Beauty in efficiency

An experimental enquiry into the principle of maximum effect for minimum means

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Abstract

Theory and discourse suggest that the aesthetic appreciation of a wide range of artifacts—including works of art and consumer products—is partially governed by the principle of maximum effect for minimum means. We conducted two studies to find experimental evidence of this principle in the context of product design. In Study 1, we tested the hypothesis that the aesthetic appreciation of a product would be positively affected by the perception of the product as the minimum means achieving the maximum effect. Encouraged by the results of this study, we conducted Study 2 to test again the principle of maximum effect for minimum means using a more controlled experimental design. Our findings provide support for our hypothesis, indicating that the aesthetic appreciation of a product depends, to some extent, on the perception that the product achieves more than other products from its category by making an efficient use of resources.

Keywords

aesthetic appreciation, aesthetic principles, design aesthetics, efficiency, maximum effect for minimum means, product experience

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The experience of beauty is undeniable, but it is also difficult to unravel. The aesthetic appreciation of physical objects—ranging from art pieces to consumer products—is often explained based on the objects' appearance, that is, based on aspects such as curvature (Silvia & Barona, 2009; Westerman et al., 2012), unity (Post, Blijlevens, & Hekkert, 2016; Veryzer & Hutchinson, 1998), and symmetry (Jacobsen & Hoefel, 2003; Locher & Nodine, 1989). The aesthetic appreciation of *Gauge*, the flower vase presented in Figure 1, might thus be explained with reference to qualities such as the roundness of its base, the unity of its shape and its rotational symmetry. Although such use of the term *aesthetic appreciation* can be ambiguous (Koren, 2010), we use it here—just as the word *beauty*—to refer to an appreciation that emerges from perceiving an artifact for its own sake, rather than from evaluating it based on some extrinsic interest. This definition is grounded in the classic understanding of aesthetics (see Goldman, 2001; Kant, 2000).

The prevalence of aesthetic judgments based on appearance does not imply that beauty can only be perceived in visual qualities or form. Many different kinds of thing are aesthetically appreciated even though they do not exhibit any conventional form or where it is not the form that is regarded as beautiful; examples include literary metaphors (Kaplan & Kris, 1948; Ramachandran & Hirstein, 1999), logical arguments (Walsh, 1979), scientific theories (Orrell, 2012), science experiments (Crease, 2004; Johnson, 2009), chess moves (Margulies, 1977), mathematical demonstrations (Hardy, 1967), and even criminal acts (Black, 1991). These very different things can all be regarded as artifacts

Figure 1. *Gauge* (2012) by Jim Rokos. As the water level drops, the center of gravity rises and the instability of the vase (with flowers) causes it to tilt over.

because they realize certain intended effects (Dipert, 1993; Hilpinen, 1992), and they can all be aesthetically appreciated for how they realize those effects. In this article, we examine this kind of aesthetic appreciation, which is conceptually independent from the appreciation of any form that the artifact might possess, and also from the appreciation of the artifact's effect in itself (for instance, when someone talks of "a beautiful murder"; see Black, 1991).

The intended effect of *Gauge* (Figure 1) is not simply to exhibit flowers, but also—and ultimately—to remind people to water those flowers when needed. Like many other vases, *Gauge* realizes this effect by exploiting the inherent transparency of glass and letting people see the dropping water level. But it does so even more effectively by exploiting the instability intrinsic to its shape (when holding flowers) and the gravitational field, which together cause the vase to tilt as the water level drops. Once people understand this about *Gauge*, either from explicit statements made about the design (Rokos, 2013) or through inference (Crilly, 2011a, 2011b), they are able to appreciate the vase not just for how it looks, but also for how it achieves its purpose. This appreciation is aesthetic because, as we previously argued, it emerges from perceiving the vase for its own sake, for the way it achieves the effect that it is intended to achieve. This aesthetic appreciation thus arises from having not just any sort of understanding of the artifact (for instance, an insight into its Gestalt, as reported by Muth & Carbon, 2013), but an understanding of the artifact in the light of its designer's intention (as suggested by Hekkert, 2014).

Philosophy on the aesthetics of everyday objects offers some theoretical insights into the type of aesthetic appreciation just described. For instance, Forsey (2013) builds on Kant's notion of dependent beauty to argue that the aesthetic judgment of an artifact is conceptually rich because it involves having knowledge of the artifact's purpose. Parsons and Carlson (2008) also provide philosophical grounds and a conceptualization of functional beauty, that is, a perception of beauty that involves understanding what the function of an artifact is, as well as how the artifact performs this function. Saito (2007) distinguishes an artifact's capacity to function from the way in which it functions, arguing—in line with the previous authors—that an artifact can be aesthetically appreciated for how it performs a function.

Discourse on the aesthetics of a wide range of artifacts further suggests that the appreciation of the way in which an artifact achieves an intended effect is governed by an essential principle. For example, Hardy (1967) sees beauty in the theorem by which Euclid demonstrates that there are infinite prime numbers through only a couple of statements. Crease (2004) sees it in the experiment by which Eratosthenes measures the large circumference of the Earth with a small shadow. Kaplan and Kris (1948) consider Eliot's metaphor "the shrunken seas" to be beautiful because it allows for multiple and nonexclusory interpretations: a mere state of the tides, a prolonged draught season and death by extension (the connection between ambiguity and aesthetic appreciation has recently

been studied by Jakesch & Leder, 2009, 2015; Muth, Hesslinger, & Carbon, 2015). The theorem, the experiment, and the metaphor might be generally taken as examples of cleverness and creativity. But, more specifically, these are instances where cleverness and creativity have been applied to achieve "the maximum effect" (a proof of infinitude, a measure of immensity, a multiplicity of interpretations) with "the minimum means" (a few statements, a small shadow, a single verbal expression). The same can be said about the theories, checkmates, and crimes discussed by Orrell (2012), Margulies (1977), and Black (1991).

The principle of maximum effect for minimum means (MEMM) is thought to govern the aesthetic appreciation of a wide variety of things (as stated by Boselie & Leeuwenberg, 1985). Yet, we lack experimental evidence that an artifact is aesthetically appreciated when perceived as the minimum means to achieve the maximum effect. Our goal is to find such evidence in the context of product design, where MEMM has been identified as a fundamental aesthetic principle (Hekkert, 2006; Hekkert & Leder, 2008), and where it is also referred to as economy (Zelanski & Fisher, 1984), efficiency (Macnab, 2012), and Occam's razor (Lidwell, Holden, & Butler, 2010). In this context, a product can be taken as the means by which a designer achieves an intended effect, and it can be appreciated for how efficiently it realizes this effect (even if the effect is considered unpleasant in its own right, as in the cases presented by Savić & Savičić, 2013).

Our investigation builds on two previous pieces of research. The first (Da Silva, Crilly, & Hekkert, 2015) applied a mixed-methods approach to examining if and how people's appreciation of a product is influenced by their knowledge of the designer's intention. Although this research did not focus on MEMM, it provided interview data suggesting that a product can be appreciated for how it achieves a purpose. The second (Da Silva, Crilly, & Hekkert, 2016) applied a purely conceptual approach to examining MEMM in the field of product design. It offered a theoretical basis for understanding the aesthetic appreciation of a product through this principle. The second piece of research provided the grounds to prepare the present investigation; for this reason, we will summarize its main points and illustrate them with the *Gauge* example (while acknowledging this example could be interpreted in other ways if other perspectives were being emphasized).

MEMM suggests that a means–effect relationship can be established between a product (the means) and the effect that the product is intended to have, and that this relationship is aesthetically appreciated when the product is judged to be the minimum means and its effect is judged to be the maximum effect. Any purpose that a designer aims at achieving through a product can be considered the intended effect of the product; this includes ordinary practical functions as well as human-centered effects (like those described by Crilly, Moultrie, & Clarkson, 2009; Fokkinga, Hekkert, Desmet, & Özcan, 2014). For *Gauge*, we have identified *reminding people to water the flowers* (in addition to *displaying flowers*) as the effect. Also, any resource that a product exploits to achieve a

given effect characterizes the product as a means; this includes the product's properties, the mechanisms by which it works, and the interactions it establishes with people. For *Gauge,* we have identified the instability of the vase and the gravitational field as salient resources.

The effect of a product can be judged maximal when it exceeds a merely practical function, while the product can be judged minimal as a means when it exploits resources that are inherent or already available—in particular, simple properties or mechanisms and intuitive or effortless interactions—to achieve a given effect. The product and its effect can be judged to be the minimum and the maximum based on artifact categories such as *flower vase*, which people develop intuitively (see Barrett, Laurence, & Margolis, 2008; Bloom, 1996; Matan & Carey, 2001) through experience and imagination (see Lakoff, 1990). A given effect can be judged to be the maximum relative to other known or imagined effects achievable by artifacts in the same category (or similar categories). *Reminding people to water the flowers* (in addition to *displaying flowers*) can thus be judged the maximum effect relative to just *displaying flowers*, which can be taken as the most immediate function of a flower vase. Similarly, a given means can be judged to be the minimum relative to other known or imagined means by which the same (or a similar) effect can be achieved. *Gauge* can, therefore, be judged the minimum means relative to, for example, a regular flower pot fitted with a sensor that assesses a plant's needs and sends notifications to the plant's owner through a smartphone application (see "Parrot: Flower power", 2012). In sum, MEMM implies that people's aesthetic appreciation of the relationship between a means and an effect is grounded in a set of assumed alternatives in comparison to which the means is perceived to be the minimum and the effect the maximum (Figure 2).

We acknowledge that the aesthetic appreciation of a means–effect relationship might be explained by factors other than MEMM. The literature providing illustrations of this principle also suggests unexpectedness and inevitability as alternatives, which makes us question the relationship among these three factors. Unexpectedness involves perceiving the means as an unanticipated or unpredicted way of attaining the effect, or the effect as being surprising or unforeseen given the means. Inevitability involves perceiving the means as a predetermined or unequivocal way of attaining the effect, or the effect as being unavoidable or necessary given the means. Both factors are thought to describe the beauty of mathematical demonstrations and architecture (Hardy, 1967; Parsons & Carlson, 2008), unexpectedness also explains the beauty of ballet leaps and rhymes (Boselie & Leeuwenberg, 1985; Poe, 1846), and inevitability that of music and scientific theories too (Howard, 1923; Orrell, 2012). The literature further suggests that these factors are not mutually exclusive. On the one hand, something inevitable is not necessarily obvious and can very well be unexpected or surprising (Howard, 1923). On the other hand, something unexpected is not necessarily arbitrary or optional and thus can still be inevitable, the result of

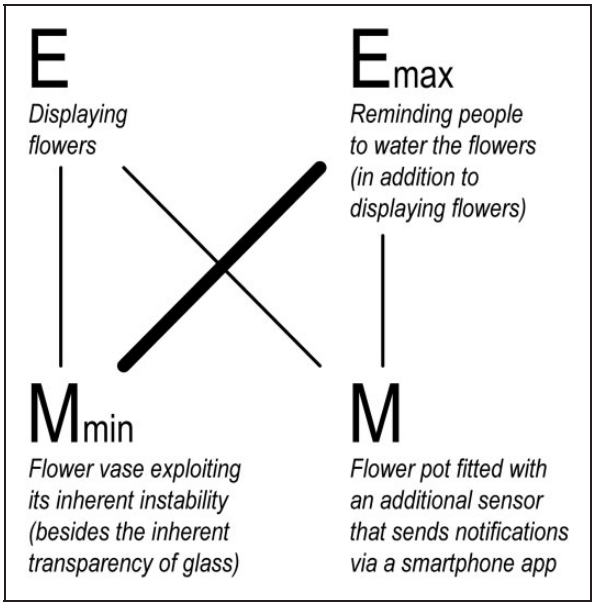

Figure 2. Aesthetic appreciation according to the principle of MEMM. Of a number of different effects and means (here we only represent two of each), people aesthetically prefer the maximum effect (Emax) that results from the minimum means (Mmin).

necessity (Cain, 2010). While the relationship between these two factors has been discussed, their relationship with MEMM remains uncertain.

To complement our nonexperimental findings regarding MEMM (Da Silva et al., 2015, 2016) and thus deepen the understanding of this principle, we conducted two studies. In Study 1, we tested the hypothesis that the aesthetic appreciation of a product would be positively affected by the perception of the product as the minimum means achieving the maximum effect, while controlling for the influence of unexpectedness and inevitability. For this study, we selected a range of products that naturally varied in their effects and the resources they used as means. Encouraged by the results of this first study, we conducted Study 2 to find further evidence of the principle of MEMM while controlling for the influence of visual appearance by employing a more controlled experimental design.

Study 1

Method

Participants. Sixty students from Delft University of Technology took part in Study 1 in return for 10 Euros each. There were 43 males and 17 females,

with an average age of 23.53 years ($SD = 2.72$). To prevent results being affected by specialized design knowledge, students from the faculties of Industrial Design and Architecture were not included.

Design. This study used a within-subject experimental design and employed a questionnaire for data collection. In the questionnaire, products were rated on four 7-point scales corresponding to the dependent variable Aesthetic Appreciation, and the three independent variables MEMM, Unexpectedness, and Inevitability.

Materials. Existing consumer products were used as stimulus materials. We represented the products with full-color photographs and written statements describing their intended effects (the real purposes for which they were designed), as well as the resources (properties, mechanisms, or interactions) that they employed as means to achieve these effects; the texts also indicated the categories to which the products belonged. For instance, one of the products preselected as stimulus was the *Gauge* flower vase. We represented this product with the image shown in Figure 1 and the following text: *This flower vase exploits the laws of physics to tilt as it runs out of water to remind people to water flowers*. We used these texts in an attempt to control for the various inferences that the participants might make about means and effects based on the product images, as well as for the different categorizations on which they would spontaneously base their MEMM judgments. Also, to prevent the participants from making comparisons among the stimuli, we made sure that the products used in the study belonged to different categories.

To make a final selection of 15 products that represented a range of variation in MEMM, we submitted a total of 25 products to a pretest. We conducted this pretest with two professional designers, considering that their professional experience qualified them as experts in the assessment of consumer products and the means–effect relationships that they represent. The designers were asked if they agreed or disagreed with the following four items regarding each product: (a) "This [product (e.g., *flower vase*)] uses unnecessary means for its purpose" (phrased to avoid double negative, answer reversed for analysis), (b) "This [product and effect (e.g., *flower vase reminds people to water flowers*)] in an efficient way," (c) "This [product] does more than [products from the same category (e.g., *flower vases*)] normally do," and (d) "Compared with other [products from the same category], this one has an additional purpose." We assigned one point to each agreement and calculated sum scores for each product, with the highest possible score being 8 (four agreements by two designers). We took sum scores of between 0 to 2, 3 to 5, and 6 to 8 points as corresponding indicators of low, medium, and high degrees of MEMM. On a first round, 15 products were pretested with the expectation that five of them would be rated as low, five as medium, and five as high in MEMM. Only 10 products

were rated according to this prediction and thus selected as stimuli (they represented high and medium degrees of MEMM only). On a second round, 10 more products were pretested with the expectation that at least five of them would be rated as low in MEMM. Only four were rated accordingly, so we completed our final selection of 15 products with one that obtained a sum rating of 3. The final selection of products is presented in Appendix 1.

Four scales were prepared for this study, each comprising a number of items on which the participants would rate the products from 1 (*disagree*) to 7 (*agree*). The scale measuring the dependent variable Aesthetic Appreciation was based on an existing scale (developed by Blijlevens, Thurgood, Hekkert, Leder, & Whitfield, 2014). To reduce the likelihood that the participants gave aesthetic ratings mainly based on the products' visual appearance, we rephrased the items of this scale so as to explicitly require the participants to take the products' effects into account. The items were phrased as follows: (a) "Given that it is designed to [effect], this is a beautiful [product]," (b) "Taking into account its purpose, this is an attractive [product]," and (c) "I like to look at this [product] knowing what it is for."

For each of the three independent variables, we developed a scale based on the theory that a product can be judged relative to a fixed effect or purpose, and that an effect can be judged relative to a fixed product or product category (as explained by Da Silva et al., 2016). Half of the items of each scale accounted for each of these possibilities. The MEMM scale comprised the four items already used in the pretest. The Unexpectedness scale included the following two items: (a) "I would expect a [product] to [effect]" (phrased to avoid negative, score reversed for analysis), and (b) "For a [product], this has a surprising purpose." The Inevitability scale comprised the following two items: (a) "Because of the way it is designed, this [product] will certainly [effect]," and (b) "[Effect] is an unavoidable outcome of using this [product]." (The fragments of the stimulus texts inserted between brackets in the scale items are italicized in Appendix 1.)

Procedure. The study was conducted in groups of up to four participants in a private well-lit meeting room of the Faculty of Industrial Design Engineering at Delft University of Technology. After being taken through a standard procedure to establish their informed consent, each participant sat in front of a 17×29 cm computer screen and completed the questionnaire in silence. The questionnaire was introduced as part of a research project on general product perception so as to prevent results being affected by the participants' awareness of the aesthetic focus of the study. As we already explained, the products were presented through images and texts; the images were displayed at a uniform 5 cm high and ranged between 3 and 8 cm in width according to their shape. The application that was used to develop the questionnaire presented one product at a time and required the participants to rate each product before presenting the next. It also required them to rate all the products on all the scale items to avoid having

missing values in the data collected. The order of presentation of both products and scale items was randomized between participants to prevent order effects. It took approximately 30 minutes for the participants to complete the questionnaire.

Results

In preparation for the statistical analyses, we reversed the ratings for the first items of both the MEMM and the Unexpectedness scales, which had been phrased to avoid possibly confusing (double) negatives. We then submitted the four scales to a reliability test (Cronbach's alpha). The internal consistency was good for Aesthetic Appreciation ($\alpha = .78$), MEMM ($\alpha = .70$), and Unexpectedness ($\alpha = .78$), and relatively poor—but still acceptable—for Inevitability ($\alpha = .54$). Next, we calculated ratings for Aesthetic Appreciation, MEMM, Unexpectedness, and Inevitability by averaging the ratings each participant gave to each product on the items of each scale. We conducted our main analysis with the ratings thus obtained.

To examine if Aesthetic Appreciation was influenced by MEMM, Unexpectedness, and Inevitability, we conducted a stepwise multiple regression analysis. At step one of the analysis, we only introduced MEMM as independent variable to test the hypothesis that the aesthetic appreciation of a product would be positively affected by the perception of the product as the minimum means achieving the maximum effect. The results supported our hypothesis, indicating that a significant proportion of the variance in Aesthetic Appreciation was explained by MEMM ($\beta = .54$, $p < .001$); $R^2 = .30$, $F(1, 898) = 381.97$, $p < .001$. MEMM had, as expected, a positive influence on Aesthetic Appreciation. The more a product was perceived to comply with MEMM, the more it was aesthetically appreciated. This linear relationship is illustrated in Figure 3.

At step two of the analysis, we added Unexpectedness and Inevitability as independent variables to examine if the aesthetic appreciation of a product would also be influenced by the perception of the product as an unexpected or inevitable means to achieve an effect, or as a means achieving an unexpected or inevitable effect. The results indicated that a significant proportion of the variance in Aesthetic Appreciation was explained not just by MEMM ($\beta = .45$, $p < .001$), but also by Unexpectedness ($\beta = .09$, $p = .003$) and Inevitability ($\beta = .06$, $p = .044$); $R^2 = .31$, $F(3, 896) = 131.85$, $p < .001$. Similarly to MEMM, Unexpectedness and Inevitability had a positive influence on Aesthetic Appreciation. But, as compared with MEMM, these variables explained a much smaller proportion of the variance in Aesthetic Appreciation.

The explanatory power of MEMM slightly decreased when we included Unexpectedness and Inevitability as independent variables in the previously reported regression analysis. This suggested that MEMM shared a fraction of its explanatory power with them. To explore the relationship of MEMM with

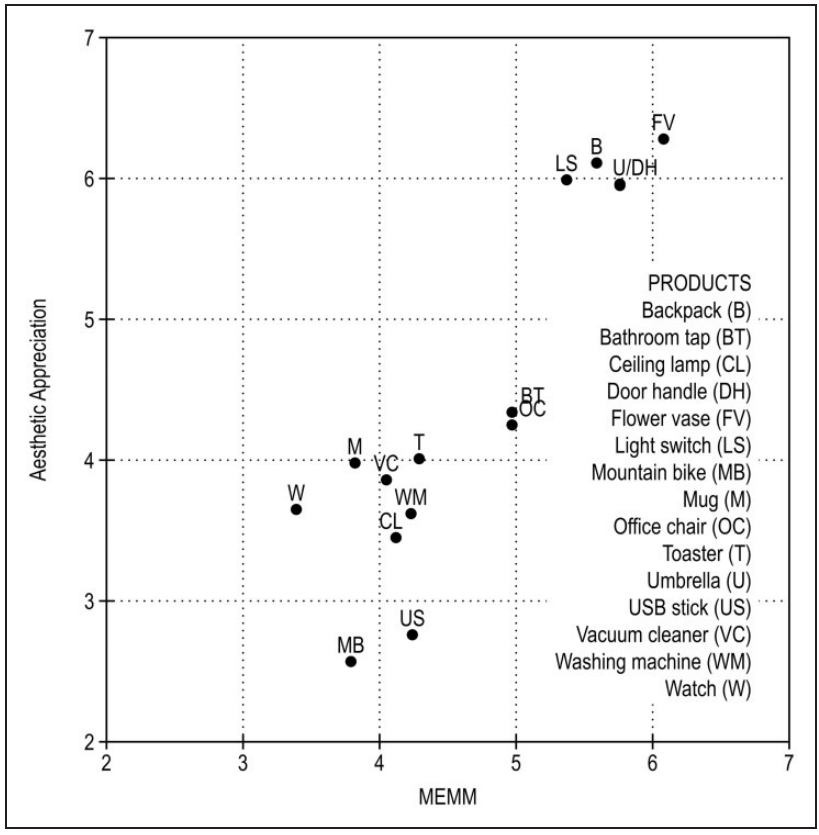

Figure 3. Relationship between mean Aesthetic Appreciation and MEMM ratings of products.

Unexpectedness and Inevitability, we conducted additional regression analyses. For these analyses, we averaged the ratings of the MEMM scale items a and b, on the one hand, and c and d, on the other, and took them as measures of Minimum Means and Maximum Effect respectively. We treated the ratings of the Unexpectedness scale items a and b as measures of Unexpected Means and Unexpected Effect correspondingly. We also treated the ratings of the Inevitability scale items a and b as measures of Inevitable Means and Inevitable Effect correspondingly. In the rest of our analyses, we tested the measures thus identified as predictors of Aesthetic Appreciation.

To explore the relationships among Minimum Means, Maximum Effect, Unexpected Means, Unexpected Effect, Inevitable Means, and Inevitable Effect as predictors of Aesthetic Appreciation, we initially conducted a stepwise

multiple regression analysis. At step one of the analysis, we only introduced Minimum Means and Maximum Effect as predictors. The results indicated that a significant proportion of the variance in Aesthetic Appreciation was explained by both Minimum Means ($\beta = .20$, $p < .001$) and Maximum Effect ($\beta = .31$, $p < .001$); $R^2 = .31$; $F\ (2,897) = 196.41$, $p < .001$. At step two of the analysis, we added Unexpected Means, Unexpected Effect, Inevitable Means, and Inevitable Effect as predictors. The results indicated that a significant proportion of the variance in Aesthetic Appreciation was explained not just by Minimum Means ($\beta = .16$, $p < .001$) and Maximum Effect ($\beta = .24$, $p < .001$), but also by Inevitable Means ($\beta = .09$, $p = .004$) and Unexpected Effect ($\beta = .11$, $p = .001$); $R^2 = .32$; $F\ (6,893) = 69.96$, $p < .001$. They also showed that the explanatory power of both Minimum Means and Maximum Effect slightly decreased when Inevitable Means and Unexpected Effect were introduced in the regression analysis. By conducting a series of stepwise regressions where we controlled for each predictor at a time, we found that the explanatory power of Minimum Means decreased with the introduction of Inevitable Means, and the explanatory power of Maximum Effect decreased with the introduction of Unexpected Effect. We will discuss this finding in the following section.

Discussion

Study 1 provided evidence that the aesthetic appreciation of a product is partially governed by the principle of MEMM. In support of our hypothesis, it showed that the aesthetic appreciation of a product is positively affected by the perception of the product as the minimum means achieving the maximum effect. For the way these concepts were operationalized, this implies that a product is aesthetically appreciated when it achieves more than other products from its category by making an efficient use of resources such as properties, mechanisms, and interactions. Of the stimuli tested, the flower vase received the highest aesthetic appreciation and MEMM ratings. Just like a normal glass vase, it displays flowers and allows the water level to be seen, but it additionally reminds people to water the flowers by exploiting the inherent instability of its shape rather than by using supplementary, external resources.

Study 1 also indicated that unexpectedness and inevitability influence aesthetic appreciation positively, although to a much smaller extent than MEMM. Our findings further suggested that there is a relationship between these two factors and MEMM; in particular, a relationship between an unexpected effect and the maximum effect, on the one hand, and an inevitable means and the minimum means, on the other. We interpret this finding as follows: An effect might be perceived to be the maximum when it exceeds the effect that is normally expected from a product of a given category, hence, when it is unexpected; also, a means might be perceived to be the minimum when it uses only

those resources that cannot be avoided in the search for a certain effect, hence, when it is inevitable.

In Study 1, we used a set of existing products that naturally varied in the effects they were intended to achieve and the resources they exploited as means, which contributed to the ecological validity of our findings. Although we thus demonstrated that MEMM positively affects the aesthetic appreciation of a product, it cannot be ruled out that the visual appearance of the products we used as stimuli played a confounding role. We mentioned the effects of these products in the scale items measuring aesthetic appreciation in an attempt to prevent participants from rating the products aesthetically mainly based on visual appearance. But this adaptation of the scale might have also biased the aesthetic appreciation ratings.

To put the principle of MEMM to a more rigorous test, which would allow us to control for the influence of visual appearance experimentally without requiring any adaptation of the aesthetic appreciation scale, we conducted a second study. In Study 2, we aimed at keeping the visual appearance of a product constant while varying the means–effect relationship that the product represented. Since Study 1 revealed that unexpectedness and inevitability only had a minor influence on aesthetic appreciation, we did not include these factors in Study 2.

Study 2

Method

Participants. Ninety students from Delft University of Technology took part in Study 2 in return for five Euros each. There were 75 males and 15 females, with an average age of 24.06 years ($SD = 2.35$). To prevent results being affected by specialized design knowledge, students from the faculties of Industrial Design and Architecture were not included.

Design. This study used a between-subject experimental design and employed a questionnaire for data collection. In the questionnaire, products were rated on two 7-point scales corresponding to the dependent variable Aesthetic Appreciation and the independent variable MEMM. The experimental design entailed manipulating stimulus materials to create two conditions: low-MEMM and high-MEMM.

Materials. With the aim of creating low-MEMM and high-MEMM conditions, we first selected a subset of the products used as stimuli in Study 1. This selection was based on the mean MEMM ratings calculated for the products with data from that study (where the average MEMM rating was 4.45, $SD = 1.27$). Five products had ratings above one standard deviation from the mean.

Table 1. Subset of Products Selected as Stimulus Materials.

	MEMM ratings obtained in Study 1	
Product	Highest	Lowest
Backpack	6.11	
Ceiling lamp		3.45
Door handle	5.95	
Flower vase	6.28	
Light switch	5.99	
Mountain bike		2.57
Umbrella	5.96	
USB stick		2.76
Washing machine		3.62
Watch		3.65

Note. MEMM = maximum effect for minimum means.

We selected these products and those five with the lowest ratings (two of which were below 1 *SD* from the mean). In Table 1, we present our selection of 10 products along with the mean MEMM ratings they obtained in Study 1.

Again, we represented the selected products with images and texts. To keep visual appearance constant, we represented each product with a single image, which was taken from Study 1. To vary the means-effect relationship each product represented and thus create the low-MEMM and high-MEMM conditions, we paired the product image with different texts. For this, we took the 10 texts already used in Study 1 and additionally developed new ones. We developed the new texts with attention to product attributes that could be directly perceived or imagined based on the images, regardless of whether these attributes really described the products or not. Like the old texts, the new ones referred to each product instance (e.g., "This") as a member of a product category (e.g., "flower vase"), so the same practical functions associated with that category (e.g., displaying flowers) could be assumed in both conditions. They also indicated the intended effects of the products and the resources the products used as means, so the same kind of information would be provided in both conditions. For the five products with the lowest MEMM ratings in Study 1, the new texts aimed at triggering the perception of a "high-MEMM" relationship. For the products with the highest MEMM ratings in Study 1, they aimed at triggering the perception of a "low-MEMM" relationship. For instance, a new description of the flower vase stimulus read as follows: *This flower vase is made of heavy glass, but can be inclined towards the sink tap so as to facilitate the*

process of watering flowers. We generated a total of 30 new texts, three for each of the 10 selected products.

To make a final selection of 10 texts that would serve as alternative descriptions of the products, we pretested the 30 new texts against the 10 old ones. We conducted this pretest with 12 professional designers, considering again that their professional experience qualified them as experts in the assessment of the means–effect relationships that consumer products represent. In this pretest, each designer rated a single set of 10 texts presented with the corresponding product images using the 7-point MEMM scale from Study 1. Since the new texts did not necessarily describe the products' real attributes, we also asked the designers to rate these texts from 1 (*disagree*) to 7 (*agree*) on the following three items: (a) "The explanation makes sense," (b) "It is possible that this [product] was designed to work as described in the explanation," and (c) "It is possible that this [product] was designed to [effect]." We considered these three items as joint indicators of Plausibility. For both the old and the new texts, we calculated mean MEMM scores; for the new texts, we also calculated mean Plausibility scores.

On the basis of the results of the pretest, we selected 10 new texts following two criteria. First, their Plausibility scores had to be above average ($M = 4.63$, $SD = 1.07$). Second, if the new text was required to trigger the perception of a high-MEMM relationship, then its MEMM score had to be higher than that of the old text describing the same product; if it was required to trigger the perception of a low-MEMM relationship, then its MEMM score had to be lower than that of the old text describing the same product. Table 2 presents the mean MEMM scores the old texts obtained in the pretest, as well as the mean MEMM and Plausibility scores of the new texts selected as stimuli.

Our final selection of stimulus materials, including the two sets of texts that allowed for the creation of the high-MEMM and low-MEMM conditions, is presented in Appendix 2.

Two scales were used in this study, each comprising a number of items on which the participants would rate the products from 1 (*disagree*) to 7 (*agree*). The scale measuring the dependent variable Aesthetic Appreciation in Study 1 was brought back to its original form (as presented by Blijlevens et al., 2014) for Study 2. This means that the scale items did not explicitly establish a relationship between the product being judged and its effect. Instead, the items read as follows: (a) "This is a beautiful [product]," (b) "This is an attractive [product]," and (c) "I like to look at this [product]." As we mentioned earlier, we had adapted the scale items for Study 1 to reduce the likelihood that the participants mainly based their aesthetic ratings on the products' visual appearance. The experimental design of Study 2 provided a strong control for the influence of visual appearance and, therefore, did not require any such adaptation of the scale. The scale used to measure the independent variable MEMM was exactly the same as in Study 1. (The fragments of the stimulus texts inserted between brackets in the scale items are italicized in Appendix 2.)

Table 2. Pretest Scores of the Selected Stimulus Materials.

	MEMM		Plausibility
Product	Old text	New text	New text
Backpack	5.08	2.17	5.11
Ceiling lamp	3.25	5.75	6.67
Door handle	6.42	2.92	4.89
Flower vase	5.83	4.17	5.44
Light switch	6.17	4.25	4.67
Mountain bike	1.75	5.42	5.67
Umbrella	5.83	5.08	6.00
USB stick	2.42	4.58	5.00
Washing machine	3.67	6.08	6.11
Watch	3.58	5.33	5.78

Note. MEMM = maximum effect for minimum means.

Procedure. Study 2 was conducted similarly to Study 1. The participants completed a questionnaire presenting each product through the corresponding image and a text describing either a low-MEMM or a high-MEMM relationship. No participant was shown the same product (image) twice, as one description of the product could affect the rating of the product when shown with the alternative description. Also, no participant was provided with a combination of both low-MEMM and high-MEMM texts. The low-MEMM texts mentioned the most immediate practical functions of the products as effects, that is, effects that could easily be inferred from how the products were explicitly categorized. By contrast, the high-MEMM texts revealed effects additional to those functions, more maximal effects that would be more difficult to infer because they were not so closely related to the way the products were explicitly categorized. If we provided the same participant with high-MEMM and low-MEMM texts, the high-MEMM texts could prompt inferences of additional (more maximal) effects in the low-MEMM condition, which would suggest that the low-MEMM products were high-MEMM instead. To avoid this, we randomly allocated each participant to either the low-MEMM or the high-MEMM condition while balancing gender between the conditions. It took approximately 30 minutes for the participants to complete the questionnaire.

Results

In preparation for the statistical analyses, we reversed the ratings for the first item of the MEMM scale, which had been phrased so as to avoid a possibly confusing double negative. We then calculated ratings for both Aesthetic

Appreciation and MEMM by averaging the ratings each participant gave to each product on the items of each scale. We conducted all our analyses with the ratings thus obtained.

To first validate our stimulus manipulation, we performed an independent-samples t test to compare MEMM ratings in high-MEMM and low-MEMM conditions. This test revealed that the ratings were significantly higher in the high-MEMM condition ($M = 5.33$, $SD = 1.27$) than in the low-MEMM condition ($M = 3.90$, $SD = 1.61$); $t\,(851.57) = -14.83$, $p < .001$. In line with the pretest we had conducted, this confirmed that our stimulus manipulation was successful. Altogether, the products selected as stimuli were perceived as the minimum means achieving the maximum effects in the high-MEMM condition more so than in the low-MEMM condition. The effect size for this analysis ($d = .97$) was found to exceed Cohen's (1998) convention for a large effect ($d = .80$).

To check the stimulus manipulation at the product level, we conducted a total of 10 independent-samples t tests to compare the MEMM ratings of each product in high-MEMM and low-MEMM conditions. The results of these tests are presented in Table 3. They showed that the ratings of all products were significantly higher in the high-MEMM condition than in the low-MEMM condition, except in the case of the light switch stimulus (for which the difference was not significant). On the basis of this finding, we omitted the ratings of this product stimulus from the rest of our analyses.

To again test the hypothesis that the aesthetic appreciation of a product would be positively affected by the perception of the product as the minimum means achieving the maximum effect, we conducted an independent-samples

Table 3. MEMM Ratings of Products in High-MEMM and Low-MEMM Conditions.

	High-MEMM		Low-MEMM		Difference			Effect size
Product	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*	Cohen's *d*
Backpack	5.86	.74	3.71	1.46	−8.80	65.00	<.001	1.85
Ceiling lamp	5.84	.90	4.04	1.26	−7.76	88.00	<.001	1.64
Door handle	5.57	1.12	4.89	1.38	−2.56	88.00	.012	0.54
Flower vase	5.55	1.01	4.94	1.23	−2.57	88.00	.012	0.54
Light switch	5.78	.83	5.57	1.37	−.91	72.24	.367	0.19
Mountain bike	5.59	1.29	2.42	1.27	−11.76	88.00	<.001	2.48
Umbrella	5.61	.95	3.92	1.44	−6.56	76.23	<.001	1.39
USB stick	3.86	1.71	2.46	.98	−4.77	69.95	<.001	1.00
Washing machine	4.70	1.09	3.61	1.46	−4.02	81.43	<.001	0.85
Watch	4.97	1.30	3.42	1.02	−6.29	83.07	<.001	1.33

Note. MEMM = maximum effect for minimum means.

t test to compare Aesthetic Appreciation ratings in high-MEMM and low-MEMM conditions. These results also supported our hypothesis, showing that the ratings were significantly higher in the high-MEMM condition ($M = 4.80$, $SD = 1.46$) than in the low-MEMM condition ($M = 4.35$, $SD = 1.73$); $t(785.64) = -4.10$, $p < .001$. They provided further evidence that a product is more aesthetically appreciated the more it is perceived to comply with MEMM. The effect size for this analysis ($d = .28$) was found to exceed Cohen's (1998) convention for a small effect ($d = .20$).

To further examine the influence of MEMM on Aesthetic Appreciation, we conducted a simple regression analysis entering MEMM ratings (from both low-MEMM and high-MEMM conditions) as predictors of Aesthetic Appreciation ratings (from both low-MEMM and high-MEMM conditions). In line with our previous findings, this analysis indicated that a significant proportion of the variance in Aesthetic Appreciation was explained by MEMM ($\beta = .43$, $p < .001$); $R^2 = .18$, $F(1,808) = 180.83$, $p < .001$. The results confirmed that the more a product is perceived to comply with MEMM, the more it is aesthetically appreciated. This linear relationship is illustrated in Figure 4.

Finally, to examine the influence of MEMM on Aesthetic Appreciation at the product level, we conducted a total of nine independent-samples t tests to compare the Aesthetic Appreciation ratings of each product in high-MEMM and low-MEMM conditions. The results of these tests are presented in Table 4. They showed that Aesthetic Appreciation was generally higher in the high-MEMM condition than in the low-MEMM condition, but that it only differed significantly for four of the nine tested products. We will reflect on this finding in the coming section.

Discussion

Study 2 provided further evidence that the aesthetic appreciation of a product is partially governed by the principle of MEMM. In line with Study 1, it showed that the perception of a product as the minimum means achieving the maximum effect has a positive influence on the aesthetic appreciation of the product. Unlike Study 1, Study 2 involved a manipulation of stimulus materials, which did not exactly reflect the world of existing products, but increased the internal validity of our findings. This manipulation allowed us to experimentally assess the influence of MEMM independently of visual appearance.

Study 2 revealed that a product can be aesthetically appreciated based on MEMM irrespective of how it looks. This suggests that, when comparing two similar looking products, people would aesthetically prefer the one that they perceive to better comply with MEMM. For example, they would prefer the vase that reminds them to water the flowers by exploiting the instability intrinsic to its shape over the pot that accomplishes the same effect by using a sensor and a smartphone app, even if these artifacts looked alike. This is not to deny that

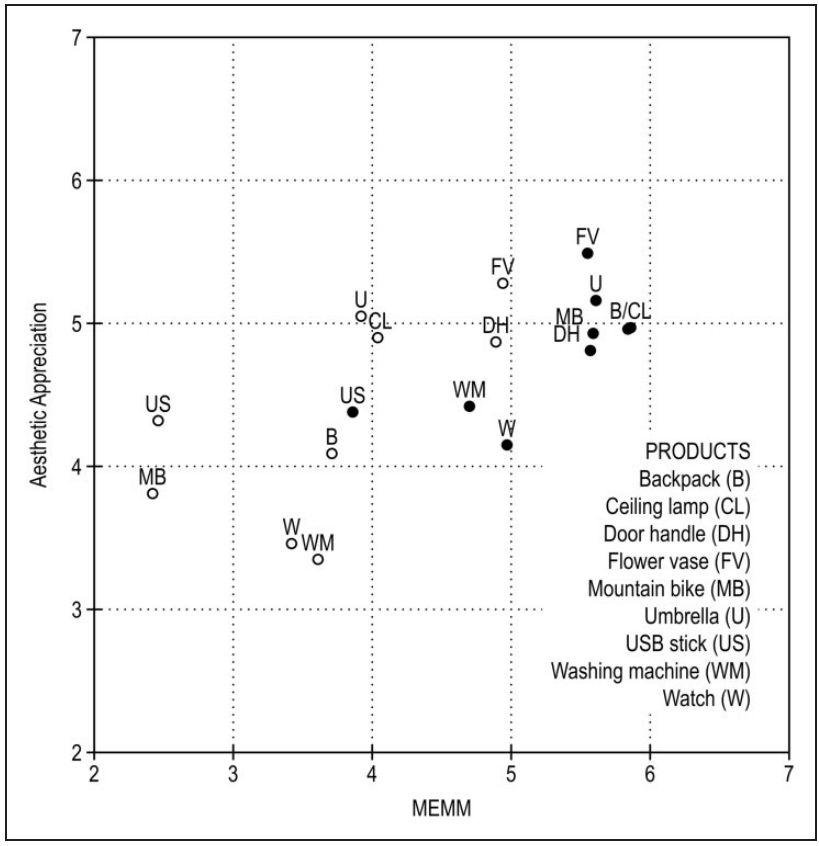

Figure 4. Relationship between mean Aesthetic Appreciation and MEMM ratings of products in high-MEMM (dots) and low-MEMM (circles) conditions.

MEMM and visual appearance can jointly contribute to the aesthetic appreciation of a product. The resources that a product uses to achieve an effect might be visible and pleasing to look at (e.g., the shape of the flower vase); and, if not visible (e.g., the vase's center of gravity), they might be inferred from visual appearance.

Although MEMM positively influenced the aesthetic appreciation of the products used as stimuli in Study 2, it only had a significant effect on the aesthetic appreciation of four of them. Two of these products had the biggest difference in MEMM ratings between conditions, which indicates that their low-MEMM and high-MEMM written descriptions triggered very contrasting perceptions of each of them. All the descriptions mentioned the effects of the products as well as the resources the products exploited as means, but they did

Table 4. Aesthetic Appreciation Ratings of Products in High-MEMM and Low-MEMM Conditions.

	High-MEMM		Low-MEMM		Difference			Effect size
Product	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*	Cohen's *d*
Backpack	4.97	1.23	4.09	1.37	−3.21	88.00	.002	0.66
Ceiling lamp	4.96	1.03	4.90	1.51	−.24	77.76	.808	0.05
Door handle	4.81	1.40	4.87	1.63	.19	88.00	.854	0.04
Flower vase	5.49	1.31	5.28	1.41	−.72	88.00	.471	0.15
Mountain bike	4.93	1.61	3.81	2.07	−2.88	82.85	.005	0.60
Umbrella	5.16	1.33	5.05	1.47	−.35	88.00	.726	0.08
USB stick	4.38	1.73	4.32	1.79	−.16	88.00	.873	0.03
Washing machine	4.42	1.37	3.35	1.65	−3.37	88.00	.001	0.71
Watch	4.15	1.59	3.46	1.44	−2.15	87.07	.034	0.45

Note. MEMM = maximum effect for minimum means.

not systematically vary in the kind of information they provided about means and effects. Hence, it remains to be seen how specific qualities of the means and the effect influence the aesthetic appreciation of an artifact.

General Discussion

Theory and discourse suggest that the aesthetic appreciation of an artifact depends, to some extent, on the perception that the artifact achieves the maximum effect through the minimum means. In this article, we sought experimental evidence of the principle of MEMM in the context of product design. In Study 1, we tested the hypothesis that the aesthetic appreciation of a product would be positively affected by the perception of the product as the minimum means achieving the maximum effect. We confirmed this hypothesis and also found that MEMM is related to two other factors, namely unexpectedness and inevitability. In Study 2, we used a more controlled experimental design to again test the principle of MEMM. We demonstrated that a product can be aesthetically appreciated as the minimum means to achieve the maximum effect irrespective of its visual appearance. In particular, our findings indicate that the aesthetic appreciation of a product partially depends on the perception that the product achieves more than other products from its category by making an efficient use of resources.

To better understand MEMM in the context of consumer products and other artifacts, further research is required. Our operationalization of MEMM and stimulus manipulation might serve as a basis for this. Although we conceptually distinguished some of the resources a product can use as a means

(properties, mechanisms, interactions) and some of the effects it can have (immediate practical functions and additional effects), these distinctions are rather broad and were not taken into account to manipulate stimuli in a systematic manner. Because of this, we cannot make any claims as to how specific aspects of means and effects affect aesthetic appreciation. Future studies could adopt an exploratory approach to research (for instance, by using interviews and questionnaires with open-ended prompts) to identify more specific aspects of means and effects and, more importantly, the qualities that make a means minimal and an effect maximal. Once identified, these qualities could be systematically manipulated in experimental stimuli to test the principle of MEMM in a more controlled manner. Future studies should further take into account the participants' level of design literacy. Although we avoided having students in Industrial Design and Architecture as participants to prevent results being affected by specialized design knowledge, it could be argued that our participants did not represent a completely naïve population insofar as they were all students in technical fields and therefore had formally acquired some knowledge of the way artifacts work. It remains to be seen whether our findings can be extended to a population with no technical background. Researchers should not overlook, however, that participants with a design background might contribute to unraveling MEMM in a way that other participants might not. For example, giving designers the task of (re)designing artifacts based on this principle could clarify how the notions of the minimum means and the maximum effect translate into design practice.

Research into the principle of MEMM can enhance the practice and teaching of artifact development in a number of areas, including design and the arts. In design, aesthetics often connotes the most superficial layer of a product, a merely decorative layer, clearly distinct from functionality. In the arts, aesthetics is a fundamental concern, but an aesthetically appealing art piece is not usually described in terms of an efficient means-effect relationship. Learning about MEMM involves acknowledging that aesthetics and functionality are not mutually exclusive. If design practitioners and educators focus on the development of products that do more than performing practical tasks, that is, products that influence people's relationship with their environment and one another, they might achieve not just efficiency, but beauty also. Initiatives such as design for sustainability, design for wellbeing, and design for behavioral change are taking a step in this direction. If artists and art critics become aware that a creative work can be aesthetically appreciated as the minimum means to convey an intended message or feeling, regardless of what this message or feeling is, they might gain a useful criterion to guide creative processes and assess works of art. This is particularly relevant for conceptual art, where the art object is not intended to be attractive in itself, but as a means to convey the artist's idea. Professionals such as marketers, advertisers, and curators, who are responsible of presenting artifacts to different audiences, might also benefit from

understanding MEMM. The principle could help them identify invisible aspects of an artifact that are aesthetically appreciated and thus deserve to be communicated. To the everyday users of products and regular museum visitors, knowledge of MEMM will provide some awareness of the reason they might like certain artifacts, an insight into their perceptions of beauty in efficiency.

Appendix 1

Stimulus materials used in Study 1.

Product	Image	Text
Backpack (by Enerplex)		This *backpack* is fitted with thin solar panels to *power portable electronic appliances*.
Ceiling lamp (by Ikea)		This *ceiling lamp* uses an electric bulb and an aluminum shade to *light up a room*.
Bathroom tap (by Tavistock)		This *bathroom tap* controls a valve mixing cold and hot water in order to *wash people's hands*.
Door handle (by The Agency of Design)		This *door handle* dispenses hand sanitizer when pulled, so as to *promote hygiene in hospitals*.
Flower vase (by Jim Rokos)		This *flower vase* exploits the laws of physics to tilt as it runs out of water to *remind people to water flowers*.

(continued)

Continued

Product	Image	Text
Light switch (by Leviton)		This *light switch* uses a motion sensor to turn off the light when there is no one around, so as to *save energy.*
Mountain bike (by The House of Solid Gold)		This *mountain bike* has heavy-duty wheels and a frame covered in 24-carat gold to *enable off-road cycling.*
Mug (by Heraldic Pottery)		This *mug,* with both body and handle made of glazed ceramic, enables people to *drink warm coffee.*
Office chair (by Zuo)		This *office chair* uses two metallic rods to connect five cylindrical cushions so as to *provide back support.*
Toaster (by Kalorik)		This *toaster* requires the user to press buttons, turn dials and push down levers in order to *toast bread.*
Umbrella (by Senz)		This *umbrella* is shaped asymmetrically, exploiting the laws of aerodynamics to *withstand strong winds.*
USB stick (by Star Enterprises)		This *USB stick* uses flash memory covered with a metallic case and pieces of leather in order to *store data.*

(continued)

Continued

Product	Image	Text
Vacuum Cleaner (by West Point)		This *vacuum cleaner* uses an electrically powered air pump to *suck up dust from different surfaces.*
Washing machine (by Ventus)		This *washing machine* requires the user to fill it with water and pump a pedal continuously so as to *wash clothes.*
Watch (by Muji)		This *watch* uses a battery-powered mechanism to move a set of hands and thus *give the time of day.*

Appendix 2

Stimulus materials used in Study 2

Product	Image	Texi in high-MEMM condition	Text in low-MEMM condition
Backpack (by Enerplex)		This *backpack* is fitted with thin solar panels to *power portable electronic appliances.*	This *backpack* is made of heavy-duty textiles and reinforced with an aluminum structure so as to *carry school textbooks and utensils.*
Ceiling lamp (by Ikea)		This *ceiling lamp* uses an occupancy sensor to turn off the light when there is no one in the room, so as to *reduce electricity usage.*	This *ceiling lamp* uses an electric bulb and an aluminum shade to *light up a room.*

(continued)

Continued

Product	Image	Texi in high-MEMM condition	Text in low-MEMM condition
Door handle (by The Agency of Design)		This *door handle* dispenses hand sanitizer when pulled, so as to *promote hygiene in hospitals*.	This *door handle* requires people to insert an identification card into a narrow slot and hold it there for 5 seconds so as to *open the door*.
Flower vase (by Jim Rokos)		This *flower vase* exploits the laws of physics to tilt as it runs out of water to *remind people to water flowers*.	This *flower vase* is made of heavy glass, but can be inclined toward the sink tap so as to *facilitate the process of watering flowers*.
Light switch (by Leviton)		This *light switch* uses a motion sensor to turn off the light when there is no one around, so as to *save energy*.	This *light switch* requires the user to turn a dial 360° to *change the intensity of light*.
Mountain bike (by The House of Solid Gold)		This *mountain bike* uses energy generated by pedaling to *charge devices like smartphones and music players*.	This *mountain bike* has heavy-duty wheels and a frame covered in 24-carat gold to *enable off-road cycling*.
Umbrella (by Senz)		This *umbrella* is shaped asymmetrically, exploiting the laws of aerodynamics to *withstand strong winds*.	This *umbrella* uses a hydraulic pump and fine oils to *activate an opening mechanism*.

(continued)

Continued

Product	Image	Texi in high-MEMM condition	Text in low-MEMM condition
USB stick (by Star Enterprises)		This *USB stick* has a flexible surface that inflates and deflates to *indicate how much data is currently being stored.*	This *USB stick* uses flash memory covered with a metallic case and pieces of leather in order to *store data.*
Washing machine (by Ventus)		This *washing machine* uses a simple human-powered mechanism to *enable people to do laundry in rural areas.*	This *washing machine* requires the user to fill it with water and pump a pedal continuously so as to *wash clothes.*
Watch (by Muji)		This *watch* employs GPS signals to set the time automatically and thus *give the correct time of day anywhere in the world.*	This *watch* uses a battery-powered mechanism to move a set of hands and thus *give the time of day.*

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