Addressing information asymmetry during design: Customer-centric approach to harmonization of car body split-lines

Downloaded from: https://research.chalmers.se, 2026-11-18 14:39 UTC

Citation for the original published paper (version of record):
Stylidis, K., Rossi, M., Žukas, J. et al (2021). Addressing information asymmetry during design: Customer-centric approach to harmonization of
car body split-lines. Procedia CIRP, 104: 110-115. http://dx.doi.org/10.1016/j.procir.2021.11.019

N.B. When citing this work, cite the original published paper.

research.chalmers.se offers the possibility of retrieving research publications produced at Chalmers University of Technology. It covers all kind of research output: articles, dissertations, conference papers, reports etc. since 2004. research.chalmers.se is administrated and maintained by Chalmers Library

(article starts on next page)

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 104 (2021) 110–115

www.elsevier.com/locate/procedia

54th CIRP Conference on Manufacturing Systems

Addressing information asymmetry during design: customer-centric approach to harmonization of car body split-lines

Kostas Stylidis[a,*], Monica Rossi[b], Jonas Žukas[c], Rikard Söderberg[a]

[a]Chalmers University of Technology, Department of Industrial and Materials Science, SE-412 96, Göteborg, Sweden
[b]Politecnico di Milano, Department of Management, Economics and Industrial Engineering, Milano, Italy
[c]Vilnius Tech, Department of Design, Vilnius, Lithuania

* Corresponding author. Tel.: +460317728284. *E-mail address:* stylidis@chalmers.se

Abstract

Implementation of methods for perceived quality evaluation is an integral part of the automotive manufacturers' strategic development plans. The development of models for objective assessment of perceived quality is a very important task, addressing information asymmetry between designers and customers. This study seeks to understand how customers perceive and prioritize attributes associated with the car body split lines. We applied best-worst scaling methodology (BWS) to understand the importance of different shape design forms from a customer perspective. This approach was tested on 125 respondents. Our results indicate the improvement of engineering practices regarding complex product development solutions and their evaluation.

© 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the 54th CIRP Conference on Manufacturing System

Keywords: perceived quality; information asymmetry; intuitive design; design; automotive; universal design;

1. Introduction

The conceptualization of design as communication has proven to be a valuable approach for research and practice, since it provides designers a new perspective on how products are experienced by users, and conceptually links the involved actors [1]. To communicate design quality successfully, every automotive original equipment manufacturer (OEM) is aiming to create a strong identity to express this identity through consistently managed and relevant "design features" with customers. Speaking of premium/luxury car market segments, the automotive OEMs communicate many of these design features through perceived quality attributes (e.g., appearance, material, surface finish, and split lines). Design features [2] also involve many aspects of customer cognition and product properties, including emotions, aesthetics, semiotics and semantics, and gestalt perception of the design. Perceived quality, in its turn, is a complex, multifaceted adaptive system - therefore, many of perceived quality attributes is hard to define explicitly, i.e., the same shape design can be perceived by the customer very differently depending on its positioning. This fact creates a "wicked problem" for any automotive manufacturer and the "typical" solution of this problem usually expressed in the creation of "another" subjective measurement scale. In other words, the critical issues with any subjective empirical method regarding evaluation of the perceived quality in the automotive industry are positioned within space of perceptual, information, design and semantic gaps between designer and customer [3-6]. The majority of the methods applicable for gathering information about customer perceptual preferences at different stages of the product development, e.g. lead-user workshops [7], Quality Function Deployment [8], Conjoint Analysis [9] or Analytic Hierarchy Process [10], lack the ability to quantify customers' perception.

As a result, there is an obvious gap between designer's intentions and customer's expectations. In most cases there is

2212-8271 © 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the 54th CIRP Conference on Manufacturing System
10.1016/j.procir.2021.11.019

also no direct contact between designers and customers, which would allow designers to clarify their intentions and explain technical details [11]. Rather the products need to speak on their own or be marketed by instructions/manuals and advertisements in order to make a clearer point on how to use and see them.

In this context, the information asymmetry is caused by knowledge gap due to existing differences and available information to the designer and user. The information asymmetry works both ways [12]. For example, from a designer perspective, limited knowledge about customer's preferences and values can result from time-critical development processes. From a customer perspective, the information asymmetry can be caused by the limited communication capacities of products and different human involvement in the world, including different epistemologies during observation and interpretation [13].

This paper is exploring how information asymmetry can be addressed during design of a car body split lines. This paper starts from a communication theoretical perspective, methodology to address these issues, and illustrates the case of intuitive design harmonization of the car body split-lines. The discussion is exemplified by the case of car split-line experimental testing evaluating the tendencies of the conceptual shape models to harmonize intuitive design of the split-lines. Finally, the paper provides recommendations for further research.

2. Background

Below we briefly describe approaches to information asymmetry and perceived quality communication from different perspectives in science, but also highlight Universal Design main principles in relation to visual product quality design features.

2.1. Design as a process of communication and the origin of information asymmetry

The evaluation of perceived quality is a process involving many aspects of human cognition and product properties, including emotions, aesthetics, and perception of the design. However, often there is an obvious gap between designer's intentions and customer's expectations about a product. In fact, automotive manufacturers often have incomplete information regarding the customer's sensory perception of the perceived quality attributes [14]. As we mentioned previously, the designers often take the intuitive approach in the process translating the voice of the customer into technical requirements mainly because of the subjective nature of some attributes and a lack of the robust methods for capturing and quantifying customer's quality impression [15]. The customers, in its turn, often find it difficult to express meaningful opinion about a product with a high level of complexity, such as a premium car. For example, customer's perception of quality often conflicts with the brand perceived image [16]. Baudet, Maire & Pillet [17] performed a study where a visual inspection of 30 product's components was performed by the customers and experts. The results indicate that there is an asymmetry between what companies think about their product's quality and how the customers perceive them. One of the theoretical frameworks explaining this phenomenon is a communication model of the design process - design as a communication process between designers and customers [1], [18,19]. In the automotive industry (as well as in many other domains of a product development) a designer plays the role of a communicator creating a range of forms (e.g., design features), and it is useful to view this relationship with the customer as part of the communication process (see Fig. 1).

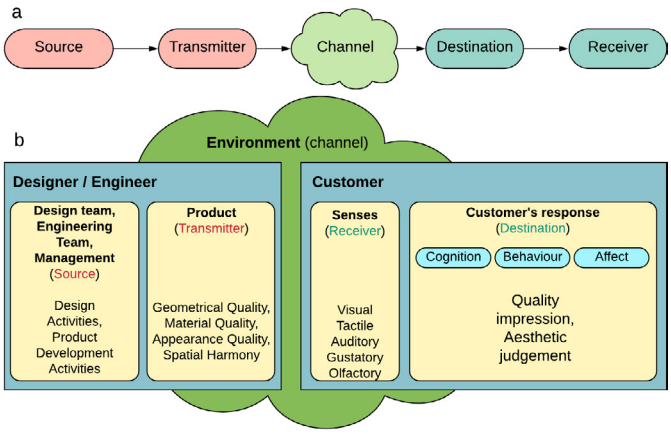

Fig. 1. (a) Shannon-Weaver's model of communication (adapted from Shannon [20]; (b) Framework for design as a process of communication (adapted from Crilly et al. [1])

We use this communication model to identify information asymmetry [21] between designers and customers. In economic and information sciences asymmetric information represents an uneven distribution of information during a transaction, making one party obviously advantageous comparing to the other. While in the case of product development, information asymmetry can appear if the actual quality of the product is not apparent due to its complexity, which is a common phenomenon in modern vehicles (see Fig.2). Designers must strike a balance in requirements definition for perceived quality attributes that convey high quality impression, while ensuring that the car is perceived by customers as having high quality. The asymmetrical information can generate lower quality perception on the eye of the customer as well as higher expenditure of resources on some attributes that indeed do not expected value for the customer, and requires the use of recourses, over engineering and under engineering of other parts [11]. Information asymmetry is detrimental to a product's success, and the ultimate design process goal should be to reduce it, so that designers and customers are considering the same set of design features with the same priority of preference. No need to mention, the identification of critical design features must be performed as early as possible in product development process. In this study we illustrate the reduction of the knowledge gap (see Fig.2) by the testing different design variants on the group of potential customers informing designers about revealed preferences for the set of design solutions related to the driver door handle shape.

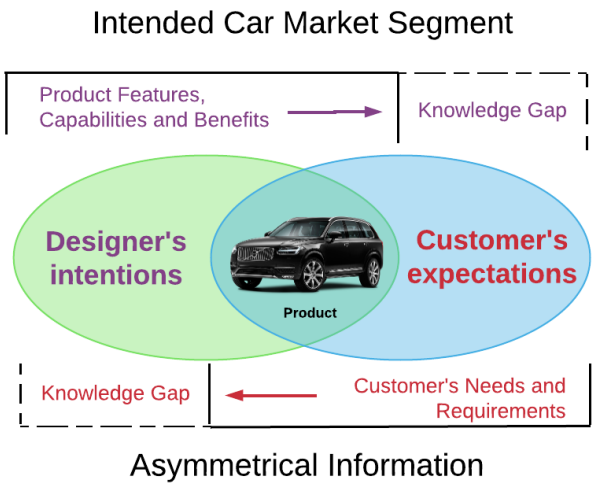

Fig. 2. Knowledge gap and information asymmetry in the automotive industry

2.2. Universal design principles and quantification of visual quality attributes

Human and environment intuitive interaction is comprehensively explored by the intuitive theories. Gerstenberg and Tenenbaum [22] proposed a simplified causal model of the relationship between the agent's goals, actions, and the environment - while the state of the environment and the actions of the agent are monitored, the value of the target is unknown and must be derived. In our case a customer evaluating the proposed design plays the role of agent and the environment is simplified to the 2D shape models. Battaglia, Hamrick and Tenenbaum [23] stated that people in their minds simulate future events using an intuitive "physics engine", and that the accuracy of the simulations depends on the number of variables - noise. The more we are unconvinced by the physical characteristics of the scene, the more future probabilities we consider. It also allows to evaluate counterfactual information that explains what happened. According to [22], even if a person has an intuitive understanding of a physical (mechanical / geometric) causality - what influenced it? A very important factor in shaping people's decisions is the assessment of - how was it influenced to cause different outcome. Counterfactual contrasts allow to intuitively understand the amount of one or another factor's influence, but such estimates vary because different people may regard these contrasts differently. Beliefs, desires, and actions are linked by the rational action principle [24].

An average customer is looking for the most efficient way to interact with the surroundings and embodied cognition [25] gives the notion of possible action affordance. Human body and especially a hand are tools to explore and influence the world around. To discover environment information, limbic system and somatic markers act on subconscious level providing clues for possible more efficient and safe actions [26]. Such process reduces the amount of mental activity; hence, bodily activity is directly influencing mental processes.

On this theoretical basis the intuitive interaction between human and environment are considered as human ability to simulate physical causality. This ability provides the opportunity to encode such information into objects shape, making it more easily and universally understandable on a subconscious level. The principles of universal design and the ensuing aims indicate factors of the shape intuitive harmonization [27], [28]:

- Shape improves the aesthetics of an object;
- Shape complements object's function;
- Shape teaches interaction with an object;

Therefore, most statistically significant (dominant) shape variable for the object's intuitive factors harmonization is - shape reveals the method of use. In our case the door handle must be used intuitively to open the car door. Its shape constituent parts are anthropometric data, human physical or sensory abilities and interaction place. These elements can be linked through shape altering using mechanical properties like bend - direction of force, gap - anthropometric allowance to interact and etc. These restrictions are explicit and can be measured and applied in the conceptual shape modelling.

3. Methodology and study design

In this study design we first adopted a shape decomposition methodology followed by discrete choice experiment in a form of Best-Worst Scaling (BWS) test. To understand subjective preference regarding shapes design, respondents were asked to complete a series of BWS questions.

3.1. Shape decomposition methodology

Shape decomposition techniques and evaluation conditions are important initial constraints. They determine perception quality and amount of information needed to reflect the shapes modification. Many studies have been done to formalize object shape decomposition and evaluation process [29-32]. Decomposition of the 3D shape to represent it in a 2D media is relevant because of the problematics arising due to the complexity of 3D shape position and view angles and, as a result, allows to reduce the information asymmetry. The Dotson's study [29] notes that it is advisable to avoid complex user stimuli (colors, textures, etc.), as this would allow to reduce the number of participating variables and provide more accurate focus on shape evaluation. Barsalou, in a study on the perceptual symbol system theory [33], points out that even 2D shape evaluation has sufficient stimulus to induce the mental simulations to informed users, that will produce a categorization effect. In another study, intended for the automotive industry [32], authors explored the context and practices for the best representation conditions of a 3D shape. According to the study, stylists are keen to isolate key form lines for further evaluation, because it has been noted that the form lines are the most informative to transfer the intentions of the designer and that the simple 2D linear representation of the vehicles contain enough information to cause customer's judgment. Another important issue is that often a "naïve" customer makes judgements of overall component's overall design (including materials, fit and finish, execution) and it is difficult to isolate the real reasoning for the specific choice. Therefore, it is important to reduce information noise of the 3D shape, that the particular shape variation model could be evaluated in a predetermined context. Linear, schematic

drawings are suitable media for the split-line shape visual decomposition. Methods of shape expression variable effectiveness assessment should target intuitive responses and avoid conscious deliberations by focusing on the integrative stage (insight) - does the shape reveals method of use? The effectiveness of the shape is evaluated as satisfaction with the result. In this study conceptual shape models were subject to test with the use of quantitative, stated-preference method (see 3.2) that captures a more explicit and transparent judgments based on preferences of customers.

3.2. Empirical structural validity test of intuitive harmonization effectiveness

The concept of product platform [34] can be used to describe common elements across a range of products. In the automotive industry these common elements determine the type of the vehicle. These shared design features (door, trunk type, hood, etc.) are fixtures that have a position in an assembled product – location schemes. In a context of the experimental object, car body shape and the location of the functional elements are important, because a depiction of these elements is necessary to understand the placement of the split-lines and their functional context. According to Dagman et al. [35], physical components are the bearers of the function. The exact position of these fixtures may vary in different brand products and in the automotive industry split lines are the main indicators of the different element joints, hence predetermined.

Experimental object in this test was the shape of the car body component split-lines. The purpose of the car split-line experimental testing is to evaluate the tendencies of the conceptual shape models to harmonize intuitive design of the split-lines. The main objective was to create shape models of the car body split-lines and monitor intuitive evaluation. Interaction with the doors (the way of use) is predetermined across majority of vehicle brands. To enter the vehicle, a person should use the handle and by pulling it with the left hand - open the door and enter the vehicle. From the physical interaction viewpoint, the way how the door and hand interact, depends on the door and handle construction. Car doors can be seen as a viable experimental option, but it possesses a significant challenge, since anthropometric interaction element (handle) is already present. However, conceptual proposal can be made to inscribe the handle interaction scenario via car body split lines. In this experimental part existing car handle shape and position was used as a reference. In the experimental models split-line mark shape, place and orientation of the handle and evaluation is limited to positive and negative anthropometric shape.

Conceptual models were practically tested in BWS exercise for qualitative evidence of intuitive harmonization effectiveness. Survey design and results were subjected to data analysis using Sawtooth Discover Survey Software [36]. The BWS method [37] is suitable for the investigating of intuitive reactions, because information is evaluated with respondent's minimal deliberation. It does not exploit principles of rating and ranking and is based on the elimination of scale use bias and only on participant's choice, hence it does not require deep consideration to evaluate and rate the object. This approach has advantages when information should be perceived and evaluated on an intuitive level.

The aim of the experiment was to apply the principles of shape mechanical formation to reveal the method of use of the particular car body element. The chosen car model for the case study is Volvo XC90 and the information on the method of use is obtained from the Volvo XC90 owner's manual [38]. Method of use is primary associated with the human - object physical interaction, therefore, anthropometrics is an important aspect of the interaction. From the mechanical interaction (intuitive theories) perspective, the size of the place should correspond and allow for the tool (hand, feet) to interact. In the experimental model it is important to correlate the specific construction and function restrictions with the user's ability to interact with the object.

Anthropometric dimension data is acquired from the Handbook of human factors in medical device design [39]. Experimental model dimensions are set in 1cm² grid. When picture resolution is 1mm to 1 px ratio and the grid is 100px² = 1cm². Grid provides framework for the car body split-line shape conceptualization of anthropometric data and interaction place. To monitor positive/negative tendencies 4 sets of shapes are proposed and each contained positive and negative interaction models (Fig. 3). For the BWS study eight door handle conceptual proposals were presented - four positive and four negative interaction scenarios.

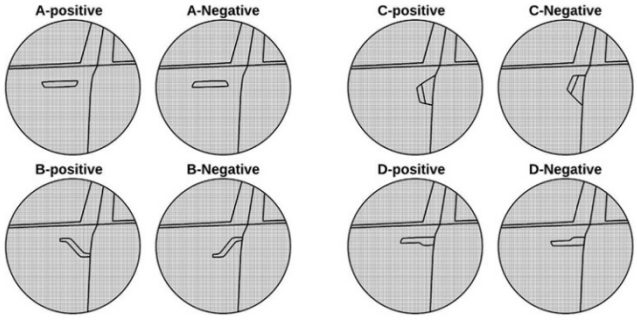

Fig. 3. Driver door handle's experimental shape models (in scale analysis grid) - (A) In a positive model upper part is more open for the grip from up to down, than lower part, for the negative – the opposite. The width of the handle is 250 mm and the height is 30 mm; (B) Handle thickness is 30mm and functional interaction length is 120mm as it is in the original product. Positive modification is done to provide more effective interaction from top down under the 45-degree angle to open and close doors; (C) Model is proposed based on measurements: palm width - 114 mm, palm thickness - 58mm, and two first phalange surface grip length - 50 mm. Positive interaction from top down, negative – the opposite; (D) The grip thickness is 30 mm, wider part of the handle has additional thickness of 20mm for thumb support, grip length – 120mm, overall length 230mm (max distance between fingers). This model also included opposite grip edge direction to observe the user's sensitivity level.

The primary question was set as: "which door handle do you like the most and which the least?" The purpose of presented shape models was to establish positive and negative tendencies on an intuitive level. Principles to form intuitively perceivable object shape communication have been examined invoking 125 respondents survey.

4. Results and Discussion

4.1. Empirical structural validity test

The experiment demonstrated a tendency to choose the positive model version of the interaction with the handle and it is perceived as a more preferable (see Fig. 4). No significant preference in right and left-handed respondents' answers was observed. BWS study analysis suggests, that the most favored shape design is A (Fig. 3A), nevertheless, there is no significant preference for the positive or negative model is observed. This might be attributed to the perception of the scale of the vehicle (SUV) and handle interaction scenario (from up or down) or insensitivity to such a minute modification. Second most favorable choice was D model (Fig. 3D). This model included the attributes of A-model to evaluate the strength of its expression. It shows, that these attributes are less important than a hand grip thickness, curvature and thumb rest displayed in a model D.

Table 1. Results of the driver door handle preference.

Shape design	Preference Score (N=125) with 95% confidence intervals
A – Negative	23.17 (21.57, 27.92)
A – Positive	23.1 (20.51, 24.45)
D - Positive	16.14 (14.77, 18.91)
D – Negative	13.90 (10.57, 15.02)
C – Positive	8.35 (7.51, 9.78)
C – Negative	6.77 (5.88, 8.02)
B – Positive	5.27 (3.89, 7.01)
B – Negative	3.40 (1.87, 5.12)

When evaluating the results of BWS exercise, it seems that judgements regarding aesthetic design are key criteria involved in the contextual evaluation of a complex experimental object. Analysis of the BWS exercise data allows us to conclude that linear, schematic drawings are suitable media for the split-line visual decomposition, and two-dimensional shape has enough stimulus to be recognized and evaluated. Experiment data analysis confirms the hypothesis that these shapes are strongly embodied in human cognition and are evaluated on intuitive level. It is noticed that positive interaction models are more preferable, and integrated variable provide intuitive harmonization effect.

4.2. Addressing Information Asymmetry

When selecting design alternatives to be incorporated in their products, designers usually limited availability of methodology to include customer preferences and perceptions [38]. This means any change in the product at that moment is impossible and the customer is going to make his/her choice based on the final solution the designer decided to pursue. This obviously might generate more than one issue. In the one hand, not including perceived quality perception from customer since the earlier stages of design implies a certain level of uncertainty and risk on whether the customer is going to properly perceive the product. This uncertainty will drive the entire life cycle stages of product introduction to the market and will only be cleared when the product is already in the market [14]. Moreover, such lack of precise information on which features the customer might finally perceive as of more quality, might lead certain design choices to require specific manufacturing processes and steps, not necessarily needed and valuable for the customer, hence might generate over engineering and over processing waste. Indeed, if we consider the previously proposed example, not all the four models require the same manufacturing processes –and cost, therefore the designer's choice might lead to a more expensive solution while the customer perception might even link that specific feature with lower costs: that is information asymmetry in that case would not only have generated lower customer appreciation, but also higher cost [39].

We argue that the impact of information asymmetry between design intent and customer perception exists, by demonstrating how perceived quality should drive design decisions since the very beginning of product development process, in order to avoid uncertainty and lack of knowledge that with high probability would lead to higher cost and less appreciation. The example of design harmonization possibilities of the car body split-lines shows how informative and important, and yet relatively easy would be to involve target users in applying quantitative research methods to address subjective human preferences, while minimizing the information asymmetry that naturally generates when no mediation is applied in that sense.

Adaptation of the existing and well-known model of design as a communication to a product development process is a step towards explanation of the engineering viewpoint on quality perception.

5. Conclusions and Future Work

This study has revealed that the Intuitive theories demonstrate human ability to simulate Newtonian physics, and embodied cognition allows to intuitively perceive and anticipate the interaction with the environment shape. Proposed experimental methodology allows to integrate functional and interaction restrictions into shape's expression. Experimental models confirm the harmonizing effect on split-lines and demonstrated correlation between integrated methodical tools and the efficiency of intuitive expression.

The study also demonstrated, that shape Gestalt can be analyzed as interrelated physical elements in particular context, and it unlocks new potential in design optimization studies. Scientific relevance unfolds in generating the research support for further exploration of intuitive design principles, their innovative application and monitoring. If we are able to demonstrate the ability of extracting from the target users information on the appreciation of a product, before the product is designed, and we are able to do that with a relatively affordable (with the good time/cost ratio) methodologies, then the doors are open towards the drastic reduction of the information asymmetry between design intent and customer perception.

Inclusion of information asymmetry into the "engineer vs customer" equation also allows us to build mathematical and

statistical simulation models behind processes of product evaluation. This opens a variety of possibilities to predict outcomes of engineering design intent and serves to fulfil the success criteria for the product design evaluation. Product quality can be assessed from different perspectives regarding the integration of Industry 4.0 technologies into product development to achieve better quality. All mentioned above, transform product design towards a holistic, measurable, and quantifiable concept that is technology supported and impacts how design and manufacturing will operate in the future. Further investigations and empirical analyses are warranted. The approach we used in the empirical structural validity test must be evaluated with larger population sample to provide a statistically significant result. Capturing respondents' profile such as geographical location, demographics and cultural background will enrich the further analysis with the preferences patterns.

Acknowledgements

This work was supported by the Swedish Governmental Agency for Innovation Systems (VINNOVA). That support is gratefully acknowledged.

References

[1] Crilly N, Maier A, Clarkson PJ. Representing artefacts as media: Modelling the relationship between designer intent and consumer experience. International Journal of Design. 2008. 2(3).
[2] Mortensen NH, Andreasen MM. On the identification of design feature characteristics. In Produktmodeller'96 1996. Linköping University.
[3] Zeithaml VA. Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. Journal of marketing. 1988.52(3):2-2.
[4] Homer PM. Perceived quality and image: When all is not "rosy". Journal of Business Research. 2008. 61(7):715-23.
[5] Burnap A, Pan Y, Liu Y, Ren Y, Lee H, Gonzalez R, Papalambros PY. Improving design preference prediction accuracy using feature learning. Journal of Mechanical Design. 2016. 138(7).
[6] Brambila-Macias SA, Sakao T, Kowalkowski C. Bridging the gap between engineering design and marketing: insights for research and practice in product/service system design. Design Science. 2018;4.
[7] Eisenberg I. Lead-user research for breakthrough innovation. Research-Technology Management. 2011. 54(1):50-8.
[8] Falk B, Quattelbaum B, Schmitt R. Product Quality from the Customers' Perspective–Systematic Elicitation and Deployment of Perceived Quality Information. In Proceedings of the 6th CIRP-Sponsored International Conference on Digital Enterprise Technology 2010. pp. 211-222.
[9] Louviere JJ, Woodworth G. Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. Journal of marketing research. 1983. (4):350-67.
[10] Saaty TL. How to make a decision: the analytic hierarchy process. European journal of operational research. 1990. 48(1):9-26.
[11] Stylidis K, Madrid J, Wickman C, Söderberg R. Towards overcoming the boundaries between manufacturing and perceived quality: an example of automotive industry. Procedia CIRP. 2017. 63:733-8.
[12] Christozov D, Chukova S, Mateev P. On two types of warranties: Warranty of malfunctioning and warranty of misinforming. Asia-Pacific Journal of Operational Research. 2009. (03):399-420.
[13] Krippendorff K. Four (in) determinabilities, not one. 2009.
[14] Stylidis K, Hoffenson S, Rossi M, Wickman C, Söderman M, Söderberg R. Transforming brand core values into perceived quality: a Volvo case study. International Journal of Product Development. 2020. 24(1):43-67.
[15] Eckert CM, Bertoluci G, Yannou B. Handling subjective product properties in engineering, food and fashion. InDS 77: Proceedings of the DESIGN 2014 13th International Design Conference 2014. pp. 791-800.
[16] Stylidis K, Rossi M, Wickman C, Söderberg R. The Communication Strategies and Customer's Requirements Definition at the Early Design Stages: An Empirical Study on Italian Luxury Automotive Brands. Procedia CIRP. 2016. 50:553-8.
[17] Baudet N, Maire JL, Pillet M. The visual inspection of product surfaces. Food Quality and Preference. 2013. 27(2):153-60.
[18] Krippendorff K, Butter R. Product Semantics-Exploring the Symbolic Qualities of Form. Departmental Papers (ASC). 1984.
[19] Forslund K, Dagman A, Söderberg R. Visual sensitivity: Communicating poor quality. InDS 36: Proceedings DESIGN 2006, the 9th International Design Conference, Dubrovnik, Croatia 2006. pp. 713-720.
[20] Shannon CE, Weaver W. A mathematical model of communication. Urbana, IL: University of Illinois Press. 1949.
[21] Akerlof GA. The market for "lemons": Quality uncertainty and the market mechanism. In Uncertainty in economics 1978. pp. 235-251. Academic Press.
[22] Gerstenberg T, Tenenbaum JB. Intuitive theories. Oxford handbook of causal reasoning. 2017. 515-48.
[23] Battaglia PW, Hamrick JB, Tenenbaum JB. Simulation as an engine of physical scene understanding. Proceedings of the National Academy of Sciences. 2013 Nov 5;110(45):18327-32.
[24] Baker CL, Saxe R, Tenenbaum JB. Action understanding as inverse planning. Cognition. 2009. 113(3):329-49.
[25] Kreuzbauer R, Malter AJ. Embodied cognition and new product design: Changing product form to influence brand categorization. Journal of Product Innovation Management. 2005. 22(2):165-76.
[26] Klein GA. Sources of power: How people make decisions. MIT press; 2017.
[27] Petrie H, Darzentas J, Walsh T, editors. Universal Design 2016: Learning From the Past, Designing for the Future: Proceedings of the 3rd International Conference on Universal Design (UD 2016), York, United Kingdom, August 21–24, 2016. IOS Press; 2016.
[28] Steinfeld E, Maisel J. Universal design: Creating inclusive environments. John Wiley & Sons; 2012.
[29] Dotson JP, Beltramo MA, Feit EM, Smith RC. Modeling the Effect of Images on Product Choices. Available at SSRN 2282570. 2019.
[30] Kang N, Ren Y, Feinberg F, Papalambros P. Form+ function: Optimizing aesthetic product design via adaptive, geometrized preference elicitation. arXiv preprint arXiv:1912.05047. 2019.
[31] Kreuzbauer R, Malter AJ. Embodied cognition and new product design: Changing product form to influence brand categorization. Journal of Product Innovation Management. 2005. 22(2):165-76.
[32] Ranscombe C, Hicks B, Mullineux G, Singh B. Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of brand. Design Studies. 2012. 33(4):319-41.
[33] Barsalou L. Perceptual Symbol Systems. Behavioral and Brain Sciences. Issue. 1999. 22:583.
[34] Simpson TW, Siddique Z, Jiao RJ, editors. Product platform and product family design: methods and applications. Springer Science & Business Media; 2006.
[35] Dagman A, Söderberg R, Lindkvist L. Split-line design for given geometry and location schemes. Journal of Engineering Design. 2007. 18(4):373-88.
[36] Sawtooth Software [Computer program]. Accessed October 21, 2020. https://www.sawtoothsoftware.com.
[37] Marley AA, Louviere JJ. Some probabilistic models of best, worst, and best–worst choices. Journal of mathematical psychology. 2005. 49(6):464-80.
[38] Volvo XC90 owner's manual, Online available from https://volvornt.harte-hanks.com/manuals/2018/17wk46/XC90_OwnersManual_MY18_en-US_TP24829.pdf
[39] Weinger MB, Wiklund ME, Gardner-Bonneau DJ, editors. Handbook of human factors in medical device design. CRC Press; 2010.
[40] Stylidis K, Wickman C, Söderberg R. Perceived quality of products: a framework and attributes ranking method. Journal of Engineering Design. 2020. 31(1):37-67.
[41] Stylidis K, Bursac N, Heitger N, Wickman C, Albers A, Söderberg R. Perceived quality framework in product generation engineering: an automotive industry example. Design Science. 2019;5.