Slow down, you move too fast: Examining animation aesthetics to promote eco-driving

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ABSTRACT

We examine how people perceive visual properties of new concepts for the design of animated vehicle instrument clusters, with emphasis on aesthetic aspects. The project is placed in the context of animations for eco-conscious driving. It consists of two stages: Creating animations and studying drivers' reactions to them. Two studies were conducted which provide various insights regarding tradeoff in the design process and drivers' preferences. The second study also serves as a first step towards the study of people's aesthetic perceptions of in-vehicle animations.

Categories and Subject Descriptors

H.5.1 [Information interfaces and presentation]: Animations, Evaluation/methodology.

General Terms

Measurement, Design, Experimentation, Human Factors.

Keywords

Animation, eco-efficiency, aesthetics, design, in-vehicle, drivers, evaluation

1. INTRODUCTION

Automobile emissions account for 27% of all U.S. greenhouse gasses [17], thus the reduction of CO_2 emissions and fuel consumption from road transportation has become an increasingly important goal for most countries, in the attempt to fight global warming, health hazards and implement the Kyoto Protocol [7]. Reducing emissions can take many forms such as the introduction of electrical vehicles (EV), technological advancements for existing solutions (e.g. improving engines' efficiency) and reducing the vehicle miles travelled [1], to name just a few.

An important (but typically overlooked) contribution to emission reduction is the modification of driving style, frequently referred to as "eco-driving". Eco-driving is a win-win proposition both for individuals, who can benefit from reduced fuel consumption of ~10%, and for society, through reduced emissions and the associated benefits thereof [1].

Animations that convey information such as eco-efficiency information, battery and gas usage in hybrid and electric vehicles, are becoming an integral part of modern in-vehicle instrumentation [16,21]. Beyond the instrumental value of the animations, they have aesthetic and symbolic value. Our major objective was to examine the relationship between animated designs and these aesthetic and symbolic values.

The project described in this paper is part of ongoing efforts of General Motors to take ownership of the user experience of in-vehicle information systems (e.g., [9]). It was performed in collaboration with the Bezalel Academy of Arts and Design in four phases. 1) Analysis of an example problem space; 2) Conceptual and detailed design of animations; 3) Evaluation study of the designs built in phase 2; 4) A laboratory study to investigate people's response to the aesthetics of the animations.

1.1 Theoretical background

While using animations to convey information dynamically within cars may be a recent trend, the concept itself is not entirely new. Still, we were surprised by the paucity of publically available literature dealing with guidelines for designing and evaluating animations, especially in contexts that involve more than the basic question of whether animations improve users' ability to interpret the underlying data.

Animations are popularly defined as the "rapid display of a sequence of images of 2-D or 3-D artwork or model positions in order to create an illusion of movement" (Wikipedia). More specifically, animation in the context of HCI is often referred to as "motion" or "motion graphics", describing "the perceived sequence of changes in a visualization's appearance over time" [18] of images that are non-figurative graphics and typography [5,8]. One may even refer to certain traditional in-vehicle displays (e.g., speedometers and tachometers) as basic types of animations.

Using animation in human-computer interaction has both drawbacks and benefits. Animation can attract a driver's attention due to "orienting response" triggered by motion in the periphery. Although drawing the driver's attention to an information display can be useful, it can also be distracting. Thus, studies suggest that to reduce distraction, animations should be subtle [18]. Still, while it may be relatively less efficient compared to more static views of information, viewers may still prefer motion [18]. Another study dealing with the use of animation of information [21] suggests two principles to ensure the usefulness of animation: Congruence – matching of the animation's content and format to that of the information to be conveyed; and Apprehension – the ease and accuracy of perceiving the information presented by the animation.

While usability-related studies suggest that motion is distracting and not particularly suitable for data encoding, animation is still widely used in computer interfaces. This may be explained by the

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benefits associated with animations, such as improving apprehension of time-dependent changes in the data and the aesthetic contribution to the interaction and to users' engagement. Moreover, motion's evocative nature can enhance aesthetics on a visceral level, thus improving perceived usability [18] and the overall user experience [4,11].

Even scarcer is research about the influence of the aesthetic and symbolic value of animations in general, and specifically of various design elements. In the context of in-vehicle displays there is no published literature that deals explicitly with these potential effects on the driving experience. The importance of studying this issue is augmented by two recent developments: first, the advance of visualization techniques has expanded the range and sophistication of possible in-vehicle animations. Second, information technology has made it possible to link driving data to broader issues, e.g., considering the environmental aspects of driving. These issues, more engaging and emotional to at least some drivers, expand the traditional range of driver-response considerations. Designers of in-vehicle animations, then, should strive to design not only for drivers' and passengers' informational and ergonomic needs but also for their aesthetic and emotional reactions [12]. Thus, we see this project as first step towards better understanding drivers' reactions to this aspect of animations in the instrument panel.

The focus of this paper is on the aesthetic aspects of animations. By that, we do not mean to belittle the importance of traditional ergonomic considerations such as the informative or distractive potential of animations. Rather, we seek to complement them with a neglected yet important aspect of the driving experience. We use the context of eco driving to study the perceived dimensions of animation aesthetics. While this domain is specific and of interest mainly to the Automotive UI community, the issue of aesthetics of animations is very broad and the results may well be generalized eventually to other domains.

2. DESIGN PROCESS

In order to conduct empirical testing of aesthetic constructs by assessing driver's reactions, we first created a set of aesthetically distinct animations that would be used in subsequent activities (Studies 1 and 2). The animation design was done based on requests and constraints outlined by the researchers. The design consisted of two phases as described below.

2.1 Phase I

In this phase, the design team defined a project design brief based on analyzing relevant issues and previous documentation in the field. A GM car brand was selected for the project to serve as an anchor. This stage included the following activities.

2.1.1 Choosing a concept and the focusing process

The concept chosen to lead the second stage of the project was that of belonging to the community. This concept led to the idea of providing drivers with information that would allow them to compare their performance to that of fellow car owners, in addition to feedback regarding their own driving style. The design teams were asked to further develop the idea in two different, parallel visual channels: expressive and minimalistic.

2.1.2 Refining and creating a design concept

The challenge of the minimalistic design was to convey multiple types of information in as clean and efficient a way as possible. The designers examined the world of clocks, in which information must be conveyed quickly. For the expressive design, on the other hand, they examined methods of conveying information more emotively and with less parameters, and considered images such as yellowing grass, a fish in an emptying aquarium or spreading smoke. The metaphor selected for the minimalistic design, was a compass, which allows focusing the user's view on a single point - the needle - to show fuel efficiency. The expressive team selected the smoke metaphor, due to its direct connection to pollution, its mysteriousness and its ability to change from beautiful to ugly.

Once the metaphor was selected, each team translated its movement to graphic parameters. This process led to two radically different outcomes (see Figure 1 for two examples), not only in terms of style, but also in terms of composition and the mechanism of communicating information.

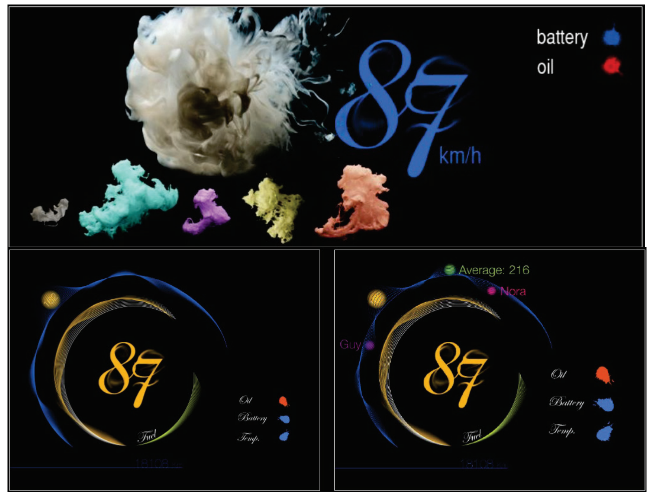


Figure 1: Two preliminary design directions (Source: [15])

2.2 Phase II

In this phase, the designers created alternative designs of animated gauges, based on guidelines from the researchers regarding the manipulation of four design dimensions; two of the overall design approach (minimalistic vs. expressive), and two of transition between states (flow vs. pulse, and dynamic vs. static). In the "Flow" condition, transitions were smooth and continuous, whereas in the "Pulse" condition, this information changed in a non-continuous way, resulting in a feeling of discrete and potentially sharp changes in the presentation.

The Static-Dynamic dimension was operationalized somewhat differently in the Expressive and Minimalistic conditions. In the Expressive condition, the Dynamic manipulation was expressed by a seemingly perpetual smoke running vertically across the screen and the Static manipulation was created by running a concentric smoke ring around the major display. In the Minimalistic design, Dynamic manipulation was achieved by concentric rings that glowed, and an outer open ring that moved as a function of driving style; Static manipulation was achieved by a small, EKG-like wave at the top of the main ring. Color was also manipulated by varying two colors (blue and green) out of four different color pallets (see Fig. 2). Thus, sixteen animations, representing the four manipulations were created. Each animation showed the same 3-minute driving scenario, including accelerations, decelerations, and driving at a constant speed.

We followed the design phase with the following two user studies.

3. STUDY 1: USERS' REACTIONS TO THE ANIMATIONS

The purpose of this study was to assess the adequacy of the designs and people's reactions to them on a variety of eco-driving related aspects.

3.1. Method

3.1.1 Stimuli

The study made use of the 16 animations produced by the design team. As mentioned above, the animations differed along four dimensions: Expressive vs. Minimalistic; Flow vs. Pulse; Static vs. Dynamic; and Blue vs. Green rendering. Examples of the first three dimensions appear in Figure 3.

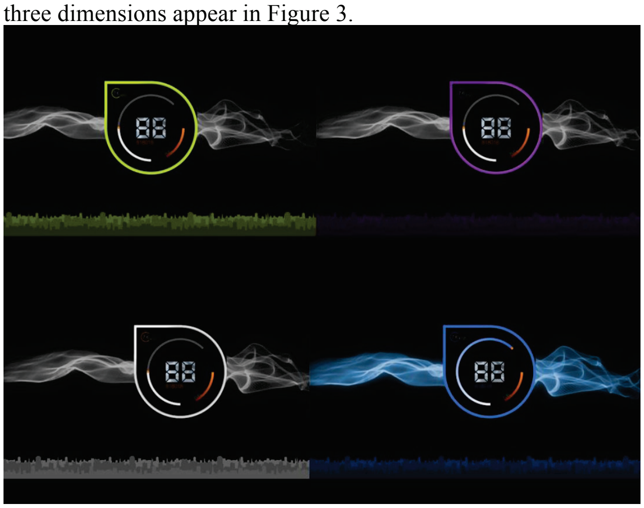


Figure 2: Various color schemes for the same design

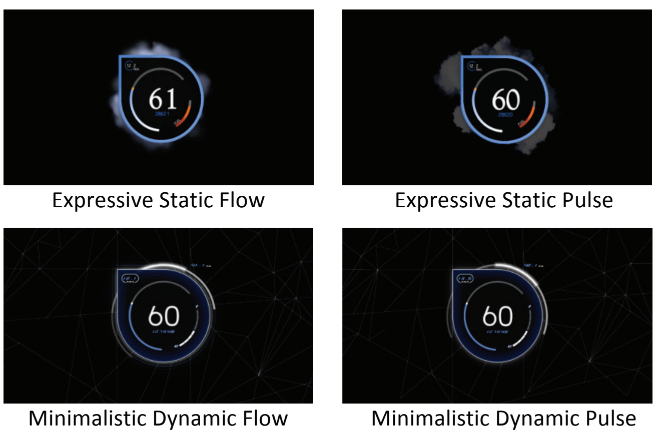


Figure 3: Four animations derived from manipulating 3 design dimensions, shown here in the blue color pallet.

3.1.2 Participants

A convenience sample of 15 participants (7 males and 8 females), was recruited through an online forum and word of mouth. Participants ranged in age from 29-45, with an average of 37. All participants own a car and drive regularly. Each received 100 NIS (about $30) as compensation for their participation.

3.1.3 Study setup

Participants were first presented with general instructions and a description of the experiment setup and its general goal. Participants were instructed to "think aloud" and to try to verbalize their reaction to each of the animations.

Two sets of animation screen captures were presented, as in Figure 3, one in a blue color pallet and the other in a green pallet. Participants were asked to choose the pallet they preferred. Consequently, 8 animations in the selected color pallet were presented to the participant, in random order.

Participants watched each animation and then were asked to fill-in a set of questions rating the animation on six dimensions: Aesthetics, creativity, distraction, clarity, ease of getting used to the animations, and the degree to which such animations may encourage eco-driving. These dimensions include central aspects of animations in the eco-driving domain. Each item was rated on a 10-point scale. After reviewing all 8 animations, we asked the participants to answer a concluding questionnaire, which included items regarding the general notion of using animations of the type used in this study.

3.2 Results

While we were more concerned in this study with people's qualitative responses to the animations, some relevant quantitative results were also collected. The concluding questionnaire revealed that, overall, participants reacted positively to the designs, with an average of 7.1 (1 = "extremely dislike"; 10 = "extremely like"). The displays were considered relatively suitable for in-car display, but not overly so, with average rating of 6.4 out of 10. Participants thought that passengers would find interest in such a display (average = 7.3 out of 10). The designs were considered relatively advanced, compared to the competition (average = 7.6). On average, the perceived eco-friendliness of a manufacturer that uses such designs was 7.5. Overall, participants believed that such displays could help reduce fuel bills, with an average of 7.5.

Due to the nature of the methodology used in this study, we are not presenting here a statistical analysis of the findings regarding individual designs. Of greater importance is the qualitative analysis of the verbal comments, which is presented below.

3.2.1 Analysis of verbal comments

During the sessions, participants expressed their thoughts and made comments about individual animations and about the overall concept of the eco-oriented animations. Participants could clearly distinguish between the designs that were Expressive/Minimalistic and Static/Dynamic. The distinction between Flow and Pulse was generally (but not always) noticed. Some participants preferred the more vibrant color scheme of the Expressive designs, while others did not notice color-related difference between the designs.

3.2.1.1 General findings

Speed change method: Participants were evenly split between those who preferred continuous change of speed, and those who preferred fragmented change of speed. Those preferring a continuous change suggested that real driving conditions (as opposed to watching on-screen animation) mean that the driver is focused on driving and does not look at the dashboard too often, therefore the exact speed should be available when attention is diverted toward this display ("When I do look at the display – I want the information to be as accurate as possible" – Beth, 29).

Accelerating/decelerating indication: most participants understood the connection between rapid acceleration and increased fuel consumption and pollution. However, the connection between deceleration and the above outcomes was not apparent to most participants ("What does braking hard have to do with wasting gas?!" – Ori,41). When further discussing this issue with the participants, a common comment was along the lines of "when I have to brake hard, like because of a car braking in front of me, I will just do it, and no display will ever change that". This implies that people braking as a result of conditions not controlled by them, either due to road conditions or other drivers, unlike accelerating, which is viewed as a more 'controlled' action.

Constant presence of the "smoke": in some of the designs, a constant animation of "smoke" was visible even in 'normal' driving conditions. This made participants experience the animation as both distracting and insinuating that the driver is constantly polluting the environment ("This is like a constant ad against driving!" – Ori, 41). Another key problem with this design is that it blurred the difference between 'normal' and 'aggressive' driving ("I can't see real difference between aggressive and normal driving – it makes me think that aggressive driving is less terrible than I thought" – Yifat, 38).

Pulse vs. Flow: Most participants preferred the flow effect over the pulse effect. One reason for this choice is a sense of 'delay' that the pulse animation generated -- as if information is not presented in 'real-time'. Another reason is the frantic effect created by a sudden appearance and disappearance of graphical objects in the display.

3.2.1.2 Findings for specific display elements

Fuel level information: Overall, this element was regarded as too prominent, and therefore could be moved to the outer part of the display. In addition, the use of red color was considered inappropriate ("Why is the fuel indication red – it looks like it's almost full" – Simona, 37). Participants suggested that this color be reserved for low level of fuel ("The fuel indication should turn red ONLY when the tank is almost empty" – Idit, 34).

Fuel consumption information: was not legible enough. In addition, several participants commented that the actual values displayed were not clear ("what is the meaning of '9.7 km/l'? is it relatively good for this specific vehicle?" – Avishai, 35).

"The dot" (a visual element indicating recommended speed) was widely understood. Still, participants commented that while it is clear and attractive, it might become less usable in real driving conditions, as it "requires too much attention" (Rachel, 41). Thus, some suggested that "the gap between the recommended and the actual speed should be emphasized" (Idit, 34).

"Smoke" animation in the Expressive Dynamic design was considered to be very masculine, aggressive, and vulgar. It was commonly associated with cigarette smoke ("It reminds me of anti-smoking commercials" – Yifat, 38) and therefore not entirely connected to car pollution. Overall it was considered to be unattractive and potentially distracting ("It is very stressful. It gets in the way of observing the important information" – Guy, 37).

"Waves" animation (Minimalistic Static): overall this graphical effect was considered to be pleasant to the eye ("It gives me the illusion of a background illumination" – Oren, 39; "It reminds me of a night drive" – Idit, 34), even if less visible than the other effects. Another common comment was that this effect is perhaps too "technical" ("It suits physicians best. It is not for the mass of drivers" – Simona, 37).

Information about current ride (i.e. distance covered) was considered to be more important than the overall accumulated distance the car has covered, and as such, participants expressed a desire for it to be presented more prominently (in some designs it was actually missing).

3.3 Discussion of Study I

Based on the study's findings, we offer the following lessons regarding the design of animated fuel-efficiency information. First, the findings confirm the notion that the more noticeable and prominent the design, the greater its distractive potential. This is demonstrated when comparing Expressive vs. Minimalistic, Pulse vs. Flow, and Dynamic vs. Static designs. All the former conditions are more visible but also more distracting. Participants liked the less distractive designs better, but still raised the issue of how these designs would be detectable in real-life driving conditions (as opposed to lab studies). As we have discussed earlier, the visibility-distraction tradeoff, while highly important is not the focal point of this study and will not be examined further.

Second, Constant visualization of "pollution" is a two-edged sword: on the one hand it provides a constant reminder of the polluting effect of cars, but on the other hand it is annoying, distracting, and lessens the effect of visualizations that should signal aggressive driving.

Third, while the current prevailing mental model of car drivers associates aggressive acceleration with excessive fuel use, this is not the case with aggressive braking. One possible solution for this gap is to offer different visualizations for accelerating and for braking. For example, Toyota Prius's visualization of how much energy the driver has harvested from braking: http://en.wikipedia.org/wiki/File:Prius_mfd_consumption.jpg.)

Fourth, some drivers' comments suggest that the information presented in the instrument panel may be known to the driver from real-life signifiers: e.g. visual (other cars, environment), auditory (engine, road, tire, wind noise) or tactile (steering feel etc.). That is, the driver often knows when s/he is accelerating too hard and additional visualizations might not be required.

Finally, many comments suggested that in real-life driving conditions, drivers would not divert as much attention to the instrument panel as they do in a lab experiment. Thus, it is possible that during active driving only a limited set of information should be presented, whereas while idling (e.g. waiting for a green light) additional information could be presented, allowing the drivers to reflect on the eco-efficiency aspects of the driving. This would also be a time for the aesthetic aspects of the animations to become more salient and effective.

The results of study 1 indicate that drivers perceive the designs as reliable representations of potential eco-driving visualizations. Various issues concerning the visual aspects of the animations were raised, mirroring the complexities and design trade-offs in this domain. In the next study we focus on the aesthetic aspects of the animations.

4. STUDY II: PERCEIVED AESTHETIC DIMENSIONS OF THE ANIMATIONS

The second study was conducted as a first step toward identifying the perceived dimensionality of the *appearance* of animations (as opposed to their content) and toward constructing measurement scales for these dimensions. In general, such a study requires several iterations that identify potential dimensions, construct a measurement scale for each measure, and test the scale's uni-dimensionality, reliability, and validity (e.g., [2]). In this study we performed the first steps in this long process, with the objectives of demonstrating the potential of this line of research and of identifying basic candidate dimensions for further development. Thus, the study included the activities of generating an initial item pool and identifying and interpreting potential scales (dimensions) using exploratory factor analysis (EFA).

4.1 Method

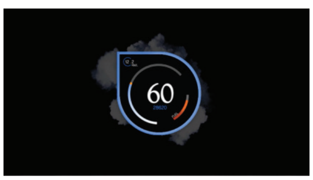
4.1.1 Item generation

Because no theory or previous empirical studies exist regarding how people perceive animations, we used an exploratory approach for this study. Items were collected from two basic sources: First, we solicited terms from the designers of the animations that describe the different types of animations produced by them. We then added various terms that did not appear in the first step but which we felt describe other aspects of the animations.

4.1.2 Stimuli

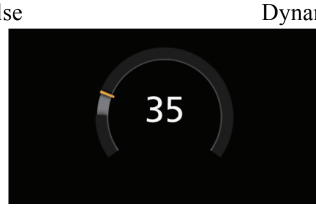
The target objects for the animation evaluations were 3 animations: two of the 16 animations described above and a third, relatively 'simple' animation, designed especially for this study. The first two animations were selected based on two factors: (1) Attributes: we chose animations with contrasting characteristics on all three dimensions: Expressive/Minimalistic, Static/Dynamic, and Pulse/Flow. (2) Results of the quantitative and qualitative studies. The two animations that were selected were Expressive Static Pulse and Minimalistic Dynamic flow. Expressive Static Pulse received relatively low overall ratings in Study 1, and was generally judged to be too intrusive and eccentric in its design. Minimalistic Dynamic Flow received the highest overall ratings in Study 1, and was generally considered to be tasteful, sophisticated and the least intrusive.

The third animation was included to increase the stylistic range of the stimuli and consequently to increase the generalizability of the item generation process. The three animations appear in Figure 4.



Animation 1: Expressive Static Pulse

Animation 2: Minimalistic Dynamic Flow



Animation 3: 'Simple' animation

Figure 4: The three animations used in this study

4.1.3 Participants

One hundred and one students at an Israeli university (49 males and 52 females) participated in the study. Participants were recruited through word of mouth. Each participant was compensated with 50 NIS (about $15). Participants' ages ranged from 21-30, with an average of 25.

4.1.4 Procedure

The study was conducted in a dedicated laboratory, in groups of up to 10 participants per session. Sessions lasted approximately 30 minutes. Participants were given a brief description of the experiment and signed a consent form. Subsequently, they were asked to carefully watch each of the 3 animations. The animations were presented in a fully mixed order. Following each animation, each participant completed a questionnaire containing 42 descriptive terms. Each term was rated on a 7-point scale. Animations were still visible during the evaluations and participants were free to rerun them. The last item of the questionnaire was an overall rating for the animation. A space for comments or thoughts appeared at the end of the questionnaire.

4.2 Results

4.2.1 Exploratory Factor Analysis

One of the main reasons for conducting an exploratory factor analysis is to detect and understand latent constructs [3]. In such cases, EFA is used to create and refine multi-item scales that reflect those latent constructs. There are three major decisions that researchers need to make when using EFA for this purpose: (a) the factor extraction model used; (b) the number of factors retained; and (c) the method used to rotate the factors. In this study we followed the recommendations from the literature (e.g., [3,6]) regarding these decisions.

Based on these recommendations, we ran a common factor model (Maximum Likelihood) as the factor extraction method. Several criteria are usually used to determine the number of factors to be extracted from the data. For our data set, the "Eigenvalue > 1" rule indicates that seven factors should be extracted. The scree-test, however, indicated that 3 to 6 factors should be extracted. A parallel analysis (Watkins, 2006) with 10 replications indicated that 3 or 4 factors should be extracted. Given recommendations in the literature [3] and the exploratory nature of this study we experimented with the number of factors to be extracted. We used the oblique factor rotation method (the Direct Oblimin procedure in SPSS 17) to evaluate rotations for 3, 4, 5, and 6 factor solutions. We examined the rotated factors for items that either had loadings of less than 0.5 on their main factor or items that exhibited high cross-loadings. Eventually, we chose the 5-factor solution because it retained more items from the original item pool and provided more interpretable factors than the other solutions. At this early point we preferred to retain more factors than suggested by the scree-test and the parallel analysis in order to not lose possible dimensions in future studies. Thus, the rest of the analysis refers to the 5-factor solution, which accounted for 61.4% of the variance. Data were analyzed in this and in the rest of this section by SPSS 17.

4.2.2 Interpretation of the 5-factor solution

The rotated pattern matrix of the five-factor solution is presented in Table 1, with item loadings above 0.4. The factors represent five perceived dimensions of the animations, which we interpret as follows:

Factor 1 – Impressive. The items loaded on this factor include terms describing positive aspects of the animation that affect the viewer, mainly in aesthetic terms. These items include terms such as *refreshing, fascinating, cheerful, innovative*, etc. This factor includes various design aspects associated with positive valence. **Factor 2 – Clarity**. This dimension includes the terms *clear, practical and sharp*. It appears to convey the degree to which the animation is helpful in communicating information (rather than affecting emotions, as in Factor 1). **Factor 3 – Subtlety**. This dimension consists of items such as: *Delicate, Pleasant, Moderate, Lucid,* and *Aggressive (reversed)*. It seems to describe aesthetic effects that are more delicate and less pronounced than those in Factor 1. **Factor 4 – Continuation.** In this dimension, loaded items included the terms *Continuous and Fragmented (reversed)*. This dimension appears to be the only emerging dimension to reflect one of the design manipulations (Pulse vs.

Flow). **Factor 5 – Distance.** Loaded items in this dimension included *Chilly* and *Distant*. These describe a neutral, perhaps negative, feeling of an animation that is aloof and not engaging.

4.2.3 *Further exploration of the 5-factor solution*

For each of the five dimensions we constructed a scale score, based on the equal-weight averaging of the items that were retained for each factor (see Table 1). The use of an oblique rotation technique (Direct Oblimin) allowed the eventual dimensions to correlate. Indeed, the correlations between the five dimensions ranged from nil to moderate (see Table 2).

Table 1: Pattern Matrix Of The 5-Factor Solution.

	Impressive 1	Clarity 2	Subtlety 3	Continua-tion 4	Distance 5
Impressive	**.863**				
Refreshing	**.834**				
Fascinating	**.827**				
Cheerful	**.823**				
Sophisticated	**.813**				
Rich	**.799**				
Decorated	**.792**				
Beautiful	**.782**				
Innovative	**.759**				
Surprising	**.736**				
Pulsating	**.710**				
Emotional	**.709**				
Colorful	**.624**				
Rhythmic	**.620**				
Airy	**.602**				
Clear		**.785**			
Practical		**.620**			
Sharp		**.558**			
Subtle			**.825**		
Delicate			**.716**		
Pleasant			**.601**		
Conservative			**.557**		
Moderate			**.541**		
Lucid			**.536**		
Aggressive			**-.533**		
Sequential				**.791**	
Continuous				**.751**	
Fluent				**.747**	
Fragmented				**-.703**	
Chilly					**.534**
Distant					**.521**

The correlation matrix provides some help in further interpreting the perceived dimensions. For example, Clarity, Subtlety, and Continuation form a set of moderately correlated factors, with little to no correlation with the first factor. This may indicate that the first factor deals with the more salient aspects of the animation whereas the other three scales reflect its fine details. This distinction resembles the distinction between the expressive and classical aesthetics in the evaluation of web sites [14].

Next, we regressed the overall evaluations on the five perceived animation dimensions (Table 3). The regression explained 62.8% of the variance in the overall score. All dimensions had a statistically significant effect on the overall rating. The regression coefficients indicate that the dimensions Impressive, Subtlety, Clarity, and Continuation all had significant positive effects on the overall animation rating. Conversely, the dimension Distance reflects an adverse attribute of the animation, having a negative effect on the overall evaluation of the animation.

Table 2: Intercorrelation matrix and reliabilities (on the diagonal) of the five perceived animation dimensions.

	Impressive	Clarity	Subtlety	Contin.	Distance
Impressive	*.95*	- .05	-.30**	.12*	-.42**
Clarity		*.74*	.48**	.49**	-.05
Subtlety			*.87*	.56**	.15**
Continuation				*.87*	.01
Distance					*NA*

** p < .01; * p<.05

Table 3: Regression results of the five perceived animation dimensions, with overall evaluation as the dependent variable.

	B	SE	Beta	t	p
Constant	-1.539	.401		-3.84	.001
Impressive	.622	.048	.531	12.95	<.001
Clarity	.237	.050	.204	4.72	<.001
Subtlety	.552	.063	.418	8.78	<.001
Continuation	.145	.049	.134	2.96	.003
Distant	-.219	.045	-.193	-4.85	<.001

We then tested differences between the average scores of the three animations along the five dimensions and the overall rating (see Table 4 and Fig. 5). We performed a mixed design ANOVA with the three animations as a within-subjects factor and gender as a between groups factor, and overall rating of the animations as the dependent variable. There was a main effect for animations (F(2, 21.127)=3.71, p=.026, sphericity assumed). Animation 2 was rated highest, followed by Animations 3 and 1, respectively. This result is similar to Study 1's findings regarding Animations 1 and 2. Gender did not have a significant effect on the ratings (p=.65) nor was there a Gender by Animation interaction effect (see Figure 6). Post hoc tests revealed that the overall rating of Animation 2 was significantly higher than animation 1 (p=.008) but not significantly higher than Animation 3 (p=.061).

Table 4: Average scores (S.D.) on five dimensions and overall rating. Letters denote animations that are significantly different from other animations on a given dimension, using Bonferroni adjustment for multiple comparisons (p < .05).

	Animation 1 Expressive Static Pulse	Animation 2 Minimalistic Dynamic Flow	Animation 3 "Simple"
Overall	3.57 (1.44) a	4.17 (1.74)	3.70 (1.70)
Impressive	4.22 (1.17)	4.23 (1.24)	2.41 (.89) a
Clarity	4.14 (1.30)	4.32 (1.34)	5.05 (1.47) a
Subtlety	3.41 (1.24) a	3.94 (1.07) b	4.81 (.99) c
Continuation	3.58 (1.46) a	5.09 (1.28)	5.17 (1.27)
Distant	3.53 (1.33)	3.89 (1.43)	4.50 (1.43) a

The results suggest that the relatively low ratings of Animation 1 were mainly due to being perceived as discontinuous (reflecting the Pulse condition) and not subtle. Animation 3 was perceived mainly as unimpressive and as being more distant than the other two animations. Animation 2, on the other hand, exhibited good balance and was not perceived negatively on any of the five attributes.

4.2.4 *Participants' Comments*

Overall, 72 comments referred to the various animations. Surprisingly, the "Simple" animation received the highest number of comments (40), despite being not as visually rich as the other animations. The participants saw this simplicity as both positive (least distracting) and negative (boring, monotonous, and not colorful enough). Similarly, they commented on pros and cons of the other two animations. For example, Animation 1's smoke was mentioned as "cool" but mostly as "unpleasant." The colors were liked but some commented that it is too complex, discontinuous, unclear and distracting. Animation 2 was perceived as pleasant, gentle, beautiful and modern, but some parts of it (the outer ring, the concentric waves) were not understood.

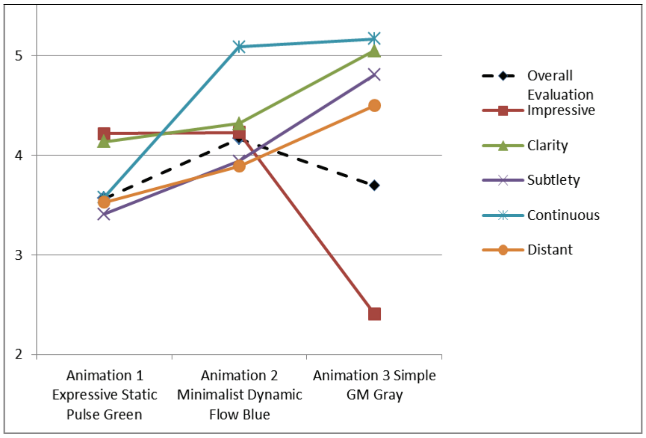


Figure 5: Average scores of the three animations on the five dimensions and the overall rating

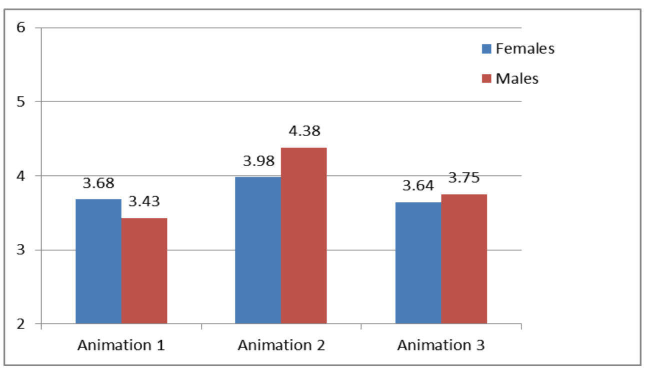


Figure 6: Overall ratings of the three animations by gender

4.3 Discussion of Study II

We used EFA to investigate how people perceive animations for in-car displays. By finding 5 perceived dimensions of animations and demonstrating their relationships to overall evaluations of the animations, we have provided evidence regarding the feasibility of this objective. The dimensions that emerged in the study reflect the respondents' evaluations of animations in terms of how they impress the viewer, their visual clarity, subtlety, continuance, and distance. Except for the last dimension, which is considered negative, the other dimensions had a positive effect on overall evaluations of the animation. This is in spite the fact that some of these aspects may emphasize conflicting design objectives. For example, the impressive dimension stands in contrast (at least conceptually, but to some degree also empirically) to the clarity and subtlety dimensions. Still, as demonstrated by the regression analysis, to design good animations one needs to use a mix of these seemingly conflicting dimensions. This finding resembles the findings in the literature about the need for both novelty and typicality in creating beautiful designs [10; 19].

While the study demonstrates the feasibility of research on perceptions of animations, we see it as only a first step in the long process of scale construction. Subsequent studies should provide further evidence for the exhaustiveness of the dimensions identified in this study, their construct validity, and their generalizability in terms of the range of animation that they describe and the universality of users' perceptions (that is, whether these perceptions are colored by culture or by task).

It is interesting to note, that although the participants viewed two animations that differed on three design dimensions, only one of these dimensions (Pulse-Flow) corresponded to a dimensions that emerged from the EFA (Continuance). One possible explanation is that the designers were asked to maintain a shared design core for the two animations. This may have had the effect of restricting the designers' ability to differentiate between the designs [15]. In addition, it is possible that ordinary viewers, like our participants, are less sensitive to differences between designs. Thus, many design differences may have gone unnoticed. Finally, it is possible that the differences between the animations were not captured by the set of terms used in our study.

Because we did not use the full set of animations prepared by the designers, it is hard to tell which of the three design dimensions was most responsible for differences in overall ratings. Thus, while it is clear, based on the perceived Continuance dimension, that the Pulse condition was less preferred than the Flow condition, it is not clear whether the basic minimalistic concept was more preferred than the expressive concept. For example, many participants commented negatively about the smoke element in the expressive design. However, this does not necessarily negate the usefulness of the smoke concept, because in our study the implementation of smoke in the Static-Pulse condition differed from its implementation in the Dynamic-Flow condition. It is thus possible that different implementations of the smoke concept would have been received more favorably.

Another difference between the minimalistic and the expressive designs was that the minimalistic animation appeared, in general, more traditional. Thus, while both novelty and typicality appeared to contribute to preference in studies of still instrument cluster design [19], it should be further explored whether they also contribute equally to animated designs.

5. SUMMARY

This study describes cooperation between designers and scientists, with the aim of evaluating in-vehicle eco-driving animations. The project has yielded several products, including the process of designing the animations, described in [15], the animations themselves, and the results of the two studies described above. One of the project's challenges was to reconcile the tension between the designers' efforts to adequately materialize the original design concept (i.e., minimalist or expressive) versus the scientific quest for control over main design features. The final animations reflect compromises between these goals that may have limited the practicality of the final products, but which also created a common ground for comparisons in user studies and contributed to more informed inference regarding people's perceptions of the animations' aesthetics. Still, there is clearly a need for methods that deal with this tension, which could guide future collaborations of this type.

The studies provided various insights in terms of drivers' preferences and facets of perceptions of animations. Perhaps one of the most important findings is the need to balance between conflicting design approaches. For example, the participants in

Study 1 preferred more restrained designs. However, they also commented that they would prefer richer colors and for specific items to be more prominent. The results from Study 2 provide more evidence for this need with the contrast between the Impressive dimension and the Clarity and Subtlety dimensions, and the apparent need for both novelty and typicality. Thus, it seems that one of the major challenges that face designers of animations of this type is to respond to users' conflicting desires. The results of Study 2 constitute a first step towards constructing a multi dimensional model of aesthetic perceptions of animations. Such a model can be helpful in the domain of eco-driving, and may also have more general implications for the design of informational animations. Clearly, while the dimensions that emerged in this study make sense, they should be further validated under different stimuli and contexts in future studies.

Finally, we should also consider how in-vehicle animation designs could actually be used in real-life, and whether our findings can be generalized to real-world situations. This issue includes, for example, questions about the extent to which the animations should draw the driver's attention, the prominence of some of the information, and the influence of real driving conditions on the use of the information system and, of course, on driving safety [13]. The issue can be illustrated by the findings concerning the Static vs. Pulse dimension: while participants clearly preferred the Flow design, it is quite likely that in real-life driving conditions they would probably not be able to notice the continuous nature of the Flow design (with intermitted glances to the display).

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