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Testing the Usability of Guidelines for the Design of Surprising Products

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Abstract

The paper introduces guidelines to support designers to generate ideas for the development of surprising products. The guidelines are structured coherently with the concept of sensory incongruity and the Function-Behaviour-Structure framework to create a mismatch between previously conceived expectations and product features. The usability of the interactive presentation is checked with an experiment that involved more than 30 subjects with a background in product design (mechanical engineers and industrial designers), which demonstrated to be capable of generating ideas using the same.

Keywords: product design, idea generation, surprise, expectations, user-centred design

1. Context and Objective

1.1. Context and Motivation

Surprise has certainly gained fame and caught the attention of many designers and researchers in the field of product design, where many contributions by different parties have claimed that surprise can be a decisive factor behind the success of a product. A surprising product tends to entice by altering the senses of the audience. This alteration leads to one questioning what they sense in general and then comparing that with what would be naturally expected from that product.

Surprising products can come in a form of a joke, or simply creating something against what the mind would naturally expect. Due to this element of attractiveness, and thanks to the naturally curious human mind and its interest in assessing peculiarities, surprising products tend to have an edge over the typical expected products. Apart from the first attractiveness, the audience has towards the surprising products; once owned, this product occasionally influences personal attachment, the overall likability of the product, the importance of its presence and hence the low probability of it being disposed of (Grimaldi, 2017). Studies however have revealed that surprise is not a static phenomenon, where the level of surprise one has due to an interaction with a product may fade with time (Ludden et al., 2012a).

Despite all such studies, existing literature has barely touched on matters related to the actual designing for surprise as these studies are addressing surprise through descriptions rather than prescriptions. Becattini et al. (2020) said that the requirements to elicit unexpectedness, as they stand, cannot be directly used as a designing tool. Designers, therefore, should rely on their talent to generate ideas for surprising products, as they are yet to have systematic guidelines to generate ideas for surprising products.

This paper, hence, aims at leveraging the findings on surprise emergence and elicitation to develop guidelines that can be used to create conceptual ideas for surprising products and test their usability. The guidelines should allow users from different backgrounds to be able to use them. These shall be meant to practically explore and expand the creative horizons of the designers and motivate them to reach a higher level of abstraction to capture the wonders of the creative mind in a step-by-step procedure.

Most importantly, the authors aim to create guidelines that are comprehensive and repeatable to allow the designers to find surprising ideas for an infinite range of products as many times as they see fit.
The guidelines, due to their early development, first require a test for usability as a methodological tool, before checking their effectiveness to generate ideas for surprising products. To address this, the authors structured the paper as follows.
The next section explores the relevant background, whose main elements will be originally exploited within the framework of the situated FBS ontology (Gero and Kannengiesser, 2004), declined for surprise emergence. This will work as the backbone of the guidelines, whose structure is proposed in Section 3 together with the description of the experiment to assess their usability as a methodological tool to generate ideas. Section 4 showcases the relevant results and discuss the findings so that the conclusions summarize the outcomes of the research and the future potential paths that can be exploited.

2. Relevant Literature

2.1. Surprise

Some authors have mentioned that surprise is a degree of novelty (Chiu and Shu, 2012 and Besemer, 2000). According to Besemer and O'Quin (1999), surprise is related to the presence of an unexpected attribute in terms of novelty of information from the point of view of the user.
Other authors have agreed on stating that surprise and novelty are in two different dimensions. According to Maher (2001), the difference between novelty and surprise stands in the reference concept. In other words, novelty means that something has never been made previously, while surprise comes off a trajectory of a family of already existing products (Maher et al., 2013). Other contributions have set surprise on the same level as novelty, as being among the main pillars of the characteristics of a creative design. Those pillars are Novelty, Value and Surprise (Maher and Fisher, 2012). Similarly, Han et al. (2019) claimed that novelty, usefulness, and surprise are core elements for design creativity.
However, further contributions have stated that even though novelty and surprise are two distinct things, they are still related to one another, where, for example, a surprising product is novel, but a novel product may not always be surprising (Maher et al., 2013).
As mentioned earlier, surprise is a big factor that leads to the overall attractiveness of the product. Surprise is given little attention in comparison to other design outcomes (Maher et al., 2013). However, designing for surprise could be a functioning tactic to realize an interesting product (Ludden et al., 2008). The presence of a surprising feature, even though may lead to slight confusion, in turn, leads to an overshadowing amusement that will give the surprising product an advantage over its non-surprising counterpart (Ludden et al., 2012b). Surprise, as much as it can be amusing, can also lead to the unlikability of a product through confusion and elicitation of negative emotions (Ludden et al., 2012b). Hence, not all surprises can be labelled as a good surprise, where one gets a pleasant after-effect. A surprising product may backfire, hence leading to a very unpleasant feeling towards that product and hence labelling this product as a non-likeable product. However, even though surprise may affect the attractiveness of a product, surprise is not a stagnant feature. According to Ludden et al. (2012a), surprise weakens over time, but it is still existent and measurable on different occasions.
The main reason behind surprise sprouts from how the expectations of a product are violated and to what degree (Grace et al., 2015). The process by which this surprise happens is that the user analyses what they sense and compare it to what they would expect. Once one or more of the analysed attributes or values do not align with the expectations, a surprising feeling arises. Even though surprise seems to be an evasive concept, Becattini et al. (2015; 2017) managed to successfully capture surprise emergence at the cognitive level using a framework known as the situated FBS framework.

2.2. Situated FBS in the Context of Surprise Emergence

The FBS ontology describes the designer's cognitive processes to realize a design through three variables: F, B and S. They stand for Function, Behaviour and Structure, respectively (Gero and Rosenman, 1990). The structure is the elements, attributes, and relationships within a product (Gero and Kannengiesser, 2002). Behaviour describes how a product carries out its purpose

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through its defined structure (Gero and Kannengiesser, 2004). Function is the purpose towards why a product exists (Gero et al., 1992) or as the purpose behind the existence of a product, factoring out affordances (Gero and Kannengiesser, 2004). Function has also been defined as the relationship between the user and the behaviour of a system (Bobrow, 1984).

Affordance was a term invented by psychologist J. J. Gibson, where he referred to it being how a subject interacts with the world around them (J. J. Gibson, 1977). It can also be limited to the dynamic and variable property of an object that results from a user's interaction with an object (Gero and Kannengiesser, 2012). Affordance is, hence, when a product can afford to conduct another function other than that it is intended.

The situated FBS ontology (Gero and Kannengiesser, 2004) extends FBS to consider the contribution of the experiences the designer has previously had along with the environment into which the design is to be placed. This declines FBS variables into three worlds: external (where the design exists) and internal to the designer's mind, subdivided into the world of interpretations of the design and the context (interpreted world) and the subset of the interpretations that become expectations (expected world).

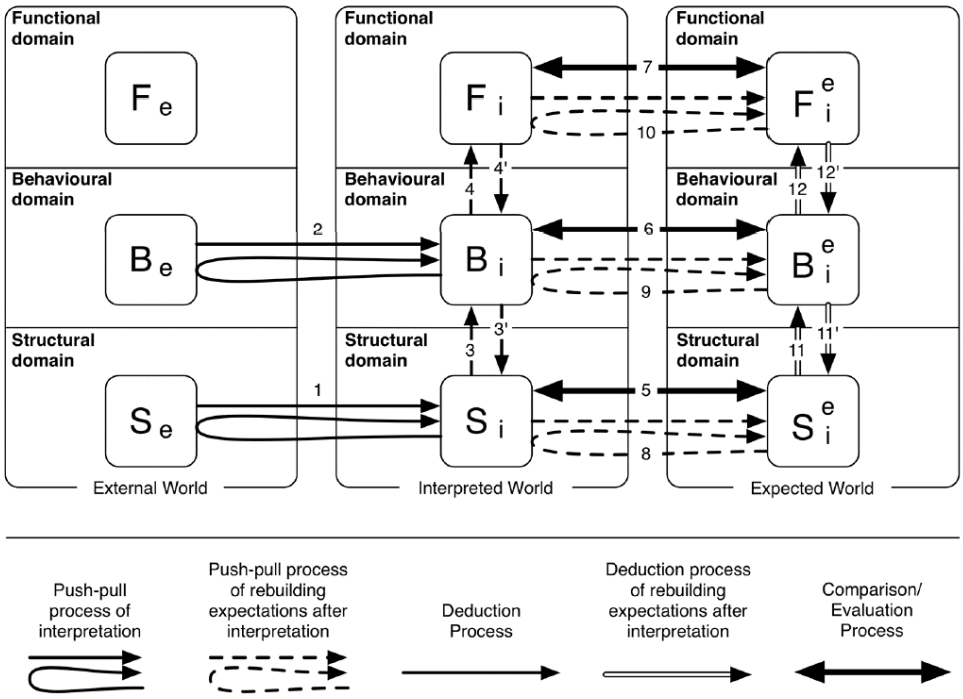

Figure 1. Framework to Describe the Emergence of Surprise as a Situated Phenomenon (Becattini et al., 2015)

Becattini et al. (2020) showed that the situated FBS framework can also capture surprise emergence if the perspective switches from the designer to the observer/user. Their experiment highlighted that surprise is a mismatch between two or more FBS variables (Figure 1) as they are interpreted from the external world and the previously conceived expectations, based on a user's experiences, beliefs, and ethics. This aligns well with a concept known as the appraisal theory (Scherer, 2001; Reisenzein et al., 2019), where the authors state that surprise elicitation is linked to experiences formed through beliefs and society.

2.3. Expected Product Attributes and Sensory Incongruities

It is widely accepted: surprise and unexpectedness are closely related (O'Quin and Besemer, 2006). Brown (2012) further added that surprise is linked with how an attribute of a product seems predictable and conventional, signifying that the more usual products seemed, the less the surprise elicitation. Maher (2010) presented surprise as a defining characteristic based on expectation,

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assessing newly developed attributes of an artefact with other pre-existing artefacts, as well as the expected values that exceed the description of artefacts. Grace et al. (2015) reiterated that it would be necessary to model expectations, to begin with. According to Rodríguez Ramírez (2014), to trigger surprise, designers either avoided the familiar and expected attributes or used familiar and expected attributes, but in an unexpected context.

Ludden et al. (2009) argued that surprise is clear in the first stages of a user's interaction with a product when different emotions are evoked from that said product. Studies by Rodríguez Ramírez (2012) have shown that surprise does not necessarily have to increase the attractiveness of a product unless support with positive emotions was present. Since surprising products naturally capture attention (Derbaix and Vanhamme, 2003), Ludden et al. (2012b) further claim that if a surprise is a pleasant experience, the product will most definitely benefit from the extra attention. Humour and surprise have been said to be intricately linked, whereas studies carried out by Borgianni and Hatcher (2017) have proved that they align. Suls (1972) delivered a widely used definition of humour in literature: by introducing the incongruity theory, he said that humour takes place when two conflicting factors come together in a surprising, yet pleasing manner. Ludden et al. (2012b) further elaborated, focusing on sensory incongruities. These were described as a user's assessment of information gathered through two different senses, where intermittent cognitive links are made involuntarily. This claim supports Cazeaux (2002). He states that individuals often make metaphorical mappings between various senses when trying to explain a specific experience. Then, sensory incongruities, specifically visual-tactual ones, can be leveraged to elicit surprise and product enjoyment (Ludden and Schifferstein, 2007).

Ludden et al. (2012b) further classified the sensory incongruities into appropriate and inappropriate incongruities, where appropriate incongruities can be drawn back to other product attributes. To search for sources of inspiration in the form of appropriate incongruities, a mind-mapping method could be used (Buzan and Buzan, 1994). The use of appropriate incongruities proved to be more attractive and more appreciated, acting like a good joke (Suls, 1972). Ludden et al. (2012b) also stated that the mind-mapping method is a viable way to generate appropriate sensory incongruities.

The presence of mutually consistent sensory feedbacks from the product to the user leads to more preferred products (e.g. Bell et al., 1991). For such conflicts to lead to a pleasant surprise, the user must still be able to recognize the object regardless of the conflict (Hekkert et al, 2003). Hence, the different senses gathered through interaction with everyday products can be sufficient to fill expected design flaws in a surprising way (Schifferstein and Desmet, 2008).

3. Guidelines Structure and their Testing for Usability

3.1. Proposal

Since the FBS ontology was proven to be successful in capturing surprise emergence, an adaption of the FBS ontology can be used as a backbone onto which the guidelines can be built. Moreover, the essence of surprise is unexpectedness; hence, to generate a surprise, the guidelines will guide the designer to trigger the evasion of expectations according to a specific FBS variable, as seen in Figure 2.

A surprising structure would consider a static state, where expectations are evaded at this specific state. A surprising Behaviour would consider a change in state, where expectations are evaded during or after a state change. A surprising Function would tackle unexpectedness, however, from a different point of view. This evasion of expectations will be limited to what a product may surprisingly afford doing, where the designers will be guided to add surprising, yet relevant, function to a product.

To evade expectations, the designer may either find unexpected product attributes or unexpected sensory links. The guidelines aim at guiding the designer to create an idea for a surprising product through

- stimulating the search and definition of unexpected product attributes that are opposite or extremely different from the current ones;
- using objects of inspiration that leverage appropriate sensory incongruities. i.e. different sensorial characteristics compared to the ones usually triggered by the target product; or
- both the previous strategies together;

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depending on the path to be chosen, as seen in Figure 2, where X can be Function, Behaviour, Structure.
For the function, since a function cannot be sensed but just interpreted through inference from S and B variables (Becattini et al, 2015), a surprising function will be limited to what a product may surprisingly afford doing with its attributes. Therefore, as said before, here the designers will be systematically guided to add a surprising, yet relevant, function to a product.
In general, both methods of evading expectations can be considered a view towards surprise from two different points of view.

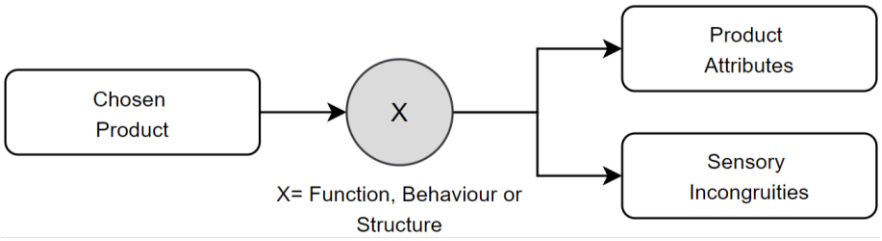

Figure 2. Proposal of the guidelines

In unexpected product attributes, the guidelines will aim to tackle expectations as per the definitions by Grace et al. (2015). Regarding appropriate sensory incongruities, the guidelines will include a mind map like the one used by Ludden et al. (2012b), as per Table 1.

Table 1. Proposed Paths for Generating Ideas for Surprising Products

	Structure	Behaviour	Function
Possible Paths	**S1**: Evading product expectations only **S2**: Evading product expectations + Sensory Incongruities from the product itself **S3**: Evading product expectations + Sensory Incongruities from Context	**B1**: Evading Product Expectations only (a product with limited inputs) **B2**: Evading Product Expectations only (a product with constant inputs) **B3**: Evading Product Expectations (a product with constant inputs) + Sensory Incongruities	**F1**: Adding an extra purpose through unexpected attributes from the product itself **F2**: Adding an extra purpose through unexpected attributes from the context

The guidelines are defined so that they do not use specific FBS jargon, to reduce the barriers of interpretation of FBS cnstructs and to ease the application of the guidelines for designing.

3.2. Testing

The effectiveness of the guidelines requires the demonstration that they are capable of supporting designers to explore concepts and leverage their creativity to generate surprising ideas for surprising products. However, these have to be organized in a way that makes them easily usable. This requires a preliminary check for their usability as a methodological tool, before testing on a large scale for effectiveness.
The eight paths of the guidelines were transformed, from basic instructions in the form of a flowchart, into software in the form of an interactive PowerPoint presentation. This was put into an early trial by a total of 7 experts in the fields of Design for Surprise, Industrial Design and UI/UX. Such examination was made to ensure the completeness of the guidelines in terms of content and to ensure the best user experience possible, to avoid confusion and misunderstandings.
It was decided that at least 30 subjects should test them for usability. To reach this target, a total of 40 mechanical engineers and industrial designers (BS completed or higher degree) with no previous background in design for surprise have been reached out, to account for those who cannot find the time to complete the tasks in due time. The test included two parts. The subjects received two separate files by e-mail as seen in Figure 3 and further clarified below.

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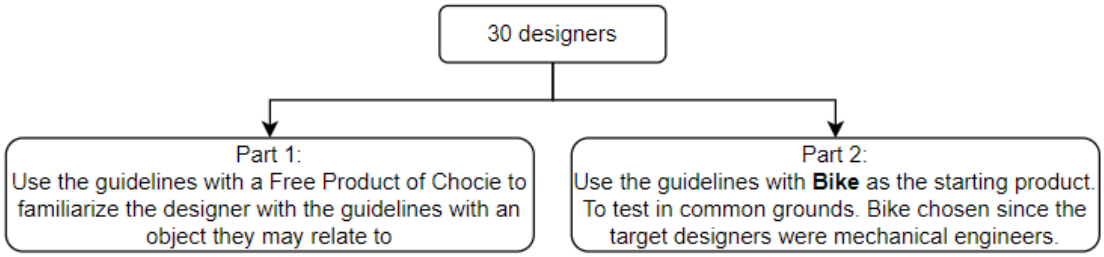

Figure 3. Proposed Testing Procedure

The measure of the usability of the guidelines as a methodological tool, therefore, will require that the designers are capable of leveraging, considering their freedom to choose, each of the proposed paths to generate surprising ideas.
The author will further analyse the number of ideas that designers were able to generate by using the interactive presentation. This will also contribute to showing the likability of using the guidelines since one idea generated per part per person would sufficiently cover the requirements.

4. Results and Discussion

The following subsections present the results for the 40 subjects involved in the testing of the guidelines. Out of them, 31 subjects holding at least a BS in Mechanical Engineering or Industrial Design agreed to participate in the experimental activity ad provided answers useful for the analysis. They were mostly Mechanical Engineers (more than 90%) and geographically distributed as follows: 23 Italian, 3 Croatian, 3 Egyptian, 1 Chilean and 1 Chinese.

4.1. Usability

30 out of 31 succeeded in using the guidelines to generate at least one idea that aims to be surprising, suggesting a high degree of usability (approximately estimated 97% usability).
Figure 4 provides a deeper view into the number of ideas the designers managed to generate. It shows the frequency of participants that generated 1 to 3 ideas (or none), for both the Free Product of Choice (left) and the Bike (right). Whenever a subject generated more than one idea, due to the structure of the interactive presentation the guidelines were presented with, it means that s/he explored more than one FBS branch.

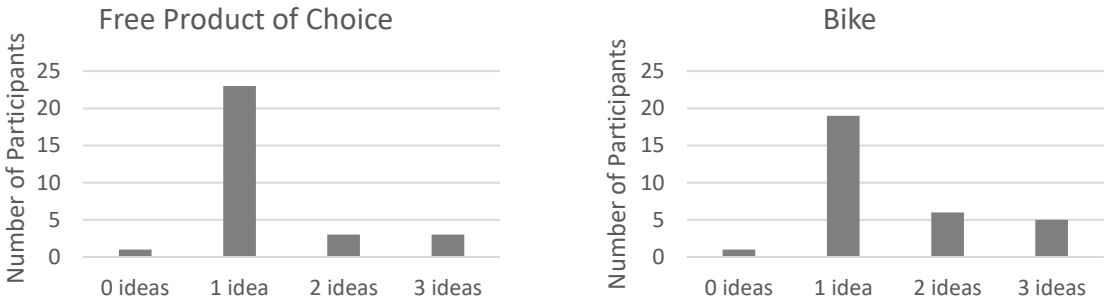

Figure 4. Frequency of Number of Ideas Generated per Participant

Overall, designers generated 38 ideas using the guidelines for the free product of choice (first part of the experiment), versus a total of 46 ideas for the bike (second part of the experiment). Thus, the average number of ideas per designer for the free product of choice was 1.27 idea/designer, versus an average of 1.53 idea/designer for a bike (+20%). Focusing on Figure 1, one may see that the average was boosted in the bike since more designers managed to generate more than one idea for the bike than in the free product of choice. For the free product of choice, only 6 out of 31 (20%) designers managed to generate more than one idea for their chosen product, while for the bike the results are almost doubled (11 out of 31, i.e. 36.7%). This increase on their second time using the guidelines is an

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indication that these are not only capable of being used repeatedly, but it also shows that, with more practice, designers are capable of showing the true potential of the guidelines.
However, the generation of one single idea per participant tends to be dominant in both parts of testing for usability, the reason due to two reasons.
Firstly, the dominating choice was to create only one idea as the subjects were explicitly asked to test the guidelines once, without any incentive or award after spending time. Thus, they may want to invest the minimum time required to accomplish the task without impairing the execution of the test. As well, some subjects might have lost interest given the lack of incentive. Secondly, testers might not be completely familiar with systematic procedures and might find the interactive presentation just partially captivating, as not all of the fields they have to fill in would make sense for every product to analyse.
However, given that designers received no incentives and that they were unfamiliar with the topic it is extremely positive that some subjects still managed to generate more than one idea. Beyond the recorded at least sufficient ease of use, this suggests that some subjects could have also found the guidelines entertaining, especially with the repetition of the trial with the bike. This likeability possibly sprouted from designers looking forward and being interested in the full potential of the guidelines in designing surprising products.

4.2. Paths Chosen

Considering those who managed to generate at least one idea while using the guidelines, Figure 5 shows the ratio of the paths (Table 1) chosen while designing the free product of choice and the bike.

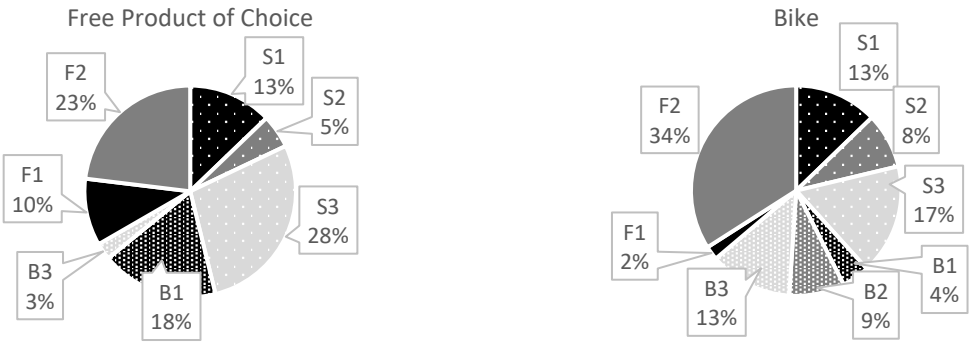

Figure 5. Accumulated Distribution of Paths Pursued

From Figure 5, one can notice a significant decrease in the percentage of designers who opted to pursue a structural surprise (S1 + S2 + S3) in the bike (38%) with respect to the free product of choice (46%).
One can also notice that the percentage of ideas generated from a behaviour path was 21% for a free product of choice compared to 26% for a bike. This was expected, since behaviour is defined as a change of state and mechanical products, in that case, a bike tends to change its state often, while this is not necessarily the case for other kinds of products. Moreover, the presence of high percentages in B2 and B3 paths for the bike compared to almost none in the free product choice suggests that the starting product might affect the paths the designer chose. The B2 and B3 paths refer to products that require constant input from the user or a stimulus for the object to change state, where the surprise is meant to arise during or after the change of state.
Overall, Function paths have been explored almost equally in the two trials, despite the distribution being uneven in the two parts of the experiments. These results require additional confirmation before determining that the products to be made surprising also triggers the path to choose. These estimations should be carried out with additional testing that the authors will require to carry out once they will evaluate the effectiveness of the guidelines for the generation of ideas for surprising products. The unveiling of a direct correlation between the paths suggested by the guidelines and the nature of the products to be made surprising will open up the opportunity to classify products according to their most suitable strategy for generating surprising ideas. Tailor-made guidelines, therefore, can be envisioned to tackle specific product classes, save time, avoid confusion and efficiently run the design activity.

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4.3. Examples of ideas generated

Figure 6 shows three examples out of the 84 ideas by the 30 subjects who used the guidelines successfully, to showcase preliminary evidence of their expected effectiveness, yet to be evaluated.

Figure 6. Some ideas generated with the guidelines: wheelchair bike (left); auto-stable bike (center) and Stool Bike (right)

Wheelchair/Bike The wheelchair bike shown in Figure 6 (left) is a bicycle that has a structure that can be modified where the front part may be assembled to act as a wheelchair. The designer further claimed that the idea may be used as an ambulance in difficult-to-access places. For this design, the designer opted to pursue a behavioural surprise, specifically the path S3.

Auto-stable bike The auto-stable bike seen in Figure 6 (center) is a bicycle that can laterally always stabilize itself without any physical constraints. The designer opted to pursue a behavioural surprise, specifically path B3.

Stool/Bike The Stool/Bike seen in Figure 6 (right) is a bicycle that when folded can serve as a seat that can be used during commuting on public transport or waiting. The designer pursued a surprise in terms of function, specifically pursuing the path F2.

While stating their final idea, it was found that some designers, even though they pursued designing in a specific path, they end up realizing potential surprise in other paths. This phenomenon can be explained in Figure 7 and derivable from the deduction processes of Figure 1: a surprising structure can lead to a surprising behaviour and surprising function and vice versa: for a surprising function to exist, it might require the presence of a surprising behaviour and a surprising structure.

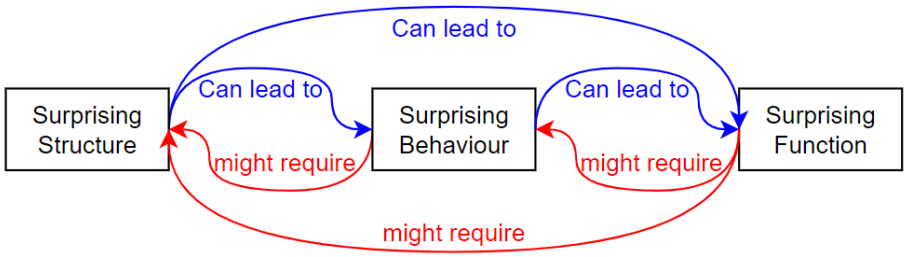

Figure 7. Description of the link between surprise emergence and FBS variables.

5. Conclusion

5.1. Outcomes

This paper presents an original research that defines guidelines to allow designers for the systematic exploration of the design space and broaden their opportunity to successfully generate ideas for surprising products. which, following the numerous claims supporting surprise, have higher chances to be attractive, intriguing or capable of capturing attention and, eventually, affection.

By understanding that surprise comes from unexpectedness, a proposal of the guidelines was built based on the literature review and the understanding of how one may evade an expectation

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systematically from a Functional, Behavioural and Structural aspect. This proposal was transformed into an interactive presentation to have the best user experience possible when testing for the usability of the guidelines as a methodological tool.
Thirty-one designers tested the proposed guidelines for their usability as a methodological tool in a two-part experiment, where they were to generate ideas for a product of their choice and for a bike to be made surprising. Most of the designers (97%) managed to generate ideas for products using the guidelines proficiently. The guidelines also proved to be repeatable where 100% of the designers who finished the first part also finished the second part and even generated more ideas, which indicates potential enjoyability and excitement while using the guidelines.

5.2. Future Paths

Since the guidelines proved to be usable, the most important thing to test for would be the effectiveness of the guidelines in generating ideas for surprising products. A potential way to do so is to evaluate the ideas generated by the designers whether if they are surprising or not. This evaluation will require a broader audience to be involved, as the generated ideas should be also assessed by third parties (e.g. potential product users/customers) that will be asked whether the ideas are surprising or not.
Moreover, to provide an accurate measure of the potential of the guidelines, it is possible to ask a control group of designers to generate surprising ideas for the same products without using the guidelines and ask the same set of third party evaluators to compare the surprising potential of these two sets of ideas.
In addition, measuring whether surprise comes from a functional; behavioural; or structural perspective in third party evaluators could enable the alignment between their interpretation and the intentions of designers These results could be a crucial factor to steer the activity of the designers so that they can trigger exactly the surprise they want in the evaluators of the products they develop.

References

Becattini, N., Borgianni, Y., Cascini, G. and Rotini, F., 2015. Surprise as a situated phenomenon. In DS 80-11 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 11: Human Behaviour in Design, Design Education; Milan, Italy, 27-30.07. 15 (pp. 071-080).

Becattini, N., Borgianni, Y., Cascini, G. and Rotini, F., 2017. Surprise and design creativity: investigating the drivers of unexpectedness. International journal of design creativity and innovation, 5(1-2), pp.29-47.

Becattini, N., Borgianni, Y., Cascini, G. and Rotini, F., 2020. Investigating users' reactions to surprising products. Design Studies, 69, 100946.

Bell, S.S., Holbrook, M.B. and Solomon, M.R., 1991. Combining esthetic and social value to explain preferences for product styles with the incorporation of personality and ensemble effects. Journal of social behavior and personality, 6(6), p.243.

Besemer, S.P., 2000. Creative product analysis to foster innovation. Design Management Journal (Former Series), 11(4), pp.59-64.

Besemer, S.P. and O'Quin, K., 1999. Confirming the three-factor creative product analysis matrix model in an American sample. Creativity Research Journal, 12(4), pp.287-296.

Bobrow, D.G., 1984. Qualitative reasoning about physical systems: an introduction. Artificial intelligence, 24(1-3), pp.1-5.

Borgianni, Y. and Hatcher, G., 2017. Similarities and differences between humorous and surprising products. In DS 87-8 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 8: Human Behaviour in Design, Vancouver, Canada, 21-25.08. 2017 (pp. 031-040).

Brown, D.C., 2012. Creativity, surprise & design: an introduction and investigation. In DS 73-1 Proceedings of the 2nd International Conference on Design Creativity Volume 1.

Buzan, T. and Buzan, B., 1994. The Mind Map Book. New York: Dutton.

Cazeaux, C., 2002. Metaphor and the categorization of the senses. Metaphor and Symbol, 17(1), pp.3-26.

Chiu, I. and Shu, L.H., 2012. Investigating effects of oppositely related semantic stimuli on design concept creativity. Journal of Engineering Design, 23(4), pp.271-296.

Derbaix, C. and Vanhamme, J., 2003. Inducing word-of-mouth by eliciting surprise–a pilot investigation. Journal of economic psychology, 24(1), pp.99-116.

https://doi.org/10.1017/pds.2022.95 Published online by Cambridge University Press

Gero, J.S. and Kannengiesser, U., 2000, June. Towards a situated function-behaviour-structure framework as the basis of a theory of designing. In Workshop on Development and Application of Design Theories in AI in Design Research, Artificial Intelligence in Design'00, Worcester, MA, pp. gk (pp. 1-5).
Gero, J.S. and Kannengiesser, U., 2002, July. Towards agent-based product modelling. In Workshop on Knowledge Intensive CAD (pp. 3-17). Springer, Boston, MA.
Gero, J.S. and Kannengiesser, U., 2004. The situated function–behaviour–structure framework. Design studies, 25(4), pp.373-391.
Gero, J.S. and Kannengiesser, U., 2012. Representational affordances in design, with examples from analogy making and optimization. Research in Engineering Design, 23(3), pp.235-249.
Gero, J.S. and Rosenman, M.A., 1990. A conceptual framework for knowledge-based design research at Sydney University's Design Computing Unit. Artificial Intelligence in Engineering, 5(2), pp.65-77.
Gero, J.S., Tham, K.W. and Lee, H.S., 1992. Behavior-a Link between Function and Structure in Design. IFIP Transactions B-applications in Technology, 4, pp.193-220.
Gibson, J.J., 1977. The theory of affordances. Perceiving, Acting and Knowing. Eds. Robert Shaw and John Bransford.
Grace, K., Maher, M.L., Fisher, D. and Brady, K., 2015. Modeling expectation for evaluating surprise in design creativity. In Design Computing and Cognition'14 (pp. 189-206). Springer, Cham.
Grimaldi, S., 2017. Surprising longevity. In Routledge Handbook of Sustainable Product Design (pp. 298-315).
Han, J., Forbes, H. and Schaefer, D., 2019, July. An exploration of the relations between functionality, aesthetics and creativity in design. In Proceedings of the Design Society: International Conference on Engineering Design (Vol. 1, No. 1, pp. 259-268). Cambridge University Press.
Hekkert, P., Snelders, D. and Van Wieringen, P.C., 2003. 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. British journal of Psychology, 94(1), pp.111-124.
Ludden, G.D., Kudrowitz, B.M., Schifferstein, H.N. and Hekkert, P., 2012a. Surprise and humor in product design. Humor, 25(3), pp.285-309.
Ludden, G.D. and Schifferstein, H.N., 2007. Effects of visual-auditory incongruity on product expression and surprise. International Journal of Design, 1(3), pp.29-39.
Ludden, G.D., Schifferstein, H.N. and Hekkert, P., 2008. Surprise as a design strategy. Design Issues, 24(2), pp.28-38.
Ludden, G.D., Schifferstein, H.N. and Hekkert, P., 2009. Visual–tactual incongruities in products as sources of surprise. Empirical Studies of the Arts, 27(1), pp.61-87.
Ludden, G.D., Schifferstein, H.N. and Hekkert, P., 2012b. Beyond surprise: A longitudinal study on the experience of visual-tactual incongruities in products. International journal of design, 6(1), pp.1-10.
Maher, M.L., 2010, August. Evaluating creativity in humans, computers, and collectively intelligent systems. In Proceedings of the 1st DESIRE Network Conference on Creativity and Innovation in Design (pp. 22-28).
Maher, M.L., 2011. Design creativity research: From the individual to the crowd. In Design Creativity 2010 (pp. 41-47). Springer, London.
Maher, M.L., Brady, K. and Fisher, D.H., 2013. Computational models of surprise in evaluating creative design. In Proceedings of the fourth international conference on computational creativity (Vol. 147). Sydney: University of Sydney, Faculty of Architecture, Design and Planning.
Maher, M.L. and Fisher, D.H., 2012. Using AI to evaluate creative designs. In DS 73-1 Proceedings of the 2nd International Conference on Design Creativity Volume 1.
O'Quin, K. and Besemer, S.P., 2006. Using the creative product semantic scale as a metric for results-oriented business. Creativity and Innovation Management, 15(1), pp.34-44.
Rodríguez Ramírez, E.R., 2012. The role of surprise on persuasion in industrial design. International Journal of Product Development, 16(3-4), pp.263-283.
Rodríguez Ramírez, E.R., 2014. Industrial design strategies for eliciting surprise. Design studies, 35(3), pp.273-297.
Reisenzein, R., Horstmann, G. and Schützwohl, A., 2019. The cognitive-evolutionary model of surprise: A review of the evidence. Topics in Cognitive Science, 11(1), pp.50-74.
Scherer, K.R., 2001. Appraisal considered as a process of multilevel sequential checking. Appraisal processes in emotion: Theory, methods, research, pp.92-120.
Schifferstein, H.N. and Desmet, P.M., 2008. Tools facilitating multi-sensory product design. The Design Journal, 11(2), pp.137-158.
Suls, J.M., 1972. A two-stage model for the appreciation of jokes and cartoons: An information-processing analysis. The psychology of humor: Theoretical perspectives and empirical issues, 1, pp.81-100.

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