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Data-informed design in the automotive industry: customer acceptance study in Sweden and China on radical car design

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Abstract

This study explores the alignment between automotive design innovation and consumer acceptance, particularly in the context of two significant trends: electrification and digitalization. We probed the acceptance of replacing rear window with wide-angle camera We surveyed 1,546 potential customers from China and Sweden to assess their openness to such a radical design. Findings suggest a consensus on its futuristic appeal but diverge in adoption willingness. The study offers insights to bridge the design preference gap, positioning customer acceptance as key for car design strategy.

Keywords: car design, conceptual design, data-informed design, case study, design methods

1. Introduction

New product development is an iterative process, and while its stages are well-described in the literature, the automotive industry often still relies on assumptions about how design solutions will be perceived by the target audience and potential customers. Currently, we are witnessing two monumental trends shaping our automotive future: electrification and digitalization. These twin forces are recalibrating our mobility choices, instigating one of the most profound metamorphoses in the automotive realm seen in recent history. This transformation raises several important questions:

- When automotive design studios should continue following existing design trends, and when should they introduce radical design solutions?
- Upon introducing new designs, what are the practical ways to forecast their success?

User acceptance is characterized by an individual's behavioral intention, or readiness, to utilize, purchase, or experience a product or service (Drew & West, 2002). The acceptance of technology by users is a critical component for the successful adoption of innovations (Davis, 1989). For the advantages of novel technological and design solutions to be fully realized, they must gain user acceptance, which ensures their proper usage and integration into daily life. A lack of acceptance can lead to reduced adoption of innovative design solutions, which may result in wasted resources, financial losses, and a stifling effect on technological progress, ultimately to the detriment of consumers (Kirlidog & Kaynak, 2013; Lee & See, 2004; Parasuraman & Riley, 1997). Notable frameworks that address the acceptance of new design features include the Technology Acceptance Model (TAM) and Product Generation Engineering (PGE). TAM, established by Davis (1985), is a prevalent theoretical framework within information systems that both predicts and elucidates user acceptance of technology. On the other hand, PGE, as conceptualized by Albers, Bursac & Wintergerst (2015), describes the product development processes that are instrumental in forging new product generations. TAM is rooted in

Information Science, while PGE finds its foundation in Engineering Design. Consequently, it is often the case that automotive design studios are not familiar with this body of knowledge. It goes without saying that there is a noticeable absence of practical tools specifically tailored to aid car design professionals in addressing the challenge of radical design acceptance. We propose introducing Data-Informed Design (D-I-D) to automotive designers as a practical framework for solving design challenges. Data-Informed Design (Diels, Stylidis, Mausbach, & Harrow, 2022) is an approach that leverages data and analytics to guide the design process, enhance design quality, and ensure that designs deeply resonate with the needs and behaviors of customers and other stakeholders. This method empowers designers to make more informed decisions, reducing reliance on trial and error, and enhancing the efficiency of the design process. By integrating customer feedback, and various data points into the design strategy, D-I-D helps bridge the knowledge gap between designers' intentions and customers' expectations, enabling a more customer-centric approach to product development. The success of any theoretical framework in practice hinges on the availability of practical tools. Thus, we've developed a strategic decision-making approach (Customer Acceptance Index™) rooted in Best-Worst Scaling (Louviere, Flynn & Marley, 2015) studies, multi-data-point analysis, and the principles of TAM and PGE. The information later synthesized into an analytical report. This report provides car designers with insights into the likelihood of market acceptance for their innovative design concepts. Previously, we evaluated existing design features in passenger vehicles such as ambient light (Stylidis, Woxlin, Siljefalk, Heimersson & Söderberg, 2020) and perceived comfort of car seats (Stylidis, Quattelbaum, Diels, Braun, Konrad & Söderberg, 2023). In this paper, we investigated the acceptance of a radical solution in car design, such as the replacement of a rear car window with a wide-angle real time camera and setting its view in rear mirror. The primary research question we set: "*In what ways does implementing Data-Informed Design (D-I-D), which integrates Best-Worst Scaling studies along with TAM and PGE principles, affect strategic decision-making processes within automotive design studios*?" The introduction of the Polestar 4 model by Swedish OEM (Original Equipment Manufacturer) Polestar in 2023, featuring a radical design change in the form of a high-definition screen replacing the traditional rear-view mirror, was an innovative step in automotive design.

Another Swedish premium car OEM was questioning whether such a radical solution would be beneficial for their vehicle's design line. Two questions have been raised by the design team:

1. Will the combination of a wide camera solution and the absence of a rear window appear futuristic to potential customers in China and Sweden?
2. Would target customers consider purchasing a car with such a design?

We addressed this challenge by conducting a study that encompassed 851 participants from China and 695 from Sweden, all representative of the target consumer demographic. The findings elucidated both the commonalities and variances in acceptance of innovative design features across the target groups. It emerged that participants from both Sweden and China perceived the integration of a wide-angle camera as a replacement for the rear window in a passenger vehicle as a forward-looking innovation. However, the degree to which each group was prepared to adopt such a feature in their "next car" differed markedly. The research provided design professionals with invaluable insights into the perceptions of their intended customers, significantly narrowing the gap in information asymmetry. It showed that the application of the D-I-D approach, influences strategic decision-making in automotive design studios by providing a structured method to align design features with customer's expectation. This approach can help to narrow down the choices in the design process and guide designers in making strategic decisions that align with customer expectations.

2. Background

2.1. Design studios considerations

Since we are referring to the Polestar 4 (see Figure 1) it is important to reflect on design studios' view related to the radical design features. A wide-angle camera display in the rear mirror isn't a fresh concept. Maserati rolled it out with the MC20. The real game-changer is the absence of a rear window in a typical passenger car. This screen displays a real-time feed from a roof-mounted rear camera, offering a wider

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field of view compared to most modern cars. According to Polestar's press release (Polestar, 2023), this digital feed is not only an advancement in vehicle safety and functionality but also offers versatility. It can be deactivated to allow drivers to view the rear occupants when necessary. This feature represents a significant shift from conventional design, aligning with the broader trends of digitalization and technological integration in the automotive industry. Furthermore, Maximilian Missoni, Head of Design at Polestar, said:

> *"With Polestar Precept we previewed a stunning new occupant experience by removing the rear window and pushing the rear header, which plays an integral safety role, further back. This means that now, rear occupants can have a unique experience in our SUV coupé."*

(Polestar Precept is a concept car that Polestar revealed the in February 2020 as a declaration of design intent.)

Figure 1. Polestar 4 in snow with performance pack. Polestar

The rapid electrification of car industry has precipitated a paradigm shift within car design studios. The traditional design language—characterized by a vehicle's basic volumes and profiles that once conveyed a clear message of power to the prospective buyer—has been rendered obsolete. Long front overhangs and prominent wheel arches no longer serve as visual indicators of engine power, as the space once reserved for the engine is frequently repurposed into a storage area, colloquially known as a 'frunk'. Concurrently, the advent of electric drivetrains has granted designers unprecedented liberty. Electric vehicles (EVs) are built around large battery packs, which are commonly placed on the floor of the vehicle. This 'skateboard' layout can lower the car's center of gravity, which not only improves handling but also allows for a more flexible and spacious cabin design. At the same time, EVs benefit significantly from improved aerodynamics for increased efficiency and range. Designers are focusing on creating smoother lines and profiles to reduce drag. This results in sleeker and more streamlined silhouettes, with features like flush door handles and covered wheels becoming more common. The motivation to remove the rear window was driven by aerodynamic considerations, reflecting the trend in electric vehicles towards increasingly smaller rear windows. Another consideration is cabin space. The absence of a large engine block and a drivetrain tunnel running through the vehicle allows for a continuous flat floor, which opens up interior space. This can change the overall profile of the car to be more cabin-forward in design, offering more room inside without necessarily increasing the external dimensions of the car. In summary, electrification is not just a shift in powertrain technology; it's a catalyst for a new era of automotive design, where the fundamental principles that once dictated vehicular aesthetics are being reimagined.

2.2. User acceptance of design

The Technology Acceptance Model (TAM) is a widely used theoretical framework in information systems that predicts and explains user acceptance of technology. Developed by Davis (1985), TAM has since been adapted and applied to various contexts, including car design, to understand how users come to accept and use a new technology. In the context of car design, the TAM can help designers understand how potential buyers might perceive new automotive technologies and what factors might influence their decision to accept and use them. The model suggests that two particular perceptions are

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crucial: (i) *Perceived Usefulness (PU)* **-** this refers to the degree to which a person believes that using a particular system or technology would enhance their job performance. In terms of car design, this would translate to the belief that a particular feature or technology in a vehicle will improve the driving experience or add value to the vehicle; (ii) *Perceived Ease of Use (PEU)*- this denotes the degree to which a person believes that using a system or technology will be free of effort. In the automotive domain, this means that a new design or technology should be intuitive, user-friendly, and should not require significant effort to operate. For features like touchscreen interfaces, voice-activated controls, or real-time feed from a roof-mounted rear camera in our case, designers must ensure these systems are perceived as improving the driving experience and are not overly complex to understand or operate.

User acceptance, as defined in the TAM, is intimately linked to consumer willingness to buy because it directly influences whether consumers decide to adopt new technology or design. If users perceive a technology as useful and easy to use, they are more likely to develop a positive behavioral intention towards it. The TAM can be particularly useful in user-centered design processes in the automotive industry, as it emphasizes understanding the users' perceptions and attitudes towards new technologies. By focusing on PU and PEU, car manufacturers can design and promote new car technologies that are more likely to be accepted by the market. This model also suggests that beyond the initial acceptance, users' continued satisfaction and the perceived quality of the technology will influence their continued use, which is critical for the long-term success of new car designs and innovations.

2.3. Product Generation Engineering (PGE)

A new product today is rarely an outcome of new developments. Speaking of cars, which are arguably among the most complex products in the world, this complexity stems not only from their mechanical and electronic systems but also from the intricate balance of safety, performance, aesthetics, and consumer preferences that must be navigated within the design and manufacturing processes. For that reason, strategically refining and adapting established solutions to introduce novel functions and attributes is often seen as a more viable approach, primarily due to economic risk considerations (Deubzer & Lindemann, 2009; Eckert, Alink & Albers, 2010). This process, known as Product Generation Engineering (PGE), involves the careful selection and combination of subsystem variations (see Figure 2). The goal is to find a balance between leveraging the proven aspects of existing products and infusing new elements to craft a distinctive product offering.

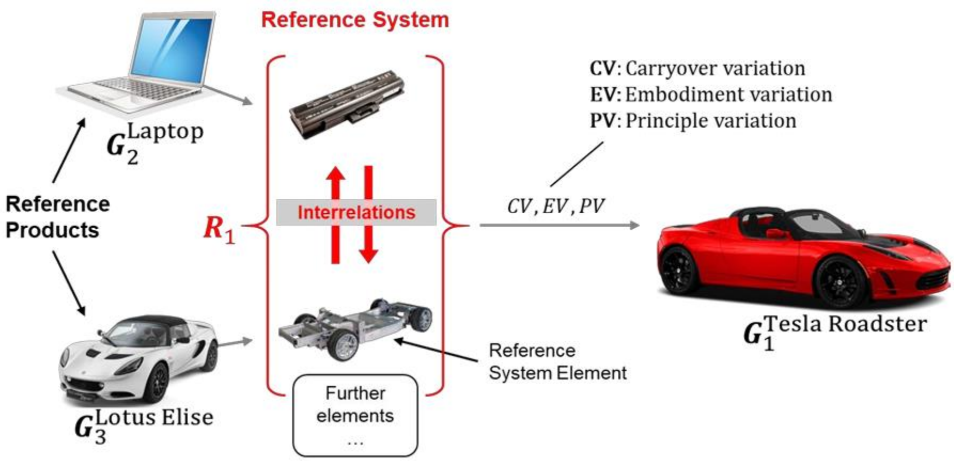

Figure 2. Simplified illustration of PGE model

The framework of PGE, as formulated by Albers et al., (2015), details the methodology for creating a new product generation through the orchestration of three distinct types of variations: carryover variation (CV), embodiment variation (EV), and principle variation (PV). These variations represent the strategies employed to develop the subsystems of a new product generation. The process invariably originates from elements within a reference system, which serves as the foundational blueprint. The reference system is comprehensive, encompassing a range of components from prior product generations, features from competing products to innovative concepts derived from research

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endeavours. It is this amalgamation of subsystems and the corresponding product documentation that shapes the reference system. This system is not static; rather, it is a repository that encapsulates all the knowledge and material used as the groundwork for fostering a new product generation. The reference system is instrumental in guiding the development trajectory, ensuring that the new product not only retains successful elements from the past but also incorporates novel attributes that propel it ahead of existing market offerings (Albers et al., 2015; Albers, Rapp, Spadinger, Richter, Birk, Marthaler, Heimicke, Kurtz & Wessels, 2019).
In deploying the PGE model, developers can strategically decide which aspects of a product to maintain without changes (carryover), which to adapt or improve (embodiment), and where to innovate fundamentally (principle). This tripartite approach facilitates a comprehensive development process that can yield a product that is both recognizably rooted in its lineage and distinctly evolved to offer new value propositions to the customer. The PGE being targeting engineering and system engineering departments can be successfully adapted for use by car designers (Stylidis, Bursac, Heitger, Wickman, Albers & Söderberg, 2019). In this study PGE alongside with TAM form the theoretical foundation of Customer Acceptance Index studies.

2.4. Origin of a knowledge gap between design intent and customer's perception of a product

There is often a discernible knowledge gap between what designers intend for a product and what customers expect from it, particularly concerning its functionality. Car manufacturers frequently operate with a limited understanding of how customers perceive the sensory attributes of design elements. Conversely, customers may struggle to articulate their views on highly complex products, such as premium automobiles. Traditional marketing research techniques often fall short in grasping the full significance and context of a design feature from the user's perspective. For instance, there can be a discrepancy between customers' attitudes toward technology and the vision that designers have of their creations.

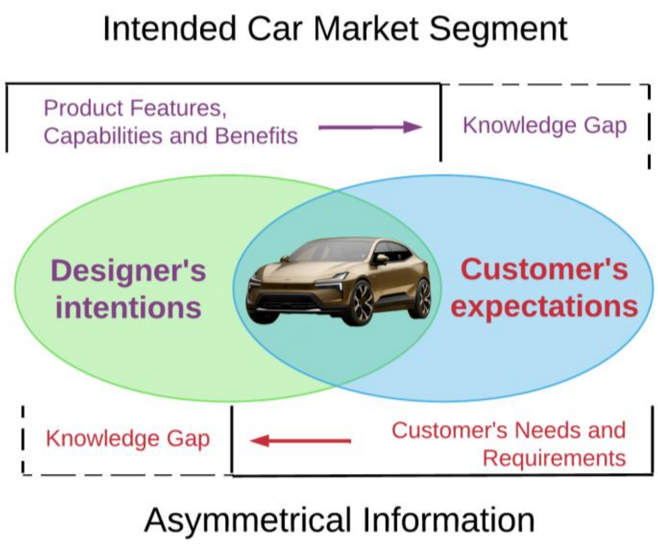

Figure 3. Knowledge gap and information asymmetry in the design

This gap in understanding and communication can be explained within the framework of a communication model of the design process - design as a communication between designers and customers (Krippendorff & Butter, 1984; Crilly, Maier & Clarkson, 2008). A designer functions as a bridge between the concept and the consumer, translating design features into a form of visual and functional communication that connects with customers (refer to Figure 3). Presently, a designer's challenge is to bridge the knowledge gap that exists due to a partial understanding of the future car owners' and drivers' specific needs and preferences. Concurrently, there is often a disconnect where the full spectrum of a design's intended features, its inherent capabilities, and the advantages it offers may not be fully acknowledged or even noticed by the prospective users. This two-way gap in perception has

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a substantial impact on the acceptance of new technology and, as such, ought to be narrowed throughout the design phase to prevent an informational imbalance between designers and customers.

2.5. The context of China and Sweden

The choice of target countries was not random. Sweden has a significant place in car design and the automotive industry for several reasons - history of innovation, sustainability focus, design philosophy (e.g. minimalistic design), high safety standards, research and development (Sweden is home to advancements in autonomous driving technology, vehicle-to-vehicle communication, and advanced materials), engineering education, global influence (Swedish automotive companies have global presence, influencing design and technology trends worldwide). Moreover, Sweden's unique climate, with harsh winters and diverse driving conditions, provides an ideal testing ground for vehicles, particularly in terms of durability and performance in extreme weather.

China, in its turn, is the largest automotive market in the world, having surpassed the United States in annual vehicle sales. This market is not only vast in terms of sales volume but also diverse, with demand ranging from entry-level cars to luxury vehicles. Inside China, automotive OEMs primarily targeting population of Tier 1 cities. China Tier 1 cities refer to the largest and most developed urban centers in China. These cities are typically characterized by their large populations, strong economic development, high degree of urbanization, advanced infrastructure, and significant cultural, political, and educational influence. The cities commonly recognized as Tier 1 in China are: *Beijing, Shanghai, Guangzhou, Shenzhen*.

Tier 1 cities in China are often the primary target for automotive OEMs for several reasons:

- **High Purchasing Power**: Residents in Tier 1 cities tend to have higher disposable incomes, making them more likely to afford and purchase new vehicles, especially premium brands and models.
- **Market Size and Density**: The sheer size and density of the population in these urban centers mean a larger potential customer base for car manufacturers.
- **Brand Consciousness**: Consumers in Tier 1 cities are often more brand-conscious and may place a higher value on brand image and status.
- **Early Adopters**: Tier 1 cities are typically home to early adopters who are keen to embrace the latest technologies, including new automotive features and electric vehicles (EVs).
- **Developed Infrastructure**: With better roads, highways, and more charging stations for EVs, Tier 1 cities provide a more conducive environment for owning and operating modern vehicles.
- **Regulatory Environment**: These cities are often the first to implement new environmental and safety regulations, which can drive demand for newer, cleaner, and safer cars that car manufacturers are keen to sell.
- **Global Visibility**: Success in Tier 1 cities can enhance a brand's visibility and reputation not just in China but globally, due to the international attention these cities receive.
- **Competitive Environment**: Being successful in the competitive environment of Tier 1 cities can be a testament to a brand's strength, often used as a benchmark for quality and desirability.
- **Consumer Trends**: Trends often start in Tier 1 cities and then spread to other parts of the country. Car manufacturers aim to establish a strong presence in these trend-setting locales to gain and maintain market leadership.

3. Methodology

3.1. Study design

Initially, our team requested that studio designers generate a series of visualizations (see Figure 4) that extended beyond the initial two concepts, which contrasted a radical design with a conventional one. This effort yielded over 20 design variations, from which we carefully selected seven for further study: (1) camera and conventional tailgate; (2) camera and split tailgate; (3) small rear window and conventional tailgate; (4) small rear window and split tailgate; (5) large rear window and conventional tailgate; (6) large rear window and split tailgate; (7) full glass tailgate.

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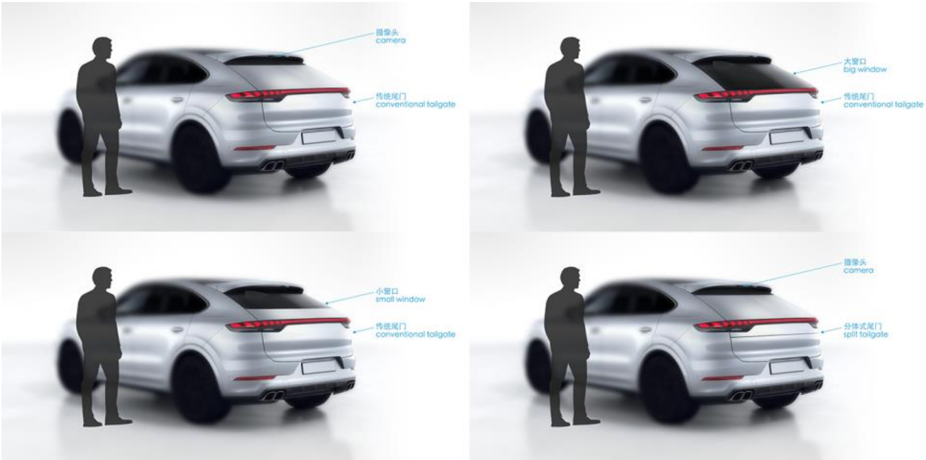

Figure 4. Example of design variants presented to participants

We developed four distinct online surveys (see Figure 5), two aimed at participants in China and two targeted at respondents in Sweden.

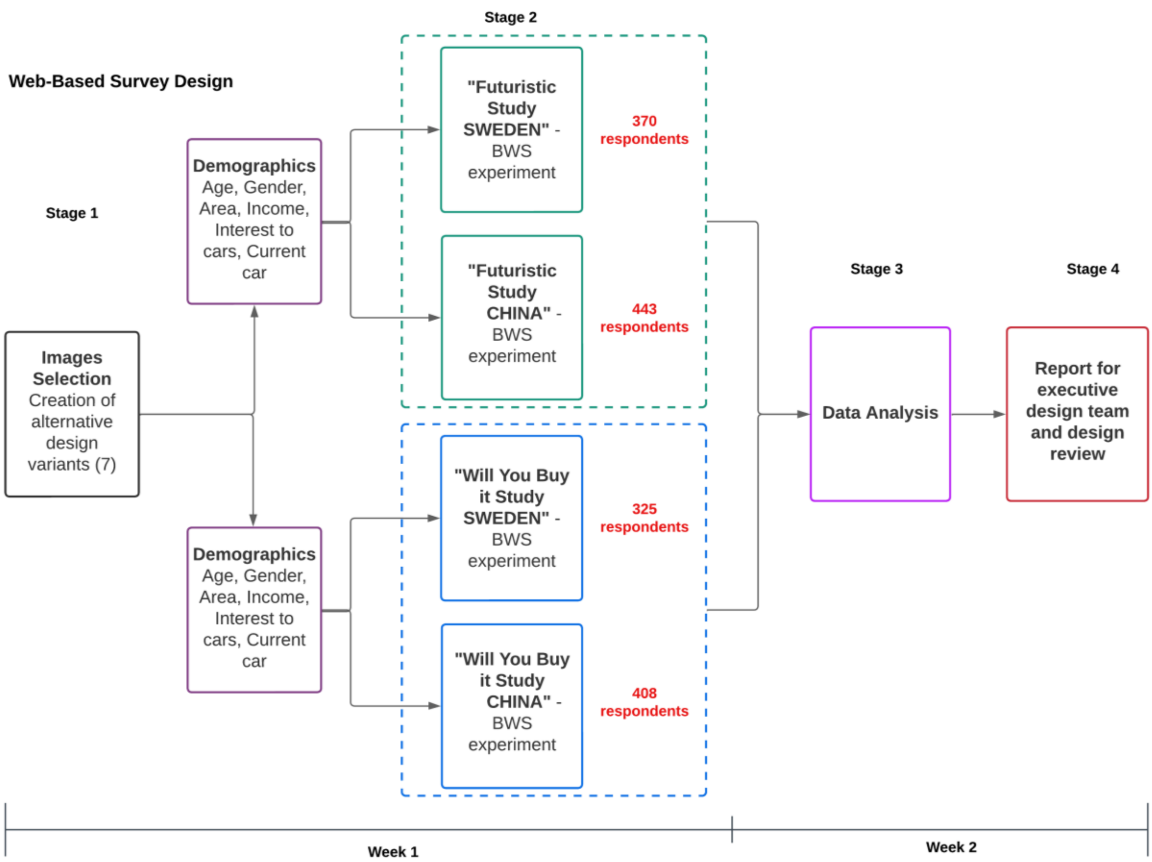

Figure 5. Study flow and procedure

The surveys commenced with demographic screening questions, followed by a Best-Worst Scaling (BWS) experiment (Louviere et al., 2015). In this phase, discrete choice experiment tasks were presented to the respondents with different permutations of the seven variants of design. The surveys were conducted in Mandarin for the Chinese participants and in Swedish for the Swedish participants.

3.2. Recruitment and procedure

In total we recruited 851 participants in China with age (M=34.9) and gender distribution of 42.54% female vs. 57.46% male. In Sweden we recruited 695 respondents with age (M=39.2) and gender

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distribution of 50.07% female vs. 49.78% male. Participants were presented with seven sets of three images each, arranged in a random order. Initially, identical surveys were conducted concurrently in Sweden and China, asking participants to identify the "Most Futuristic" and "Least Futuristic" design variants. Subsequently, two more identical surveys were launched simultaneously in both countries to gather respondents' preferences on which design variant they would most likely choose for their next car purchase and which they would least likely consider. We also solicited open-ended feedback at the conclusion of each survey. The duration of the activity ranged from 10 to 20 minutes in average.

3.3. Data analysis

The data analysis was performed with the help of PowerBi Pro (Microsoft Corporation, 2023). The analysis regarding "camera solution" acceptance vs "conventional design" was performed across multiple data points including combinations such as:

- Family Composition
- Gender/Age
- Cities
- Marital Status/Number of kids/Houshold
- Income/Next car price range
- Income/Age
- Drivemode today/Next Car

This analysis allowed to understand customer's sentiment across various groups. For example, it illuminated the perspectives of a Swedish woman and a Chinese woman, both aged 30-39, married without children, and current drivers of Electric or Plug-in Hybrid Electric Vehicles (see Figure 6).

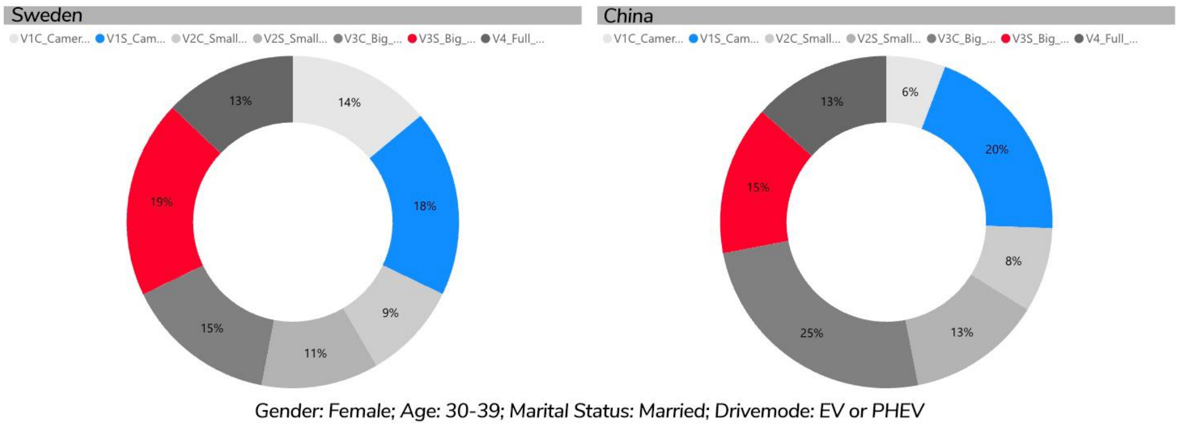

Figure 6. Multiple datapoints connected for deep analysis

4. Results

The initial phase of our study, which focused on assessing perceptions of futuristic car designs, revealed a striking consensus between Chinese and Swedish participants. This part of the research specifically investigated if a wide-angle camera integration in place of a traditional rear window could be seen as an indicator of futuristic design. The results showed a clear preference in both countries for three design variations: (2) camera with a split tailgate, (1) camera with a conventional tailgate, and (7) full glass tailgate, which received top rankings from diverse demographic groups. Interestingly, the full glass tailgate, a design element with its roots in the automotive innovations of the 1970s, was still regarded as a symbol of modernity. This suggests that elements of design nostalgia are being embraced as indicators of future trends. It also points to a certain conservativeness among some participants, a trait further underscored by a pragmatic approach that became apparent in subsequent parts of our research. In the second segment of the study, which investigated the willingness of consumers to purchase cars with radical design features, we uncovered nuanced preferences. In China, the more forward-thinking segments of the target demographic currently exhibit a marked preference for the "camera solution" as

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opposed to the traditional large rear window. This contrasts with the conservative Chinese segment and the Swedish cohort, both of which expressed significant resistance to abandoning the classic rear window in favor of a wide-angle camera setup. In-depth feedback from Swedish respondents suggests a cultural lean toward traditionalism and utilitarian values. Meanwhile, in China, we observed gender-based differences in the acceptance of the "camera solution," it tends to increase with age in men, whereas it decreases among women as they age. Middle-income individuals in China, especially those between the ages of 25 and 29, were most receptive to this new design feature. Furthermore, the study highlighted a compelling link between the type of drivetrain participants currently use and their openness to radical design changes. In both China and Sweden, drivers of Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) displayed a greater tendency to embrace such radical design features. This trend underscores the potential for innovative design acceptance to grow in tandem with the rise of environmentally friendly vehicle technology. The research provided design professionals with invaluable insights into the perceptions of their intended customers, significantly narrowing the gap in information asymmetry. It showed that the application of the D-I-D approach, influences strategic decision-making in automotive design studios by providing a structured method to align design features with customer's expectation.

5. Discussion

Designing a car is not just about its aesthetics; it's a harmonious blend of functionality, innovation, sustainability, and appeal. The paradox of choice in this context implies that while we have endless possibilities for car designs, designers also face the challenge of choosing a design that fits within real-world constraints, aligns with their brand vision, and meets with customers' expectations. Traditionally, car designers have relied heavily on study data and customer insights from marketing departments to determine what these expectations might be. However, the process of creating and gathering this data often remains a "black box". More so, this data is frequently detached from the tangible context of car design, whether through the design of the study, which lacks design stimulus, or because participants are not able to adequately articulate their preference and rationale for a certain type of design. Marketing teams often assess specific customer attitudes, conduct surveys, and condense results, but the quality and relevance can be questionable. For instance, user experience and interior designers often work off the opinions of survey-takers who may have little to no driving experience. While qualitative research methods like focus groups and panels are often well-executed, they sometimes suffer from statistical insignificance and may inadvertently introduce bias, offering limited depth for true innovation. As standalone strategies, these methods often fall short, providing data but lacking the deeper insights necessary for genuine breakthroughs in design. In response, the role of the designer is evolving into that of a co-creator, informed by a methodology we describe as Data-Informed Design. Data-Informed Design employs data and analytics to guide the design process. Its primary aim is to enhance the design process, elevate design quality, and ensure that designs deeply resonate with the needs, behaviors and attitudes of customers and other stakeholders. This approach empowers designers to make more informed decisions, reduces reliance on trial and error, and enhances the efficiency of the design process. The automotive market, a multi-trillion-dollar global industry, is undergoing rapid transformation, driven by technological advancements and changing consumer preferences. Within this vast landscape, Data-Informed Design and AI/ML are emerging as game-changers, offering brands the ability to tailor their products more precisely to consumer needs and market trends. For example, the structure provided by Data-Informed design can be exploited by AI/ML to better understand or predict the customer's responses to design variants potentially reducing the number of required research participants. Importantly, this study demonstrates the practical application of these concepts. Within just two weeks of posing a question about a radical design solution, we managed to bridge the knowledge gap regarding its acceptance in China and Sweden. This collaborative effort has led to the development of the Customer Acceptance Index™, a strategic planning tool for automotive design teams. By facilitating a more precise match between customer need, behaviour and attitude, and an aesthetically and functionally pleasing design solution, this tool help brands increase word-of-mouth and product sales in key markets while minimizing design and marketing risks. It represents a scientific approach to vehicle concept development and validation, showcasing the profound impact of Data-Informed Design in the automotive sector.

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