cases.

With reference to the FBS variables involved in the emergence of surprise, Table 2 shows that functional aspects of the observed object triggered surprise in just one case out of fourteen, while behaviour-related elements were involved in three cases. Structural characteristics of the evaluated objects, in turn, were considered responsible for surprise emergence in 10 cases. The authors consider that this unbalance among FBS variables involved in surprise emergence mainly depends on the way the experiment has been administered. Indeed, the presentation of potentially surprising objects through pictures, which are static images, provides information concerning the structural variables largely, but less elements about the behavioural or functional ones, which an observer can just infer in most cases. The side-to-side rocking chair perfectly points out this issue: some of the respondents were surprised by the twisted position of the rockers, while others directly referred to the motion that the object produces despite they were both considering the same picture. It would be likely different to expose the same subject to a short movie where one can just see the seatback tilting and a person rocking side-to-side. In such a case, the structural features of the object under evaluation would be even less evident than the behavioural ones.

Still within the fourteen analysed products of Table 2, different cognitive reactions emerged among the respondents. A respondent can feel surprised just by considering facets referring to a single FBS variable. However, there are also cases in which the respondent refers to more than one FBS variable as for the case A-b, where the considered object is the Rubik's cube for blind people:

Answer A-b to question #1: I found the fact that all of the squares on the Rubik's cube white to be surprising because the whole point of the Rubik's cube is to match the colors up on each side.

This example is among the most significant ones for what concerns the occurrence of cognitive processes beyond the comparison of the same variable between the interpreted and expected world. The mismatch depends on a structural feature of the game (all the squares are white but squares should have colors). The answer, however, also refers to the purpose of the game ("[...] is to match colors up on each side [of the cube]), which can be more directly referred to characteristics concerning the functional domain. It is clear that the respondent did not notice the presence of the Braille code on the different facets (from the external world). This wrong interpretation leads them to a structural mismatch with the expectations that have been built through the experience of the more common coloured Rubik's cube. Considering the whole set of

answers for the A – b case, the respondent clearly demonstrated that they had no idea of how the player should deal with the white Rubik's cube and what its purpose can be. In other words, this represents a case in which surprise does not trigger further reflections or the need, in the observer, for conferring a new meaning to what they just experienced.

On the contrary, the case E – b shows a significant difference with respect to the previous excerpt:

Answer E-b to question #1: I think the idea of the blind being able to do a Rubik's cube is incredible. I think it is a nice spin on an old classic

The observer here just referred to the function of the game, catching the intention of the designer to allow blind people to play with something that usually requires sight, but with no reference to the white color of the cube faces.

Answer E-b to question #4: I am not use to seeing braille at all. I don't know too many people who are blind. I feel that the complete white color of a Rubik's cube throws me off as well. It should still probably have color to it.

In the above answer, in turn, the respondent clearly stated that the structural characteristics were among the ones that triggered surprise (the white color [...] throws me off as well). Despite in this and in A-b case both structural and functional characteristics contributed to the generation of surprise, the latter excerpt shows that respondent A managed to interpret the external world properly and, thanks to this appropriate interpretation, to build new meaning out of what they experienced. Once the structural features are properly interpreted (white + braille), the constructive memory of the observer is updated with novel paths conferring meaning to the game. In this way, the observer can both understand how it works (B) and what is the purpose of this version of the game (F), which still remains surprising.

The attitude towards the building of meaning on what is experienced (and the consequent update of the constructive memory) is also present in several other answers among the ones processed for this study. Another interesting example is the flying lamp (labelled e in Figure 3) as evaluated by the respondent A.

Answer A-e to question #1: I found the fact that the lamp cover is hovering above the post to be surprising since I thought that the bulb had to be attached to the post for the lamp to function

Answer A-e to question #3: It is not clear how this works because I don't know how the lamp would light the room if the cover/bulb are not attached to the lamp post. It may be controlled wirelessly, but I am not sure by just looking at the picture.

The first answer shows that the mismatch triggering surprise depends on structural characteristics. This mismatch, however, is among the ones in which the observer is not fully capable of understanding purpose and working principles through deductive processes based on their previous knowledge stored in their constructive memory. The answer to question #3, differently from the ones discussed before, highlights the attitude of attempting to daydream in the search of a meaning to be clarified. Despite this kind of reasoning (even if more targeted) appears to be more common in design activities, here the observer produces some hypothesis that should account for a more general principle that, in this specific case, deals with the hovering of the lamp shade and the capability to generate light. The attempt is particularly naïve ([...] *it may be controlled wirelessly*), but the authors would like to continue the investigation about the potential emergence of abductive reasoning when surprise emerges also in users/observers. Such kind of investigation would contribute to shedding light on potential positive correlates with the supposed increased attractiveness of surprising products and on the mechanisms through which they trigger curiosity (here seen as the need/appetite for new information capable of explaining what does not match the concepts stored in the constructive memory).

4. Final remarks and future work

This paper presents an original research to define a model capable of mapping the situated cognition underlying the emergence of surprise in an agent that acts as an observer, potentially as an evaluator. The purpose is the creation of a model capable of clarifying the phenomenon of surprise, to improve the understanding behind it and nurturing further studies, which aim at supporting the definition of guidelines

or strategies for designing surprising products. Moreover, in parallel with the recent evolution of techniques to record and map emotions with biosensors in product evaluation sessions, a model characterizing surprise emergence would also support those investigations from the perspective of cognition. Consistently with literature, the model works under the assumption that surprise emerges when reality (what is sensed out of it) does not match observers' expectations. In order to discern the different nature of expectation mismatches that can trigger surprise, the model relies on some of the main constructs of the situated FBS framework. It also embeds an original set of cognitive processes for explaining the emergence of surprise in situatedness.

In order to check the model effectiveness, the authors have carried out an experiment with external participants. A tailored questionnaire has been developed and refined along a three-step process to take into account the effectiveness of the questions. The authors have interpreted the answers individually in order to highlight which variables are involved in the mismatches between interpretations and expectations that trigger surprise. The strongly statistically significant coherence among authors' evaluations proves the effectiveness of the model for its intended purpose. Besides, the model allows to display different ways of surprise emergence for the same object under the evaluator's attention and no specific deficiency of representation arises.

Speculative insights drawn from the processed answers are also presented in order to highlight potential limits of the approach together with novel elements regarding cognition in product evaluation.

Given the promising results, the authors are currently continuing the activity by extending the number of questionnaire respondents (the target is indicated in Figure 2), so as to gather novel insights about the role played by surprise in product appreciation and the involved cognitive phenomena, such as the emergence of abductive reasoning. Besides, the authors intend to readapt and use the model to map and analyse the experimental behaviour of users in field tests, e.g. in the preliminary marketing campaign of new consumer products. The ultimate goal is to codify the mechanisms behind the stimulation of surprise and to identify the traits that prompt wonder, amazement, astonishment or curiosity into users, so as to exploit these findings in a *design for surprise* paradigm.

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