The Combined Effect of Perceptual and Conceptual Dimensions on Product Design Aesthetics

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Abstract

In design research perceptual features of a design such as unity-in-variety as well as conceptual properties (whether the design is a good instantiation of designer's intentions) have been found to affect the aesthetic experience independently. In the course of a research design using systematic manipulations of USB stick designs in three subsequent phases, we have been able to formally relate these distinct dimensions, after having assessed optimal levels for them separately. We have found that both conceptual and perceptual features impact on aesthetic liking, but the perceptual dimension is more decisive. We also encountered a positive interaction, indicating that effects of dimensions are interdependent to an extent.

Keywords: design aesthetics; unity-in-variety; design and intention; Unified Model of Aesthetics

Introduction

The question as to what determines our aesthetic experience of objects has been occupying scholars for ages. Following in the footsteps of Fechner (1876) and later Berlyne (1971) the tradition of empirical aesthetics has turned to empirically tackling this issue through systematic experimentation. Although many researchers within this tradition tended (and still tend) to focus on art, its tenets can easily be extended to any object that could provoke sensory delight – especially designed products (Hekkert, 2006).

Initially this branch of research primarily focused on objects' structural, perceptual features (e.g. Boselie & Leeuwenburg, 1985; Cupchik & Berlyne, 1971), but gradually it considerably broadened its scope to different aspects as well – like prototypicality, meaning, social significance – thereby paying heed to the intricately complex and multidimensional nature of the aesthetic experience (i.a. Bornstein, 1989; Leder, Carbon & Ripsas, 2006; Temme 1992; Whitfield, 1983). However, to date much of the individual studies tend to focus on particular well-defined aspects, leaving others deliberately out of the equation. This leads to an in-depth understanding of the aesthetic effects of the considered aspects, but the result is a set of thorough, but fragmented explorations.

For this reason Hekkert (2014) has coined the Unified Model of Aesthetics (UMA) of product design. The model attempts to integrate the various dimensions that impact our aesthetic experience of products. It rests on the main assumption that people's behavior is guided by an urge for safety as well as for accomplishment. When a balance of these countervailing forces is struck, we experience aesthetic pleasure. However, these urges can manifest themselves in various ways[20]. Therefore, the model accommodates for multiple dimensions. On the perceptual plane, people seek for *unity* as well as *variety* in the sensorial stimuli they encounter (which will be elaborated below). As concerns cognitive processing, the urge for *typicality* (familiarity, recognizability) is counterbalanced by a drive for *novelty* to avoid repetition and tedium. Furthermore, as products figure in interactions between people, on the social level we want products to signal our belonging to a group (*connectedness*), while also offering us the means to distinguish ourselves as an individual (*autonomy*). In addition to these balances, it is characteristic for products to serve certain practical purposes. Hence, they can be conceived as a means to instantiate a particular intention. In this sense, to a varying extent they can be deemed an appropriate means, which in turn is also quite likely to affect aesthetic appreciation. Therefore, a fourth, *conceptual* level can be added to the model.

The various levels of UMA effectively refer to different features constituting the design. As such, they will impact on the aesthetic appreciation of the product in their own specific way. However, by no means does this imply that they are comparably decisive. On the contrary, when considering the aesthetic experience in confrontation with a product, it is rather probable that some dimensions weigh in a lot more than others. Moreover, as the dimensions are jointly operating in a given product, they exert their individual effects in conjunction. For that reason, these effects are arguably not independent. It is well imaginable that the impact on aesthetic appreciation of one dimension is affected

[20] For a thorough discussion of the model, we kindly refer the reader to Hekkert (2014). On these pages we will suffice with a concise introduction to the central tenets of the model.

by the impact of another (Hekkert, 2014). To date, such interrelations have not empirically been explored systematically in the frame of UMA, but – as mentioned – they are also largely lacking from the empirical aesthetics literature in general.

This study makes a first attempt towards a formal integration of various dimensions affecting the aesthetic experience by empirically testing the relations between distinct levels of UMA through systematic manipulation. In particular, we will establish the relative effects of and interaction between the perceptual and the conceptual level. Although any combination of levels is imaginable and is likely to render substantial insights, we chose to include these levels in the present study because they are far apart in the model and therefore refer to very distinct features of a design. The perceptual level denotes the sheer sensorial processing of tangible design features, whereas appreciation on the conceptual plane implies reflexive interpretation. Hence, these dimensions are more likely to operate independently. In that sense, with respect to interaction effects, the selection of these levels in particular offers a strong test.

Research Design

As hinted at in the introduction, per level of UMA it is possible to identify an optimal state – that is, a state (in many levels it concerns a balance) that maximizes the aesthetic appreciation for that dimension of the design (Hekkert, 2006; 2014). However, it needs little argument that these levels vary in different ways. This is why we decided to conduct the study through three consecutive phases. Two pre-test phases were designed to separately establish optimal states of the two dimensions under scrutiny. Afterwards a main test was conducted to integrate the levels. The general design of the study is presented in the diagram below.

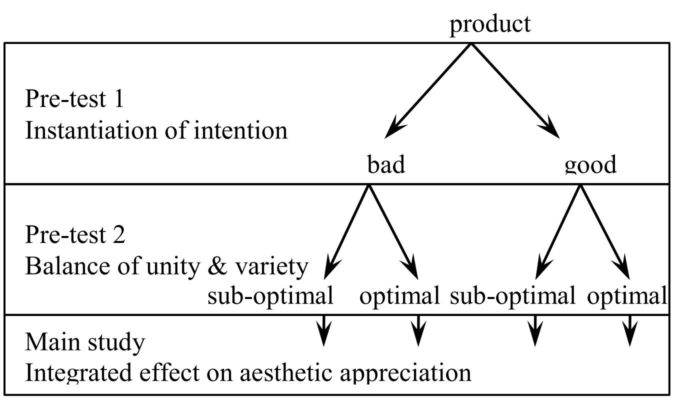

Figure 1: Research phases

In the following sections we will discuss the distinct phases consecutively, covering literature, research design and results per phase. In this section we will address the features that are in common to the three phases.

Throughout the different phases, systematic manipulations from a single product category were used as stimulus material – USB memory sticks. This choice was informed by the limited number of basic elements of this product type, which allowed for feasible and realistic manipulations, and made 3D rendering manageable too. Also, being a technological product, it was expected to allow for the introduction of additional elements (like indicator lights,…) and specific purposes (in the form of a special functionality). The manipulations were done by one of the authors, who is a trained designer and has experience with 3D modeling and rendering. The designs were developed virtually only (so they were not physically made) and presented to the participants as images on paper. The orientation of the designs and their backgrounds were kept constant over the phases.

The participants were invariably design students of Delft University of Technology. Apart from the practical merit of accessibility, this group was selected for its homogeneity. By keeping differences in expertise and age more or less constant, we could compare findings across the phases.

Conceptual Level

Design as an Instantiation of an Intention

An artifact by definition is made out of an intention. Knowing that intention affects the opinion people contrive of the artifact, as has been illustrated by numerous studies (i.a. Pfaff & Gibbs, 1997; Temme, 1992; Specht & Van Dewerker, 2008). This arguably applies no more to products than to other artifacts, although it is probably more apparent. For products are made to serve particular purposes. Hence, a product's design could be conceived as a means of communicating that intention from the designer to the users, who in turn make an interpretation (Crilly, 2011). This communication does not necessarily run smoothly. The recipient of the message may be incapable of interpreting the message adequately and, as a consequence, use the product not as intended. Or the user does get the message, but does not recognize the design to be a suitable (practical, efficient, elegant, …) way of getting this across. The numerous choices and decisions made in the design process are likely to affect the user's interpretation of the designer's intentions. They may be deemed effective or clever in view of the product's purposes, or otherwise obsolete, indeterminate or downright bizarre. Although this situation could already occur when the user learns the intention through inference from the product's features, it is especially striking in those cases where the user does get an explicit clue about the product's actual purposes – through designer's statements, product names, instruction manuals, notes on the packaging, …. In those cases, the user will be able to assess fairly easily whether the design as it is constitutes a good instantiation of the intention at its base, regardless of whether one thinks that intention is appropriate for a product in itself (which is more of an ethical issue). For example, a garbage bag may be designed to discourage wastefulness. One needs not endorse sustainable consumption as such to assess whether this particular bag is a good design in view of its goal. Hence, the conceptual loading of a product will affect the user's evaluation. Although this mainly seems to be a matter of understanding as the intention instantiated by the design is not a sensorially detectable property of a design as such, it has been found to affect the aesthetic appreciation. Da Silva, Crilly and Hekkert (2014) get clear indications that a product is considered more beautiful if users think its design fits with its purposes.

Pre-test 1

In the first phase of the present study, our aim was to assess the degree to which a particular design is to be considered a good or bad instantiation of a product's intention. More specifically, we tested how participants (n=20) would evaluate various USB memory stick designs in relation to the intention "designed to tell the user *as precisely as possible* how much storage capacity has already been used". We designed eight USB stick concepts that plausibly instantiated the intention. Per concept, three images were produced – representing an empty, half full and full state, in order to provide the participant with an idea of its functioning. The following concepts were thus developed (name between brackets by way of shorthand for the ensuing discussion).

- USB stick with a display showing the used space numerically (numeric).
- USB stick with a display showing a growing bar as it fills up (bar).
- USB stick with a display filling up with tetris blocks (tetris).
- USB stick with a scale along which a button mechanically moves (scale).
- USB stick with a line of red LED's that gradually light up as it fills up (red line).
- USB stick with a green, orange and red LED that light up depending on the used capacity (traffic lights).
- USB stick that grows/inflates as it fills up (grow).
- USB stick emitting light that fades down as it fills up (glow).

The designs were presented to the participants on cards. They were instructed to arrange these in line with the intention, which was mentioned explicitly in the instruction. A Friedman's ANOVA indicated that designs were placed in significantly different ranks ($\chi^2(7)=81.92$, $p<0,001$). In the left hand panel of table 1, the mean ranks are presented.

In order to establish that the ranks assigned by participants were due to the intention – and therefore not to other factors – we also tested whether ranking would differ if the intention was altered (slightly). Hence, we repeated the ranking assignment with a different group of participants (n=20), telling them that it concerned USB memory sticks "designed to tell the user *in a fun way* how much storage capacity has already been used". A Friedman's ANOVA showed that the designs were ranked differently as a consequence ($\chi^2(7)=56.60$, $p<0,001$). Mean ranks are presented in the right hand panel of table 1 (stars indicate a significant difference ($p<0,05$) in ranking as compared to the *precise* condition based on Mann Whitney's *U*).

Table 1: Mean ranks of concepts

	mean rank 'precise'	mean liking 'precise'	mean rank 'fun'
glow	1.70	5.40	5.90*
traffic lights	2.50	5.55	4.35*
grow	2.85	6.70	6.60*
tetris	5.10	7.30	5.75
red line	5.50	7.32	3.85*
scale	5.70	6.05	4.30*
bar	5.80	7.00	3.50*
numeric	6.85	6.15	1.75*

On the basis of these findings we could conclude that the 'numeric' design is the best instantiation of the intention priming precision of information offered by the USB stick, whereas the 'glow' design is considered the worst. Therefore, we decided to proceed with these concepts to the subsequent phases.

Apart from the ranking assignment, respondents were also instructed to award a liking score on a 10-point scale to the various designs (higher is better). This was done for two reasons. On the one hand, in that way we could establish whether an optimal instantiation would also result in higher liking, which is expected by UMA. On the other hand – and more importantly in view of the present study's purposes – it allowed for comparison of the results across phases. As in the final, main study we were to assess the relative weight of the conceptual and the perceptual level in explaining aesthetic appreciation, we needed a way to ascertain that variation within both levels would be comparable. However, these levels refer to essentially different qualities of a design. Therefore, in line with a procedure introduced by Schifferstein et al. (2010), by relating them directly to liking, we could establish a common ground and benchmark variation in the levels in a comparable way.

The liking scores (only for the precision condition) are presented in the central panel of table 1. As mentioned, these were used mainly in relation to the results of the second pre-test. However, they are informative in themselves, because they tell us that although the optimal instantiation of the intention based on ranking (numeric) was not liked the best on average, the lower rankings tend to coincide with lower liking scores. Hence we find some additional corroboration of UMA's expectations concerning the conceptual level.

The two remaining designs differed a lot in terms of general appearance – 'glow' was white and quite crisp, whereas 'numeric' was black and it had a green lcd screen, which could come across as old-fashioned. Also, some respondents indicated that it made little sense that 'glow' dimmed down instead of lighting up. As a consequence, we altered the designs slightly. 'Numeric' was brought more in line stylistically with 'glow' (white translucent plastic with a white display shining through) and the order of 'glow' was turned around. These were re-tested on different participants (n=20) to ascertain reliability after the changes. With the liking score for ‘numeric’ again being higher (‘glow’=6.15 – ‘numeric’=7.80) the initial findings of pre-test 1 were confirmed, although the difference was slightly larger (1.65, $t(19)=-3.12$, $p=0.006$).

Perceptual Level

Unity-in-Variety

The principles of unity and variety have separately been very well documented in the literature. On the one hand, people seem to derive pleasure from discovering orderly patterns in the things they perceive. It is argued that our brains have evolved to appreciate unity, as it facilitates the processing of stimuli. This principle is adopted eagerly in art and design, especially through the application of the Gestalt laws, documented by behavioral psychology. Symmetry, repetition, proximity, continuity, … are used to establish coherence between the various elements that constitute an artifact (Arnheim, 1971; Wagemans et al., 2012).

On the other hand, our sensory apparatus has evolved to accommodate variety too. As our environment is made up of various elements we need an ability to detect difference and explore new information. Hence, our senses welcome some challenge in the form of variety to avoid boredom (Berlyne, 1971; Biederman & Vessel, 2006).

As a consequence, both unity and variety, although contradictory, positively affect aesthetic appreciation. In the frame of UMA, this has been acknowledged for various products and different types of perceivers (Post, Blijlevens & Hekkert, 2013).

Pre-test 2

After having established the suitability of the USB sticks as instantiations of an intention in the first phase, we wanted to determine the optimal balance of unity and variety in these designs. As mentioned before, we did so for reasons of comparability in view of the main study, but also it was interesting in itself to get an idea of the balance for the product category of USB sticks. Although unity and variety have both been found to affect aesthetic appreciation for a wide variety of products, the extent to which they do tends to differ depending on the product category (Post et al., 2013). In advance, there was no telling where the optimal balance would be located.

As stimulus material, the two concepts retained from pre-test 1 were manipulated systematically on unity and variety. For unity, symmetry of the designs was subtly increased in three steps – by moving the position of the displayed text for the ‘numeric’ design and in the case of the ‘glow’ design by changing the part of the stick that lit up. For variety, the number of elements was increased, also in three steps – a band was put around the stick’s body in the second step, in the third step an additional indicator light was added. As a result, nine distinct manipulations were designed per USB stick concept (3 unity steps × 3 variety steps). These were presented to the participants on paper questionnaires (single image representing only the full state). Participants were split into two groups, so they would view only the nine manipulations of either ‘glow’ (n=37) or ‘numeric’ (n=40). They were requested to rate the manipulations (0-10) on three items tapping into unity (“design is orderly”, “looks unified”, “is coherent”) and three variety items (“design consists of various parts”, “presents variety”, “is rich in elements”). Scores were then averaged into a composite unity scale (Cronbach’s $\alpha=0.91$) and variety scale (Cronbach’s $\alpha=0.80$). Again, a liking scale was also included.

When performing a multiple linear regression analysis on liking with unity and variety as independent variables ($R^2=0.43$), results were in line with previous studies. Both perceptual principles bore a significant positive effect on liking (unity $\beta_1=0.69$, $p<0.001$, variety $\beta_2=0.29$, $p<0.001$). Also corroborating previous findings, unity and variety were correlated negatively ($r=-0.33$, $p<0.001$).

In order to establish the optimal balance for unity and variety, we inspected the average scores of the individual manipulations for unity, variety and liking. For the purpose of clarity, these results are presented graphically in figure 2. The dots represent the various manipulations (blue for ‘glow’, orange for ‘numeric’). The tags encode the specific manipulation – ‘U’ for unity, ‘V’ for variety, ‘L’ for low, ‘M’ for medium and ‘H’ for high. (To illustrate, LU-MV means that it was manipulated to be low in unity and medium in variety.) Behind the code, the average liking score is mentioned.

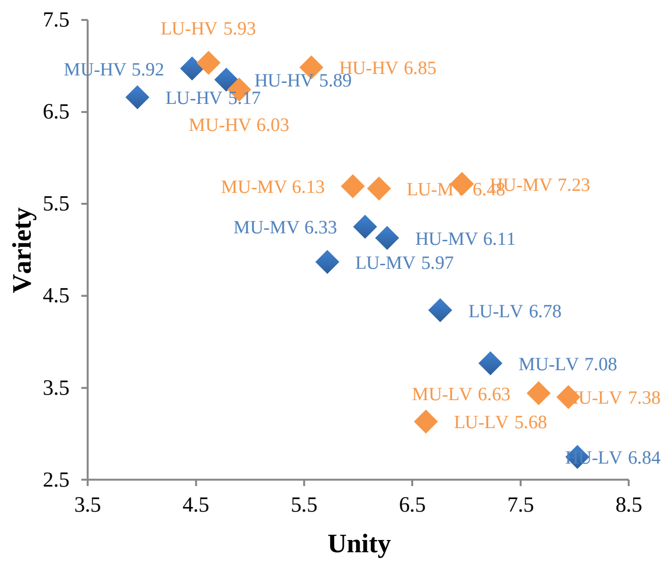

Figure 2: Manipulations’ scores for unity and variety

It is plain to see that for both the manipulations of ‘glow’ and ‘numeric’ higher levels of perceived unity are preferred and higher variety scores lead to disapproval. We get few indications of a preference for maximization of both principles. It should be noted that this may be due to the specific manipulations we performed, though. From the positions in the graph, we can gather that the variety manipulations had the intended effect. However, for unity this is not the case. In fact, scores on unity seem to reflect decreasing variety levels to a greater extent than systematic increases in manipulated unity. The limited distances between the unity manipulations suggest that they differed only *within* the variety manipulations. This probably means that the systematic manipulations of unity were too subtle in comparison with the variety manipulations. Furthermore, the larger effect of unity scores on liking might indicate that actually both unity and variety manipulations were collapsed in the eyes of the participants and to a large extent perceived in terms of unity.

Notwithstanding this methodological limitation, these data do allow us to identify the unity/variety manipulations that are deemed optimal and sub-optimal. For 'numeric', 'high unity/low variety' was liked best (7.38). In the case of 'glow' this was 'medium unity/low variety' (7.08). However, we opted for 'high unity/low variety' in this case as well, which was rated second best. Apart from the fact that in that way the manipulation could be held constant for both concepts, the scores it got on unity and variety were also more in line with the intended manipulation ('medium unity/low variety' was deemed far more unified than intended).

For the selection of the manipulations presenting sub-optimal balance, we had to take into account the liking scores of pre-test 1. As the difference in liking between the (altered) designs of 'glow' and 'numeric' amounted to 1.65, the difference between the optimal and sub-optimal unity/variety manipulations had to be of a similar order of magnitude. Hence, for 'glow' we found that 'high unity/low variety' was liked 1.66 more than 'low unity/high variety', which conveniently is its diametrical opposite. As in the case of the optimal manipulations, again we selected this manipulation as sub-optimal for 'numeric' as well. It was liked less by 1.45, which we considered sufficiently similar.

Main Study

Having established optimal and sub-optimal states for the conceptual as well as the perceptual level, we could move on to integrate both levels in a main research design to determine their relative weights and possible interaction in affecting the aesthetic appreciation. Four designs, retained from the second pre-test, presented the manipulations needed to do so (2 instantiations × 2 unity/variety balances).

- perceptually sub-optimal/conceptually sub-optimal (glow low unity-high variety).
- perceptually sub-optimal/conceptually optimal (glow high unity-low variety).
- perceptually optimal/conceptually sub-optimal (numeric low unity-high variety).
- perceptually optimal/conceptually optimal (numeric high unity-low variety).

As we wanted to gather how beautiful these would be considered relative to one another, we used a paired comparison procedure. In other words, participants (n=85) were to compare them in pairs and indicate which they found most beautiful. Hence, six possible pairwise combinations could be formed, which were printed in a questionnaire. As in pre-test 1, it was mentioned explicitly in the instructions that it concerned "USB memory sticks designed to tell the user *as precisely as possible* how much storage capacity has already been used". Also, again images of three states of used space were shown. To indicate aesthetic preference, the participants were asked to tick a box below one of the designs constituting a pair.

After the data had been gathered, per design the number of 'wins' of comparisons was calculated for individual participants. As a given design was compared to three others, this resulted in a scale ranging from 0 (no wins) to 3 (no losses). This variable was then regressed on whether it constituted a good instantiation and whether the unity/variety balance was optimal.

Surprisingly, this model only explained 10% of the variance in beauty (as operationalized through the number of paired comparison wins). This is a rather small proportion considering the fact that only the perceptual level was already found to explain 43% of liking in the second pre-test. Arguably, there is some difference between beauty and liking in general, but it would seem that this is mainly due to the different procedure of data collection (with paired comparisons). However, both the conceptual and the perceptual level bore a significant main effect on the number of wins (good instantiation β_1=0.14, p=0.008, optimal unity/variety balance β_2=0.25, p<0,001). Moreover, a significant interaction between instantiation and unity/variety was encountered ($\beta_1\beta_2$=0.16, p=0.003 – which is also quite strong relative to the main effects). Thus, we could formally establish that both levels contribute to the aesthetic experience, both independently as well as in combination.

Discussion

In the present study we were able to relate two aspects that have been found to affect aesthetic appreciation, but are usually considered to be of a very different order. Using a research design that comprised a careful sequence of steps and by relating these through liking scores, we managed to establish and benchmark variation of the variables involved in a comparable way. Thus, we could take a considerable step towards an integrated understanding of design aesthetics.

From the findings we can conclude that both the way in which a design instantiates the intention of the designer as well as the extent to which it is unified and varied affect its aesthetic appreciation independently. Hence, these features really are distinct and belong to different levels – not just theoretically, but also empirically.

However, it is quite clear that the perceptual level has a greater impact on the aesthetic appreciation than the conceptual level does. In other words, the impression a design makes on our senses is more decisive for the aesthetic experience than the knowledge of what the designer was aiming for. It certainly helps that a design is a clever, elegant or effective solution for a particular use, but in order to be aesthetically pleasing it should foremost strike an optimal balance in terms of the unity and variety it presents.

On that note, the significant positive interaction between the levels adds an interesting nuance. The UMA is not a merely additive model. We get a clear indication that its levels do communicate. If a design instantiates an intention suitably, it is also deemed more beautiful on the basis of its perceptual features. Or, the other way around, if a design strikes a pleasant balance of unity and variety, its conceptual quality becomes more important as well. This opens up a number of interesting hypotheses. On the one hand, it is imaginable that the other levels of the model too stand in interaction with one another. This would imply that, although the individual levels add to the aesthetic experience in their own right, a truly beautiful design should be adequate on any level. On the other hand, some levels may figure as preconditions for the others to some degree. Stated differently, only under the condition that certain levels are deemed aesthetically optimal will the others be able to reach their full effect. The current analyses do not allow for such causal inferences, but this hypothesis presents itself as a promising direction for future research.

The merit of this study lies not just with its substantive findings. In methodological respect too, it offers a fruitful ground for future research. The stepwise approach is arguably intensive, but also very effective for systematic manipulations of diverse qualities in stimuli, as it provides the required degree of control on variation.

However, not unrelated to this, the findings of the second pre-test also call attention on some methodological pitfalls of a comprehensive approach towards aesthetics. The manipulations of unity that were probably too small in comparison to those concerning variety, illustrate the vulnerability of this type of study to insufficient (or just differing) degrees of variation in the variables. This could easily lead to effects of some variables being overshadowed by the effects of others. Although this does not compromise the general conclusions, it does warrant caution for future research. Also, the choice for USB sticks as a stimulus category may not have been ideal. Empirically, it is clear that these products require high degrees of unity. To test the UMA in future research, a product type where unity and variety are more in balance would be preferable.

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