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Cognitive Quality: An Unexplored Perceived Quality Dimension in the Automotive Industry

Alina Braun [a,] *, Kostas Stylidis [b], Rikard Söderberg [b]

[a] *Geely Design, Valdemar Noréns Gata 3, 417 55, Göteborg, Sweden*
[b] *Chalmers University of Technology, Department of Industrial and Materials Science, 412 96, Göteborg, Sweden*

* Corresponding author. Tel.: +44-7387-809019; *E-mail address:* alina.braun@geelydesign.com

Abstract

Well known, perceived quality is a game-changer in consumers' decision-making processes and is seen as one key predictor of a product's and company's success. Today, the automotive industry faces challenges not only to deliver superior manufacturing quality in order to excel in perceived quality, but also to induce a positive sensory and cognitive response from its customers. Previous research aimed to quantify and unpick consumers' perception of quality in order to meet consumer expectations and requirements. Cognitive processes related to product design have been explored in a variety of disciplines, ranging from the design research, specifically in the field of aesthetics, to sociopsychology. In the engineering and manufacturing research field, however, there is a significant gap regarding 'intangibles' related to car design. In this conceptual paper, we extend our previous work by presenting the concept of *Cognitive Quality* as a new dimension of the Perceived Quality Framework (PQF). The PQF, in its turn, illustrates the sensory, attribute-centric engineering viewpoint on quality perception. Therefore, the new *Cognitive Quality* dimension significantly contributes to the theoretical foundation of perceived quality in engineering and manufacturing research, specifically in the automotive field.

Keywords: cognitive quality; perceived quality; automotive; product development; aesthetics

1. Introduction

Most car consumers judge a car's quality based on a mixture of its design and performance characteristics, instead of a combination of mechanical parts, software, advanced materials, cutting-edge manufacturing processes, technical knowledge, and production volumes – all elements involved in today's car creation. Additionally, consumers' previous experiences with cars also have a strong influence on their judgments. According to Krippendorff [1], "*Humans do not see and act on the physical qualities of things, but on what they mean to them*." Closing the door of a Mercedes-Benz S-Class limousine produces a signature sound with a vault-like thunk, which may evoke memories of a special moment in life. The distinct smell in a new Bentley may illicit perception of high-quality materials, creating a feeling of luxury and quality very different from that in a used car sold by a nearby car dealership.

As these examples show, understanding consumers' perceptions of quality is a challenge for researchers and, mainly, for practitioners. "*Which product characteristics require the most attention for successful car design*?" This is one question engineers and designers need to answer under the pressure of shrinking product development time, available technologies, and financial limitations. In addition, an exact answer in the form of quantitative data is often expected to sustain the fierce competition in the automotive industry. In that case, if an automotive Original Equipment Manufacturer (OEM) wants to ensure the ability to exactly meet the consumers' expectations, there is a need to quantify these quality aspects. The quantification of consumers' demands can be achieved by aiming to control the perceived quality (PQ) of the vehicle during all stages of product development. This control is extensively based on the definition of the correct requirements for automotive-specific PQ attributes. In general, PQ attributes can be defined as characteristics that convey the functional and psychosocial benefits of a product to the consumer [2]. In the automotive industry, these attributes are usually associated with and summarized in the complete vehicle, its components or system-level requirements. Thus, a correct PQ requirement set-up and early implementation are essential to meet and, if possible, exceed consumers' quality expectations. Recently, perceived quality in engineering science has been defined within the Perceived Quality Framework (PQF) [3] in the form of a two-dimensional typology: (i) Technical Perceived Quality (TPQ),

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encompassing intrinsic attributes - everything that is part of a product and can be controlled by design and/or engineering specifications; (ii) Value-based Perceived Quality (VPQ), including extrinsic attributes - such as brand image, brand heritage, affective consumer judgments, design, hedonic or social values, the impact from other global attributes, advertising, and marketing promotion techniques. From the engineering point of view, the *perceived quality domain is a place where the product meaning, form, sensorial properties, and their execution intersect with human experience. Such an experience is driven by the interplay between product quality and its context* [3]. However, if the newly developed Perceived Quality Attributes Importance Ranking (PQAIR) method can successfully address quantification of perceived quality attributes related to the TPQ [4], the impact of perceived quality attributes reflecting hedonic attributes (i.e., VPQ-related), to our knowledge, has not yet been measured in the engineering field in a way that can be applied in the automotive industry [5-8]. The perception of hedonic attributes represents holistic multi-sensory experiences. Consequently, one of the serious challenges for the automotive industry is the development of a quantitative model that conforms with human intuitive perceptions.

In this research paper we argue that previously introduced research in the automotive engineering and manufacturing field indicates a gap when it comes to consumers' mental processing and understanding of a product, triggered by its design. At the same time, existing frameworks related to the aesthetic appreciation of product design do not offer any practical solutions towards the quantification of perceived quality in the automotive industry. We propose the augmentation of the sensory attribute-centric engineering viewpoint on quality perception with an additional dimension, *Cognitive Quality,* covering consumers' mental processing of the product design.

This paper is structured as follows: Section 2 discusses related work and motivation for this study. Section 3 describes interrelations between aesthetics and cognition. Section 4 presents the *Cognitive Quality* dimension of PQF. Section 5 offers conclusions and recommendations for future research.

2. Perceived Quality - Background

Perceived quality has been addressed through a variety of approaches in different research disciplines. Despite important research on perceived quality, there is still an opportunity for the definition of new dimensions considering the interrelation between designer/consumer understanding of quality. To date, perceived quality attributes in relation to cognitive perception have not been defined explicitly in any related discipline. Below we briefly describe approaches to perceived quality from different perspectives in science, but also highlight industrial practices related to the automotive industry.

2.1. Perceived Quality in Product Development

Considerable research presenting perceived quality as an important element of product quality, with a variety of definitions, has been conducted in the past. Most viewpoints on perceived quality can be classified as: (i) A manufacturing approach to quality known as 'conformance to requirements [9-12]; (ii) Consumer-centric marketing research [13-15]; (iii) Geometrically Robust Design and variation management approaches [16-18]; (iv) Affective and Emotional Engineering [19, 20]; and (v) An engineering approach, which is a predecessor to this research [3], [21]. The first two approaches share a common agreement in seeing perceived quality as the antagonistic entity to 'real' or 'objective' quality (i.e., not quantifiable, imaginary, subjective). Nevertheless, in recent a gradual shift towards the 'objectification' of perceived quality has been identified [22, 23].

2.2. Perceived Quality in the Automotive Industry

In industrial practice the design and performance properties of a vehicle are often handled by a number of perceived quality attributes. A typical car manufacturer operates with 20–120 perceived quality attributes, depending on organizational structure. These perceived quality attributes are responsible for the definition of requirements and requirement levels that determine consumers' quality impressions of the car. Further, these perceived quality attributes can differ from company to company and are a 'secret ingredient' of the design and engineering team to achieve their perceived quality targets. Perceived quality target setting, from evaluation until sign-off, is an ongoing process throughout the product development cycle. The group of engineers responsible for the perceived quality competence area define requirements for design and engineering, then predict issues, verify engineering solutions, and evaluate design status until the final sign-off. This is a continual iterative process, as one issue can be solved while a new one can occur. Indeed, every new decision affecting visible components can become a potential new issue. The issue-related evaluation work continues until the end of the product development process, and a final decision is taken.

The creation of a modern vehicle is an extremely complex design and engineering task that is impacted by the multi-dimensional nature of perceived quality. Thus, quite often the expertise areas responsible for different perceived quality attributes are distributed among different departments within the OEM. For example, often issues related to 'squeak and rattle' are handled by the Noise, Vibration, and Harshness (NVH) department, while 'material finish' requirements are overseen by the Color, Material, and Finish (CMF) department. The multi-dimensionality nature of perceived quality leads to a cross-functional effort between different departments in achieving perceived quality targets. Automotive industry professionals usually design a new car with full awareness of this challenge and complexity level; however, the average consumer usually does not make any distinction between the design itself and the engineering affecting the final product. For that reason, it is challenging to both communicate sophisticated engineering design features to the consumer and to receive meaningful feedback.

2.3. Current State of the Perceived Quality Framework

Quality perception is formed from physical and cognitive inputs, usually triggered by a physical signal received by our sensory apparatus. The information obtained through the senses forms the basis of a product experience. However, sensory processing is often performed in the background, without entering a state of conscious awareness [24]. Thus, it is possible to communicate perceived quality attributes (i.e., included in TPQ) in connection with the consumer's sensorial experience, and it is quite challenging to isolate processes related to the cognitive processing of quality impression. In PQF [3], the quality perception connected to the primary human senses forms the first level of perceived quality attributes: *Visual Quality*, *Tactile Quality*, *Auditory Quality*, *Olfactory Quality*, and *Gustatory Quality* (see Fig.1).

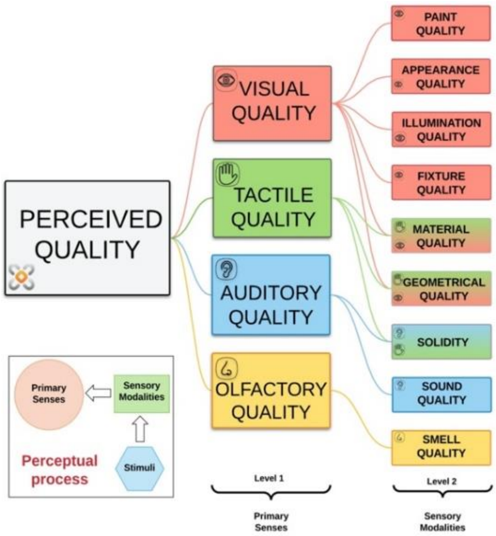

Fig. 1. The PQF and the first two attributes levels [3].

The second attributes level of PQF is organized in *Sensory Modalities*. The *Sensory Modalities* are the nine distinctive sets of product attributes encoded for presentation to humans. Each of these sets has a description and includes the thirty-two *Ground Attributes* (GA). The GA is the 'lowest point', where the engineer can still communicate with the consumer to receive meaningful feedback. In essence, the PQF reflects human perceptual processing to delineate, test, and explore product designs. We acknowledge the fact that perception is not a fixed concept, as it is significantly modulated by many contextual factors such as multi-sensory information, past experiences, internal predictions, associations, ongoing product behavior and internal or external spatial relations [25], i.e., split-lines and overall design. As of today, the PQF does not cover cognitive processes linked to quality judgments as the final stage of communication between the design and engineering team and the customer (see Fig. 2). For this reason, it is essential to conceptually define the difference between attributes associated with sensory-based perception and cognition. Perception is the processing of information related to a product by the sensory systems [24], including sensory processing modules, multi-modal integration, event perception, and object recognition [26, 27]. The product design evaluation by the processing of perceptual information obtained through the basic senses forms the subjective product experience. This subjective product experience can be aimed to be captured with the use of PQF and transformed into objective measures [3]. However, to some extent, sensory information processing is isolated from cognition [24]. Therefore, if in future we aim to quantify cognitive aspects of quality perceptions, we need to extend the existing PQF by adding another dimension – one capturing the cognitive processing related to the justification of the perceived quality. In other words, we need to address and consider parts of what has previously been defined as a part of VPQ – extrinsic attributes of quality perception.

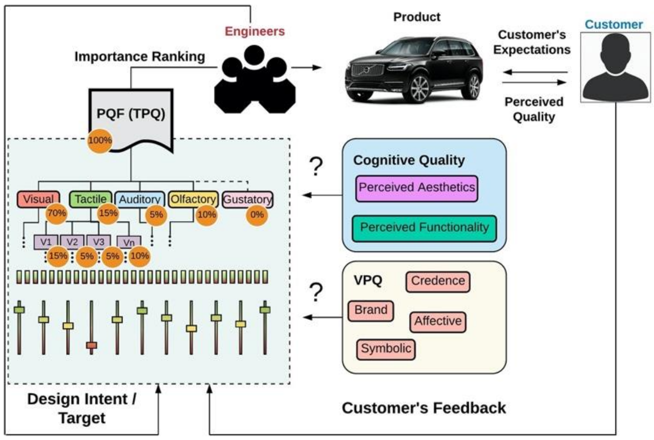

Fig. 2. The perceived quality evaluation process cycle.

3. Aesthetics and Cognition

In today's automotive market, functionality and performance are often taken for granted, shifting consumers' attention to the aesthetics. Crilly et al. [28] state that "*Attention to a product's appearance promises the manufacturer one of the highest returns on investment.*" Cognitive response to product design and aesthetics has been widely studied in design research, aesthetics, psychology, consumer research, sociology, marketing, and semiotics [29, 31]. However, many of the ideas presented in the literature have not been connected, even when they are complementary. On this basis we argue that previously introduced concepts have not yet been applied in the automotive industry and engineering field, showing a gap when it comes to consumer's cognitive processing and understanding of a product triggered by its design. We understand that perceptions of quality are influenced not only by design execution (technical execution), but also by design itself. Therefore, if we want to communicate quality aspects of the car holistically, there is a need to bring these characteristics into the measurable space of perceived quality attributes.

3.1. The Importance of Aesthetics

When encountering a new product, an initial response in the form of 'like or dislike' or 'approach or avoid' is formed within the blink of an eye [30]. Judgments about the product's qualities are also made within a few moments of thought. Such judgments and opinions can be formed even before interacting with the product. Indeed, consumers have an immediate 'gut feeling' about a product's quality without the ability or even the need to use complex descriptions. Previously, researchers have endeavored to investigate the influence of aesthetics on consumers' product evaluations [31, 32]. Numerous studies with automotive stimuli were performed. Ranscombe et al. [33] observed the influence of different aesthetic attributes on the consumer's brand perception. Burnap et al. [34] investigated the dependency of changing vehicle visual attributes and brand recognition by the consumer. Other researchers specifically focused on the impact of aesthetics on consumers' perceptions of quality. For example, Reid et al. [35], attempted to quantify subjectively perceived quality attributes regarding vehicle silhouette design and found that product representation matters when measuring consumer opinions. One approach in aesthetic research is to first decompose a complex form into its' design characteristics, which reflects the demand for understanding this matter from an industrial perspective [37-38]. The visual assessment of the vehicle is considered to be one of the early and critical aspects for perceived quality. However, as indicated previously, a variety of existing automotive engineering approaches are lacking in completely understanding aesthetics concerning cognitive processing, which we aim to approach next.

3.2. Cognitive Quality

When encountering a product, consumers look at the design, trying to decode the design and also interpret it [28]. Consumers' interpretation of the design is based on the product's visual form, but also on physical interaction with the product. Thus, judgments on whether a product is of high quality or attractive include not only consideration of whether the product looks good, but also whether it appears functional or usable. Indeed, subconscious mental processing, also described as cognitive processing, influences consumers' judgments [39].

Cognition, in general, encompasses the area of mental function that deals with logic. Further, it encapsulates the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. In other words, cognition is the process of acquiring knowledge through thought, experience, and/or sensory perception. Perception can come through sensory input to the brain but can also come through subconscious stored memory. Previous research has discussed cognitive processing when encountering art or design in general. For example, Norman [40] describes cognition as information processing systems. Crilly et al. [28] and Leder et al. [39] have shown that cognitive mastering is needed for information processing. Their [39] Information-Processing Model of Aesthetic Experience introduced consumers' aesthetic judgment as a result of the evaluation of the cognitive mastering stage. The model differentiates two types of outputs in aesthetic processing – aesthetic emotion and aesthetic judgment. Aesthetic emotion encompasses the experience of pleasure or happiness that results from success in the continuous affective state from processing stages. In contrast, aesthetic judgment can be understood as the cognitive aspect of aesthetic processing, including quality judgments. This model basis for the processing of a product's design impacts consumers' judgments about the product; thus, it provides support for the introduction of another perceived quality dimension - *Cognitive Quality*. Additionally, research has shown that cognitive response includes the mental categorization of the product as well as related beliefs such as quality, durability, and ease of use. For example, Bloch [41] has shown the positive relationship between good design and consumers' responses.

Based on the Processing Fluency Theory [42], the mental processing of the perceiver can influence consumers' responses. Specifically, based on this theory, the perceiver's response to an object depends on the perceiver's fluency of processing, indicating that the more easily the perceiver can understand an object and its attributes, the more positive the response and attitude towards the object and vice-versa. In other words, fluid processing of an encountered design leads to successful and error-free perception, recognition, and interpretation of the target. On the other hand, processing which cannot be completed in a fluid matter can lead to a non-successful recognition and interpretation, resulting in a negative response. Based on previous research, fluency increases with ease of processing and serves as a factor of amplification. Effortless perception leads to positive outcomes due to cognitive processes such as perceiving, imagining, retrieving, or categorizing are completed with more or less effort. Thus, if a design is perceived to have high aesthetic qualities – e.g., a harmonious, well balanced design – it is likely to eventually impact cognitive processing and quality judgments in a positive way.

Consumers' response to a product's visual form and cognitive quality focuses mainly on the visual form of products but can also be impacted by the other senses. Thus, the logic of physical interaction with a part can also impact consumers' responses. For example, the current electrical seat switches of McLaren sports cars (i.e., McLaren 570S, 720S, Senna) have elicited strong dislikes, frustration, and complaints due to the complicated design and operation. The frustration has been so strong that complaints on social media and professional auto reports were published classifying the switches as the "devil's own job" [36]. The single switches are organized in a non-intuitive layout, making it dreadful for the driver and passenger to operate (see Fig. 3). This leads immediately to an avoidance behavior, dislike, and eventually to poor quality perceptions of the seat switches and even the car in general. In such a case, the switches' haptic feedback could still be well-tuned, normally leading to a high-quality feel, however, due to a very poor design and layout, the driver's cognitive quality will reach below expectations, thus, leading to overall poor-quality judgments.

Fig. 3. McLaren Sports Cars Seat Switches

This example shows the multidimensionality of consumers' quality perceptions and inter-correlation between the different perceived quality dimensions. A product's appearance must be congruent with other sensory aspects of design as "*the product form that the eye sees creates in the observer expectation of what the other senses will perceive*" [28]. However, if conflicting information is presented, a trade-off will be made – as the previous example shows. A trade-off between those information cues is needed, forcing consumers to pick one or several cues and base judgment on those. Less positive contextual cues may result in abortion of processing [43]. For example, consumers may ignore certain cues due to a lack of interest or difficulties in processing. Thus, a trade-off between information cues can be expected, and hopefully can be quantified.

4. Cognitive Quality as a part of the Perceived Quality Framework

Cognitive Quality focuses on processes related to the consumers' perceptions of product quality based on subjective processing and understanding of the product's design as a whole, as well as its features. Such an understanding can be a result of previous experience, but can also represent a summary of cognitive processing and sensorial impact. *Cognitive Quality* encompasses aspects of quality impression driven by both the perception of the stimuli and pre-existing knowledge. Furthermore, *Cognitive Quality* incorporates the tactile and kinesthetic sensory experience, rather than solely focusing on vision. We define *Cognitive Quality* as a composition of two

Cognitive Modalities: (i) based on aesthetic evaluation and emotion – *Perceived Aesthetics* and (ii) based on utilization evaluation – *Perceived Functionality* (see Fig.4).

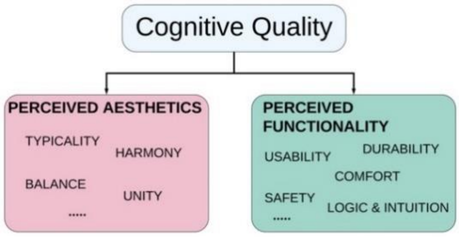

Fig. 4. Dimensions of Cognitive Quality.

4.1. Perceived Aesthetics

Cognitive Quality based on perceived aesthetics refers to the product attributes that are mainly linked with aesthetic values. Evaluation of a product by the consumer is influenced by specific design elements or principles. Fechner introduced the term Gestalt (German: 'form') and introduced principles such as complexity (number of elements, alignment, an order of objects), typicality, unity, harmony, and balance, to define 'good Gestalt' [44]. A product's Gestalt can lead to the viewer's sensations such as interest, pleasure, frustration, or arousal. In this framework the product's *Perceived Aesthetics* as a dimension of *Cognitive Quality* capture its' design's perceived hedonic tone [45] and can provide sensory pleasure and stimulation to the viewer [46]. With the application to the automotive industry, *Perceived Aesthetics* are influenced by the product's Gestalt (source) such as: typicality, harmony, innovativeness, complexity, and unity and provide emotions such as unpleasantness/pleasantness or arousal to the customer. Thus, we highlight that the definition of *Perceived Aesthetics,* and thus the concept of *Cognitive Quality* in this framework includes the product's Gestalt, as well as the resultant aesthetic emotions. It should be noted that the number of *Perceived Aesthetics* attributes can vary, depending on the depth of the automotive OEM's internal attributes structure, similar to the other perceived quality attributes included in the PQF.

4.2. Perceived Functionality

Cognitive qualities based on utilization evaluation refers to all qualities that are linked with perceptions of practicality and handling of the object. A product's utilization evaluation encompasses its perceived usability, ergonomics, safety, functionality, intuitiveness, practicability, reliability, and comfort. *Perceived Functionality* includes, but is not limited to, the *Cognitive Attributes*: Usability, Durability, Safety, Comfort, Logic and Intuition.

4.3. Three dimensions of Perceived Quality Framework

Designing a vehicle with the aim of achieving high perceived quality is never an isolated task. The PQF provides a basis for meaningful discourse around the topic of perceived quality in engineering science. However, the PQF (see Fig.2) is a dynamic structure that evolves at the pace that the automotive industry's challenges appear. The TPQ and its *Ground Attributes* can convey a meaning of tangible perceived quality attributes as engineers see and communicate this. Consequently, the introduction of *Cognitive Quality* and its modalities opens the path for discussions of previously 'hard to define' perceived quality attributes, and most of all, it provides a foundation to extend the understanding of quality impression. It is important to note that while there is a distinction between quality judgments relying on cognition versus quality judgments based on sensory input, a considerable interdependence exists. Product quality judgments based on senses influence cognition and vice versa. It can be said that the primary goal of the PQF is on the one hand to secure the correct execution of the specific perceived quality attributes, and on the other hand to convey its intended meaning to the consumer.

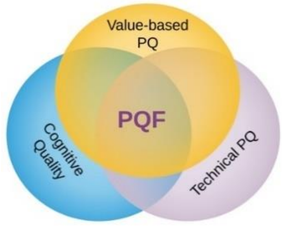

Fig. 5. Threefold construct of the Perceived Quality Framework.

5. Outlook

The term *Cognitive Quality* and its modalities presented by the authors is the first step in organizing the taxonomy of perceived quality attributes previously defined as intangibles. There is an apparent demand from the automotive industry for the creation of methodologies able to reflect the aesthetic preference of the consumer. There is a significant amount of research in the fields of consumer psychology [47, 48] and marketing studies emphasizing the significant role that product aesthetics plays in consumer response [49]. However, only limited research represents the engineering viewpoint on quantification of aesthetic-related perceived quality attributes, even though potential consumers consider both design and functions.

This paper presents a new dimension of the PQF – *Cognitive Quality*, a dimension that aims to define the perceived aesthetics of the product and its perceived functionality from the customer viewpoint. The discussion about the relationship between form and function and the ability to measure aesthetic qualities dates to the Plato Dialogues. However, as discussed, only a few advanced engineering tools have been developed with the aim of assisting engineers in decision-making processes related to perceived quality evaluation. The previously existing PQF aims to show the interplay between technical characteristics of the product and consumer perceptions. The *Cognitive Quality* dimension sheds further light on how perceptions of quality are formed with the aim of depicting the relationship between functional and aesthetic product characteristics, and the consumer's cognitive response to the vehicle design.

We do want to state three issues we recognize. Firstly, aesthetics of a product should not be analyzed independently from the car as a whole, as the individual factors are never independent of each other [51]. However, we aim to fill a gap in the PQF, and this is the first step. A solution to how *Cognitive Quality* can fully be integrated in the PQF needs to be further understood. Secondly, the PQF follows the method of 'object-related approach' [51] dividing and sub-dividing a car's features into a group of independent, objective characteristics to assess customers' subjective quality perception. This approach has been conceptually challenged [51]. Although we acknowledge this limitation, we aim to fill a gap by providing further insight into one supporting tool for the Design and Engineering teams in their decision making to achieve the highest perceived quality ratings for their designed vehicles. At last, User Experience (UX) related research has received increased attention in the automotive sector recently. However, we argue that the application of UX principles requires in-depth understanding of the already existing notion of *Perceived Quality* in automotive. There is a need for a comprehensive insight into the relationship between UX and *Cognitive Quality* revealing the potential overlap and distinction.

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