Designing for the new vehicle DNA

Evaluation of the MAYA principle for the rapid adoption of sustainable vehicles

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Abstract: Current trends in automotive technology allow for radical changes in vehicle design. Electric powertrains, drive-by-wire technology, new materials, and increasing levels of driver assistance, expected to ultimately lead to fully autonomous vehicles, will lift the mechanical and safety constraints that to this date have defined the shape and size of the automobile. Besides creative freedom and enhanced aesthetics, novel vehicle designs can also be expected to have wider societal benefits with regard to energy consumption, traffic congestion, road safety, and driver comfort. However, for these benefits to materialize, consumer acceptance of new vehicle designs is paramount. The primary aim of this research is to investigate the relationship between consumers' response to novel vehicle designs. Participants (design experts / non-experts) were exposed to 9 pictures of urban compact electric concept vehicles of differing typicality and novelty. Based on the MAYA (Most Advanced, Yet Acceptable) principle, it was expected that aesthetic preference is determined by an optimum combination of typicality and novelty and that participants prefer novel design as long as the novelty does not affect typicality. The results of the study provide support for the MAYA principle whilst highlighting the methodological need to include an appropriate range of stimuli to avoid floor and ceiling effects. The finding that non-experts have smaller tolerances towards novelty than experts suggests that the sustainability agenda is better served by restrained design.

Key words: Car design, Sustainability, Aesthetics, MAYA principle

1. Introduction

"The adult public's taste is not necessarily ready to accept the logical solutions to their requirements if the solution implies too vast a departure from what they have been conditioned into accepting as the norm"

– Raymond Loewy

Since the introduction of mass-produced vehicles at the beginning of the 20th Century, the design of the automobile has fundamentally remained unchanged. Currently we find ourselves however at a crossroads where radical changes to automobile design have not only become a possibility but, alas, a necessity. With more than half the global population living in urban areas, 850 million vehicles powered by petroleum fueled internal combustion engines (ICE), and emerging markets, the need for sustainable personal mobility is now widely recognized. The *new automotive DNA* [9] represents a promising departure from the current model and has the potential to bring us closer towards this goal.

This new DNA is centered around electrification. Although by no means a new idea, the first 4-wheeled electric car was built in 1888 by Andreas Flocken [10], electric vehicles that can accommodate modern driver requirements have only become feasible as a result of improvements in battery storage capabilities. It should be noted that electrification not only refers to the replacement of ICEs by electric motors powered by clean renewable energy sources, but also the introduction of *drive-by-wire*. The term drive-by-wire is used to describe the replacement of traditional mechanical control systems by electronic control systems using electromechanical actuators. By eliminating both the ICE and mechanical control systems such as the steering column, shafts, pumps, hoses, belts, coolers and vacuum servos, a so-called *skateboard platform* is created (see Figure 1). With all propulsion and energy storage systems contained within this platform, interior and exterior designs are no longer dictated by the position, shape, and size of mechanical parts, which, in turn, provides an unprecedented design freedom.

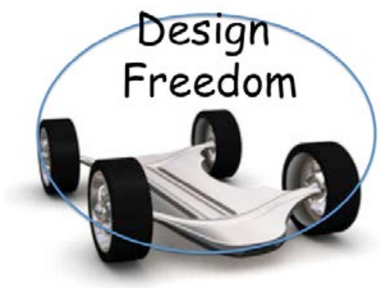

Figure.1 Illustration of the design freedom offered by skateboard platforms (GM)

This freedom is further enhanced by advancements in crumple zone, safety cells, and passive safety technologies. As a consequence, considerably less real estate is required to absorb the impact of a collision which allows even compact microcars such as the Smart car to achieve high crashworthiness ratings. Active safety, i.e. crash prevention systems, is also becoming increasingly effective in mitigating or avoiding collisions altogether. Considering current developments in Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication in combination with GPS technology and detailed digital maps, the connected vehicle will ultimately enable fully autonomous driving as recently showcased by Google.

As a corollary of the abovementioned developments, crash protection requirements are reduced which in turn allow for vehicles to become smaller and lighter, making them more conducive to electric drive and thereby encouraging the use of renewable energy sources [9]. Besides direct environmental benefits that emerge from this downsizing, the reduced spatial footprint also translates into reduced road and parking space required, leading to improved traffic flow and reduced congestion.

However, these benefits will only materialize if this new vehicle DNA results in high-volume consumer acceptance. The central question therefore becomes how we can encourage consumers to purchase and use these vehicles. Assuming that over the next few years electric cars will be similar in terms of their technical characteristics, quality and price, customer enthusiasm and uptake will to a large extent be determined by their visual appearance and associated customer’s product affection [2, 5]. Given the new vehicle DNA, how do we best make use of this newly acquired design freedom? From a designer's standpoint, there may be a desire to celebrate the new technology and create a new shape and surface vocabulary. However, are customers ready for these changes, or better, how far could or should one push the boundaries to create desirable vehicles but without alienating potential customers? Is the sustainability agenda better served by designing conventional vehicles?

Raymond Loewy [8] famously stated that aesthetic appeal was a balancing act between typicality and novelty. According to his Most Advanced Yet Acceptable (MAYA) principle, the most advanced form of a product that is still recognizable as familiar will stand the best chances of commercial success. In their 2003 paper [7], Hekkert et al. referred to Bornstein's [3] evolutionary account of this apparent incompatibility between novelty and typicality. A preference for the familiar over the novel can be considered biologically adaptive by avoiding risk inherent in any venture in the unknown. Conversely, seeking out novelty facilitates learning and can be rewarding and stimulating. Hekkert et al. [7] empirically evaluated the MAYA principle using a range of products, including vehicles. By showing participants a picture set of 20 medium-sized cars, it was found that, in line with the MAYA principle, vehicle typicality and novelty jointly determined aesthetic preference but that each one of them suppressed the positive effect of the other. This mutual suppression can be understood when considering that for most products, novelty and typicality are negatively correlated. Hekkert et al. also showed that experts in car design discriminated more between typicality and novelty. That is, compared to non-experts, for experts typical designs may be regarded as novel and, conversely, novel designs may be typical. Irrespective of the level of expertise, however, novelty was found to be only a slightly stronger predictor of aesthetic preference than typicality which was interpreted to suggest that experts do not rate novelty more highly than typicality as often assumed. On the basis of their data, Hekkert et al. [7] concluded that "…in order to create a successful design, the designer should strike a balance between novelty and typicality in trying to be as innovative as possible while preserving, as much as possible, the typicality of the design" (p. 122).

Returning to the question how to make best use of the design freedom, the objective of this paper was twofold. First, does the MAYA principle apply to more extreme vehicle designs and can we thus use it as a tool within the design process. Unfortunately, Hekkert et al. [7] failed to report the full stimulus set and aesthetic preference ratings. As a consequence, beyond the empirical evaluation of the MAYA principle, it is difficult to gain an insight into the relationship between vehicle design characteristics and ratings of typicality, novelty, and aesthetic preference. Furthermore, the variability in novelty and typicality in vehicle design was more than likely restricted due to the mere fact that their stimulus set consisted of mid-size production cars. In this study we choose to include a wide range of electric compact urban concept vehicles. Rather than production vehicles, the use of concept or pre-production cars allowed us to collect a dataset of responses to vehicles more closely aligned to the new vehicle DNA. Secondly, we evaluated the same vehicle designs with two clearly distinct groups in terms of car design expertise. Whereas Hekkert et al. [7] operationalized expertise via a car expertise questionnaire within a relatively homogeneous group of industrial design students, we selected a group of automotive design and psychology students. By mere virtue of their curriculum, this allowed us to create two clearly distinct groups in terms of car design expertise. The inclusion of automotive design students also allowed us to obtain some data to feed into the wider discussion whether it is the designer's task to challenge or seduce customers and the designer's ability to produce product forms that elicit the intended effect [6].

2. Methods

2.1 Participants

Two groups of participants, both from the student population of Coventry University, were asked to rate nine different vehicle designs. The first group consisted of 97 (87 male, 10 female) final year automotive and transportation design students (mean (SD) age = 23(2.7)). The other participant group consisted of 68 (9 male, 59 female) second year psychology students (mean (SD) age = 20(3.0)). Due to the nature of the two student populations, the two groups were assumed to significantly differ in their expertise on design and car design in particular and are henceforth referred to as the *expert* (automotive and transportation design students) and *non-expert* (psychology students) group.

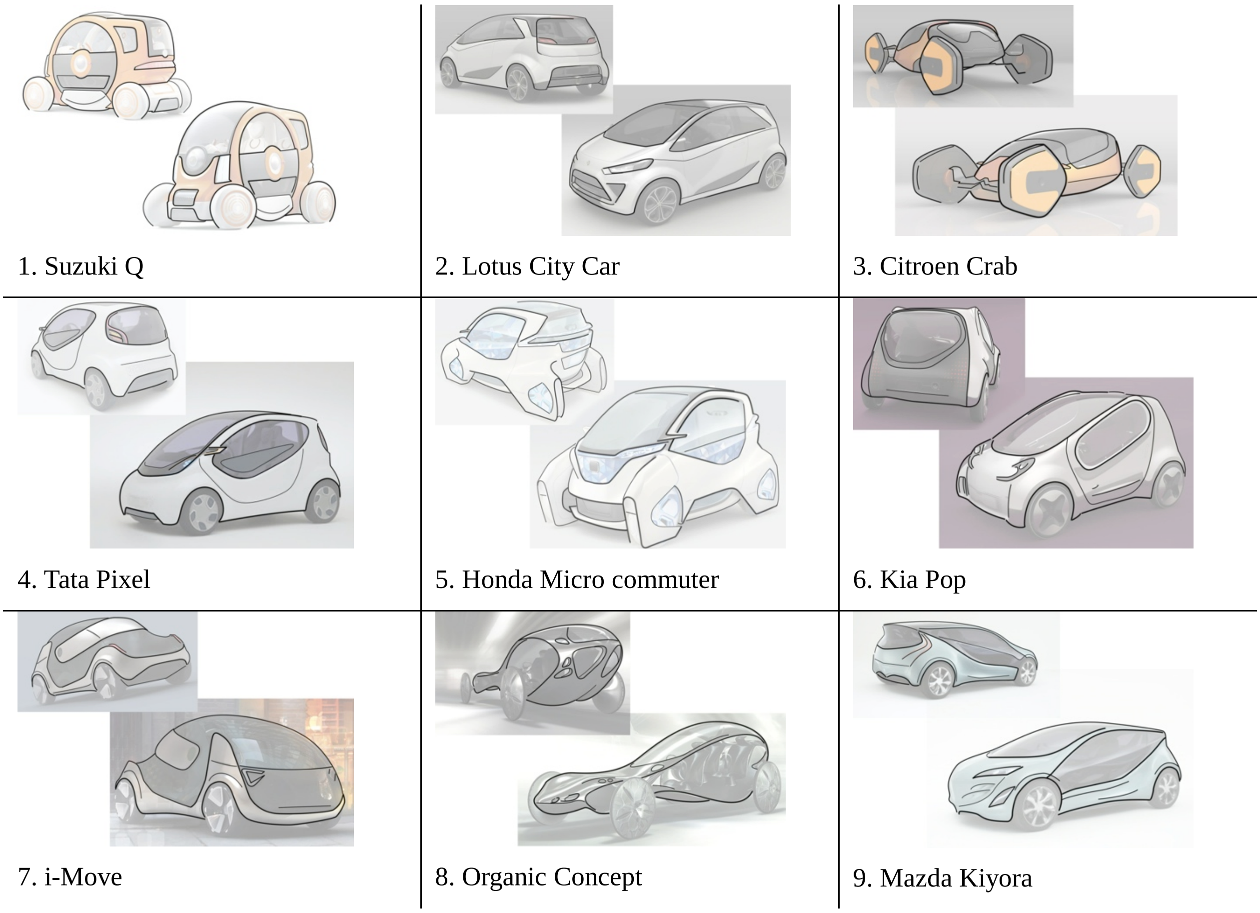

Figure 1. Rear and front three quarter images of the electric concept vehicles

2.2 Stimuli

Nine electric compact urban concept vehicles were selected to be included in the stimulus set. Urban vehicles were chosen to control, at least to some extent, for difference in vehicle type and size and focus on the aesthetic differences within this specific category. Rather than conventional ICE powered compact cars, we here focused on electric vehicles given their shared characteristics with the new vehicle DNA. Within this vehicle class, as wide as possible a selection of typical and novel designs was made and consisted of both OEM (designs 1-6, 9) and non-OEM (designs 7 and 8) concept vehicles (see Figure 1). For each vehicle design a three quarter perspective picture was selected showing the vehicle from both the front and rear. To control for differences in components, form and non-form shading, each picture was overlaid with a white transparent layer. Secondly, the vehicles' form lines (i.e. lines along shut-lines, or car body panel edges) were traced. As demonstrated by Tovey et al. [11], form lines are of primary importance in delineating the shape that the designer intends for the design.

2.3 Procedure

Data was collected at the beginning of two lectures. Students were asked to rate 9 vehicle designs that were projected on a wide field of view screen in a lecture theatre. At the beginning of each lecture, a slide showing all nine designs was presented to familiarize participants with the stimulus set. Next, they were presented with each consecutive design in isolation and asked to rate each design on the following 7-point rating scales (adapted from Hekkert et al. 2003): *Poor example—Good example* of the category (typicality), *Not original—Original* (novelty), and *Ugly—Beautiful* (aesthetic preference). For the first scale, participants had to indicate how good an example each model was as an instance of the category 'car'. Each consecutive design was presented after approximately 30 seconds, the time it required for participants to fill out the three questions for the specific design. The order of presentation was identical for both participant groups.

4. Results

For each design, the mean of the ratings for typicality, novelty, and aesthetic preference was calculated over the participants. Figure 2 (top graph) shows the mean (± Standard Error of the Mean) preference ratings for each vehicle design for the expert and non-expert group. The designs are ordered from the most to the least preferred designs for the expert group. Comparing the mean ratings across the two groups, it is apparent that there were wide differences in aesthetic appreciation of the different vehicles.

For the expert group, the designs broadly fell within two distinct groups of vehicles with designs 2, 3, 5, and 9 rated considerably higher than designs 1, 4, 6, 7, and 8. Post-hoc pairwise comparisons showed none of the preference ratings within each group to be significantly different, whereas each of the designs in the preferred group were rated significantly higher than the designs in the non-preferred group ($p < .01$, Tukey's HSD).

Figure 2 also shows that the preference ratings for the non-expert group showed considerably more variation compared to the expert group. Visual inspection of the graph clearly indicates that the non-expert group rated the same designs considerably different to the expert group. Statistical analysis showed that only designs 6 and 7 did not significantly differ between the expert and non-expert group ($p > .05$, independent samples T-tests).

Because of the large differences observed in aesthetic preference, the two groups were separately analyzed with regard to the relationship between preference, novelty, and typicality. In the below, the results of the expert group are described first, followed by the same analysis for the non-experts.

Experts: The mean typicality and mean novelty ratings showed a high negative correlation (Pearson's $r = -.90$, $p < .01$) (see Figure 2). Neither the correlations between the mean typicality and mean preference scores (Pearson's $r = .34$), nor the correlations between the mean novelty and mean preference scores (Pearson's $r = -.04$) reached statistical significance ($p > .05$). As discussed in the introduction, the presence of a high negative correlation between typicality and novelty would suggest that either of these variables may have acted as a

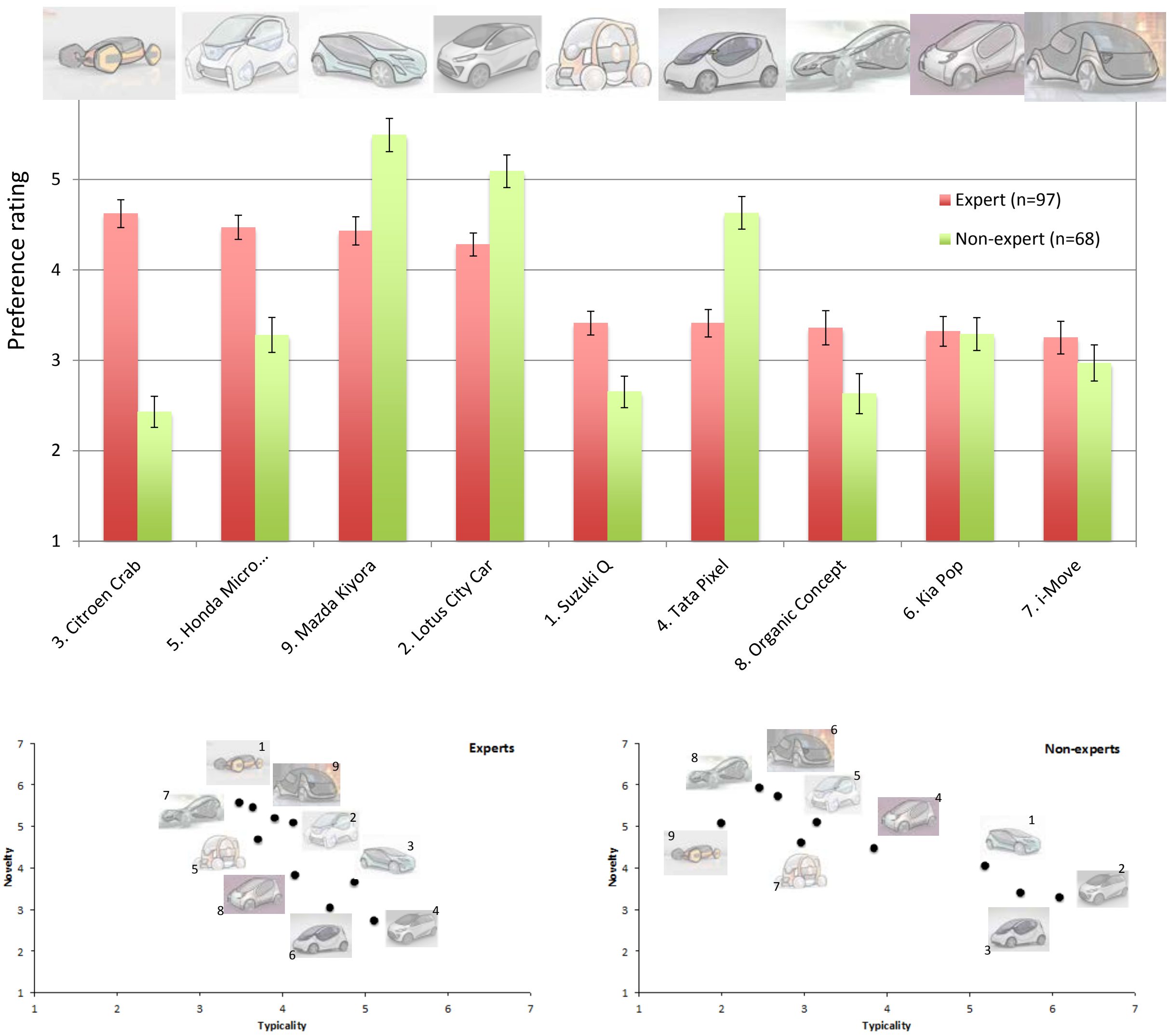

Figure 2. Top graph displays the mean (±SEM) aesthetic preference for the expert and non-expert group for each vehicle design. Bottom graph shows the typicality vs. novelty per design for the experts (left) and non-experts (right). The number on each design is the aesthetic preference with 1/9 being the most/least preferred design, respectively.

suppressor variable. To evaluate this, the partial correlation coefficients were calculated. After partialling out the common variance with novelty the mean typicality scores showed substantial relationships with the mean preference scores (Partial r = .69, p = .06). The mean novelty ratings also showed a substantial increase in correlation with the mean preference score after partialling out typicality (Partial r = .64, p = .09). Note that although the partial correlations failed to reach the level of significance required ($p < .05$), the substantial increase in the relationship with preference scores suggest that both typicality and novelty indeed acted as suppressor variables. To assess the amount of variance in the preference ratings that can be explained by the two predictor variables, a regression analysis was subsequently performed which indicated that only 23% of the variance could be explained by typicality and novelty. The standardized regression coefficients of typicality (beta = 1.56, p = .06) and novelty (beta = 1.36, $p = .09$) indicated that typicality was slightly more important determinant of aesthetic preference.

Non-experts: Similar to the expert group, the mean typicality and mean novelty ratings showed a high negative correlation (Pearson's $r = -.91$, $p < .01$) (see Figure 2). However, unlike the expert group, strong correlations were observed between the mean typicality and mean preference scores (Pearson's $r = .94$), and between the mean novelty and mean preference scores (Pearson's $r = -.80$). Both correlations were shown to be statistically significant ($p < .01$). Despite the negative correlation between typicality and novelty, the partial correlation coefficients indicated that novelty and typicality did not act as suppressor variables as both the relationships with the preference ratings decreased after partialling out novelty (Partial $r = .86$, $p < .01$) and typicality (Partial $r = .41$, $p = .32$). The regression analysis showed that 82% of the variance in preference could be explained by typicality and novelty, with typicality playing a considerably more important role as indicated by the standardized regression coefficients of typicality (beta = 1.24, $p = .00$) and novelty (beta = .33, $p = .32$).

5. Discussion and conclusions

The aim of this study was to evaluate the MAYA principle in the context of current changes in automotive technology, i.e. the introduction of the new vehicle DNA, which allows for radical changes in vehicle design. Besides creative freedom and enhanced aesthetics, this new DNA is expected to have significant environmental benefits. In order for these to materialize consumer acceptance is paramount. The MAYA concept would suggest that in order to maximize acceptance and uptake, vehicle design should be as innovative as possible while preserving, as much as possible, the typicality of the design.

Overall, the results of the current study provide support to the MAYA principle. When considering the expert group, our results were in line with previous findings by Hekkert et al. [3] in that novelty and typicality jointly determined aesthetic preference, and furthermore, that both novelty and typicality acted as suppressor variables as indicated by the higher partial correlations. The results of the non-expert group in first instance seemed to contradict the MAYA principle. Unlike Hekkert et al. [3], we observed strong direct correlations between preference and both novelty and typicality. As evidenced by reduced partial correlations compared to the direct correlations, novelty and typicality did not act as suppressor variables in this group. Even though 82% of the variation could be explained by novelty and typicality, the standardized regression coefficients showed that for the non-expert group typicality had a far more important role than novelty. In line with this, it can be seen in figure 2 (bottom right) that the three most preferred vehicle designs were those rated as most typical and least novel. This would suggest that at least for the non-expert group in this study, the preference-for-prototype theory [13] would be a better fitting model than the MAYA principle.

However, there are a number of possible explanations for the apparent discrepancy with Hekkert et al.'s [3] findings. First, our stimulus set differed in several respects. Rather than production cars, concept vehicles were used that differed considerably in design language. Although Hekkert et al. did not specify their dataset, given that they were all production vehicles they more than likely showed less extreme variation in design language. Stimulus presentation, i.e. white transparent overlay with pronounced form lines, is another factor that differed between the two studies which may have had an effect on perceived typicality, novelty and aesthetics. Most importantly, however, it cannot be ruled out that in the current study a floor effect has occurred. The stimulus set consisted of compact urban electric vehicles that in itself can be considered a relatively novel vehicle category. For non-experts, these vehicles may well have represented the extreme end of the spectrum. Hence, it is not surprising that the non-experts preferred the most typical and least novel designs within this stimulus set and future research into the MAYA principle would therefore benefit from extending the stimulus set with more conventional vehicles.

Stimulus range may also be responsible for the striking differences in variation of preference scores between the two groups. Whereas the different designs led to a wide range of preference ratings in the non-expert group, the expert group appeared to have categorized the designs into a preferred and non-preferred group with only small differences in preference ratings within each group (see Figure 2). Although this was not assessed as part of this study, these findings may be related to the idea that experts have a more fine grained conceptual structure [1]. Experts seemed to have categorized vehicles into preferred and non-preferred in a homogenous fashion with little variation in aesthetic preference within each category. This may be explained by the fact that experts will have a wider frame of reference when it comes to vehicle design. With this larger variety of vehicle designs, the selected stimulus set used in this study may perhaps not have been as extreme, which also explains the narrow distribution in typicality ratings. That is, within the reference set of experts, the stimulus set only covered a relatively small amount of possible design language. In particular, car design experts would be familiar with far more extreme vehicle designs. The lack of this reference set in the non-expert group would also explain the larger variation in typicality ratings within this group, i.e. unusual vehicle designs would have been rated more extremely by the non-experts than the experts both in terms of novelty and typicality.

Returning to the original question how to make best use of the design freedom provided by the new vehicle DNA, it is worthwhile considering the aesthetic preference ratings in the expert and non-expert group (Figure 2). Designs 2 and 9 were highly rated in both groups. However, the two most preferred designs as indicated by the experts (designs 3 and 5) were amongst the least preferred designs as rated by the non-experts. Acknowledging the fact that experts were not asked to rate the different designs according to preference of the general public or potential customers but according to their own personal preference, the discrepancy in preference ratings raises the question to what extent designers are tuned in to customers' aesthetic preferences. It has been suggested that experts tend to suppress their initial, affective response in favor of an intentional and reflective mode of evaluation characterized by a striving for novelty [4]. Hence, this raises the question to what extend experts' responses reflect aesthetic value as opposed to aesthetic preference [14] and to what extent designers are able to disentangle the two.

In conclusion, the findings of the study provide support for the MAYA principle whilst highlighting the methodological need to include an appropriate range of stimuli to avoid floor and ceiling effects. The finding that non-experts have smaller tolerances towards novelty than experts suggests that the sustainability agenda is better served by restrained design.

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