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Experimental Harmonization of Shape Intuitive Interaction

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Abstract – **With the increasing functionality and complexity of the material environment it is becoming important to universally improve the quality of its shape design for people with different knowledge. When the material environment shape does not match its value content or acquire unpredictable meaning, it creates disharmony between the function and user that requires intellectual and / or emotional effort for interaction. The intuitive design improves user's interaction because the information is presented on the subconscious level, hence it is accepted as a natural part of our environment and demands less effort to grasp and evaluate it. In this study, the scientific context of intuition is examined to determine methods and values of shape intuitive expression modeling. The goal of the study is to assess the effectiveness of shape experimental intuitive harmonization methodology using qualitative and quantitative methods. Functional and interaction restrictions are integrated into the object's shape by employing experimental modeling techniques. Surveys, controlled observations and MaxDiff analysis were used to monitor intuitive harmonization effects on car body split-line and box shape physical models. Experimental results show that the majority of participants consider conceptual shape models to be more intuitively attractive and informative. The study concludes that it is possible and viable to employ a proposed shape intuitive harmonization variable to achieve a universally positive effect.**

Keywords - **Intuitive design, intuitive harmonization, spatial modeling, universal design.**

Introduction

In today's material environment where people with different knowledge, experience and various abilities have to interact with unknown or increasingly complex objects / environments, it is necessary to improve the added value of these elements by adapting shape intuitive harmonization techniques. The aim of this research is to deepen spatial design knowledge in order to universally increase the quality of social, cultural and functional interaction with the environment. The research object is intuitive interaction between the material environment shape and human, and the objective is to evaluate the possibility to harmonize shape expression on intuitive level. The aim of the paper is to experimentally test methodology of shape intuitive harmonization for the future application in spatial design fields. The main tasks are to validate various shape intuitive harmonization integration techniques and experimental methods for its performance monitoring.

I. Concept of Shape Intuitive Interaction

In this study, the concept of intuition is considered on basis of theoretical and practical cognitive science research. Kenneth S. Bowers viewed intuition as an informed assessment in the context of discovery [1]. According to him, intuition is related to informed evaluation, and it is conditioned by memory, evaluation experience, and problem-solving abilities, hence cues to coherence (object or interface) activate the corresponding mnemonic connections leading to insight about the object. When the level of modeled activation becomes sufficient to cross the threshold into consciousness, at this moment suspicion or hypothesis arises [2].

Gibson [3] proposed visual stimulation patterns as a solution to long-standing problems in human sensory perception and meaning formation. According to him, the environment is providing a perception of possible actions for an agent, thus analysis of the environment explains behaviour of agent. He emphasizes environment not as sensually based but as an information based in terms of affordance with the perceivable opportunities for action, in other words, a human is looking for the ways to interact. Gibson advocates the idea of embodied cognition, which would explain the human body and mind unity – human body proposes the options for interaction with the environment.

Intuitive interaction of human and environment is comprehensively explored by the intuitive theories [4]. They consist of a system of ontological ideas and laws (causal) that governs the interrelationship between different ideas. The main characteristic of intuitive theories is that they do not only simply describe what happened, but also interpret the action in theory vocabulary. Gerstenberg and Tenenbaum proposed a simplified causal model of the relationship between the agent's goals, actions, and environment – while the state of environment and actions of agent are monitored, the value of target is unknown and must be derived. Battaglia [5] states 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 scene, the more future probabilities we consider. It also allows to evaluate counterfactual information that explains what happened. According to Gerstenberg [4], 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.

The ideas of intuitive theory of physics are detailed and structured. Concepts like power and momentum are related through abstract laws, such as the law of energy conservation. In case of intuitive theory in psychology, beliefs, desires and actions are linked by the rational action principle – individual will try to fulfill his desires in the most efficient way possible, taking into account his beliefs about the world [6], [7].

The process of intuition occurs when individuals encounter the clues, details of which need to be understood and solutions

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to complex problems in dynamic situations need to be quickly obtained [8]. In terms of situation assessment, the limbic system has evolved from the need to avoid mistakes as a mean to increase survival chances. Stimuli are judged from a position of potentially negative (primarily somatic markers act as "alarm") and positive outcome. Somatic markers are "early warning" and emphasize any potential adverse effects of a particular choice [9], [10].

Gibson suggested exploratory and performatory hand movements. Exploratory movements are related to tactile scanning when observer does not intend to modify the environment and performatory movements are related to rigidity or plasticity of the object. This provides user with the information on direction of movement as well as shape pattern of a new object [11]. According to Gibson, planarity, curvature, slant, parallelism, span, edge, and corner may be conceived as variables of solid geometry. This approach can be attributed to the entire human body, which is a tool to interact with the environment.

Kirsh and Maglio [12] described motor activity as dual: epistemic or pragmatic. Pragmatic actions are bringing the agent closer to his goals, and the purpose of epistemic actions is to obtain new information (explore the environment) by revealing what is hidden, that would eventually lead to the pragmatic actions. According to their study, motor epistemic actions are helping with the cognitive processes by reducing the amount of mental effort to get insights. This understanding is close to Gibson's hand movement exploratory and performatory classification.

Empirical evidence based data on cognition embodiment was obtained from the psychology laboratory studies [13], [14]. Inspired by Barsalou [15] and Gibson, who were seeing perceptual symbols as affordances – actions available, and that the meanings of these symbols are grounded in a sensory-motor system (human or animal), authors conducted experiments where they were asking participants to evaluate sensible and nonsensical mechanical environment, and the answer should be provided via motorial and verbal action [13]. The first experiment demonstrated that it is faster to evaluate affordances with motoric action than using linguistic answers. Their experiment demonstrated consistent data that perceptual spatial affordances are easy to simulate and motor and other sensory data should not be separated. The results of the second experiment demonstrated that language understanding is directly related to the bodily states and the emotional response is indirectly related, since it does require comprehension of meaning. These results strongly confirm concept of embodied cognition and its modal and non-arbitrary representation in a motor system. Such process reduces the amount of mental activity; hence, bodily activity is directly influencing mental processes.

Human intuitive interaction with the environment is based on the embodied cognition, which allows to explore, modify and simulate actions in the environmental conditions. 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 object's shape, making it more easily and universally understandable on a subconscious level. The intuitive shape expression should be organized by abstract means and avoiding symbolic (learned) content. Mechanical shape design creates an opportunity to practically harmonize interaction between the object and user (agent) by communicating a particular message in a contextual situation.

II. EXPERIMENTAL RESEARCH METHODOLOGY

The principles of universal design and the ensuing aims must be combined to improve the quality of human life in a given environment [16], [17], [18]. Aims [19] of the principle "simple and intuitive use" indicate factors of the shape intuitive harmonization:

- the aim of cultural appropriateness – shape improves the aesthetics of an object;
- the aim of health and wellness – shape complements object's function;
- the aim of understanding – shape teaches interaction with an object.

Shape intuitive expression variables are very diverse as well as their states (separation, centre, joint, closure, balance, etc.). These variables acquire meaning in the specific context of physical, cultural and social environment [20].

The author conducted a survey of the shape variables in which 77 design professionals were participating. According to the survey, the most statistically significant (dominant) shape variable is – shape reveals the method of use, which prominently participates improving all the intuitive harmonization factors [21]. This variable consists of the particular space / object's function and human interaction peculiarities. These elements can be linked through the shape altering using mechanical properties like bend – force direction, gap – anthropometric allowance to interact, etc. These elements can be measured and applied in the conceptual shape modeling, providing opportunity to document, monitor, modify and test the effectiveness of intuitive interaction.

Experimental object has predefined conditions and they serve as a basis for further shape conceptualization. A semiotic understanding of the shape modeling requires to understand Gestalt components from which it is made and the environment where it is placed [22]. User interaction analysis is based on the function of the object, predetermined by the initial conditions, and human contact data. The interaction with the shape has direction of force, this allows to map it on the shape according to the force vector direction. Environment or object mechanical interaction analysis provides sizes, positions and directions of the human interaction, which reflects as a conceptual shape. Mapping of conceptual shape requires scale and fixed visual reference.

Methods of assessment of shape expression variable effectiveness should target intuitive responses and avoid conscious deliberations by focusing on the insight – does the shape reveals method of use? The effectiveness of the shape is evaluated as satisfaction with the result.

Proposed method for qualitative testing is a comparative two dimensional model survey. The aim is to test the validity of variable integration. Modified and non-modified models are compared , which shape better reveals the method of use.

To monitor the quantitative effectiveness of shape intuitive design, various criteria or a set of criteria, such as time, distance, amount of force, number of attempts, etc., can be employed. Applied functional and interaction analysis of the specific object allows to define such values of criteria. The experiment should be performed in a controlled environment and in a particular interaction context. The object's shape performance is evaluated against a non-modified or control object. The data is processed statistically to indicate the effectivenes of interaction harmonization.

MaxDiff method [23] is used to assess qualitative aesthetic properties of the models. This method is suitable for the investigation of intuitive reactions because information is evaluated with respondent's minimal deliberation. It does not exploit principles of rating and ranking and it 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.

III. Experimental Data

Volvo XC90 car was chosen as an object for the validation of variable integration. The information on the method of use and dimensions were obtained from the official sources [24], [25]. The experiment addresses two functional car body elements, exposed by the split-lines: tailgate and hood (bonnet). Method of use of the car body panels is primarily associated with the human – object physical interaction. From the mechanical interaction perspective, the size of the place should correspond and allow for the tool (hand, feet) to interact [26].

The survey is divided into two parts. In the first part data about respondent's car user status have to be acquired. The second part is designed to evaluate car tailgate and hood split-lines. This part consists of two questions each. The first is a control question – to identify participant's informativeness level to understand the function and a way of interaction with the element. The second question is how modified and non-modified models compare in respect of the shape variable – shape reveals the method of use.

Form decomposition techniques and evaluation conditions are important initial constraints. They determine perception quality and amount of information needed to reflect the modification. Many studies have been done to formalize the process of object shape decomposition and evaluation [15], [27], [28], [29], [30]. Decomposition of the 3D shape to represent it in 2D media is relevant because of the problematics arising due to the complexity of the 3D shape position and view angles and, as a result, allows to reduce the information noise (Fig. 1).

Effectiveness of the conceptual models has been examined invoking the survey of 125 respondents (Fig. 2). Non driving people tend to identify the proposed hood model slightly less variable confident, and this can be attributed to the specific knowledge, which might be associated with the vehicle service experience.

The design of the box shape was chosen for a quantitative experiment. Functional interaction with the box can be attributed to the split-line as a border of the component – cover. The conditions for the experimental split-line altering are set to have a minimal expression on the evaluation process of aesthetics and function.

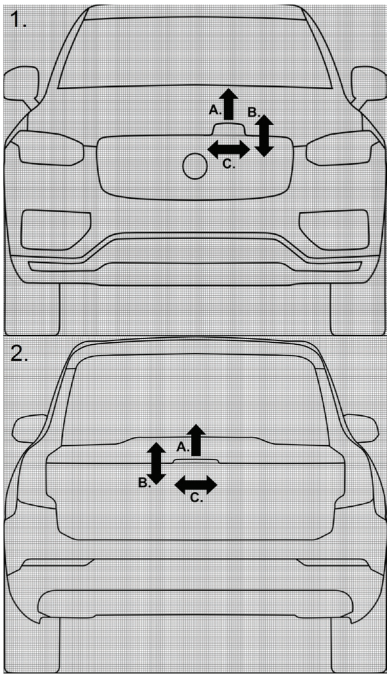

Fig. 1. Picture resolution of the car elevations are set in 1mm to 1 px ratio and the grid is 100 px² = 1 cm². Grid provides approximate framework for the car body split-line shape conceptualization of anthropometric data and interaction place. 1. Experimental hood model (in scale analysis grid): A – movement direction; B – palm thickness; C – palm width; 2. Experimental tailgate model (in scale analysis grid): A – movement direction; B – fingertip thickness; C – fingertip distance from each other.

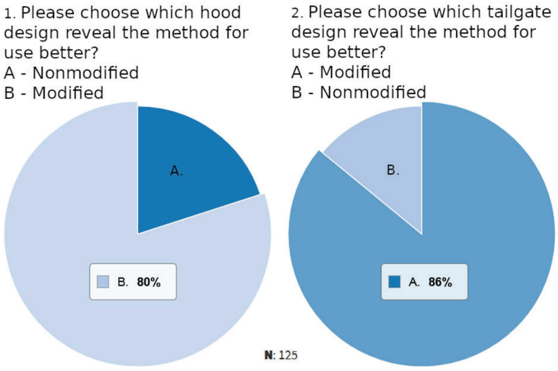

Fig. 2. Survey results of the effectiveness of shape variable implementation.

Intuitive interaction effectiveness criterion is a number of attempts to open the box. Less attempts – better shape effectiveness. The models are divided into 3 sets, each set consists of two – positive and negative – variations (Fig. 3). The positive model contains hints of the integrated shape variable, but the negative – does not. To the first set of boxes the 3D shape variable is applied as a handle to mark the direction of the action force (curvature inwards). The second set is displaying a fake split-line and is related to the anthropometric data – hand size (grip width 97 mm, depth 21 mm), and the third set is a 2D contrast shape displaying curvature towards the action direction. Two models of the same set are shown and evaluated at the same time. Participants are asked to interact with the object’s marker (to open the lid) using one finger (Fig. 3).

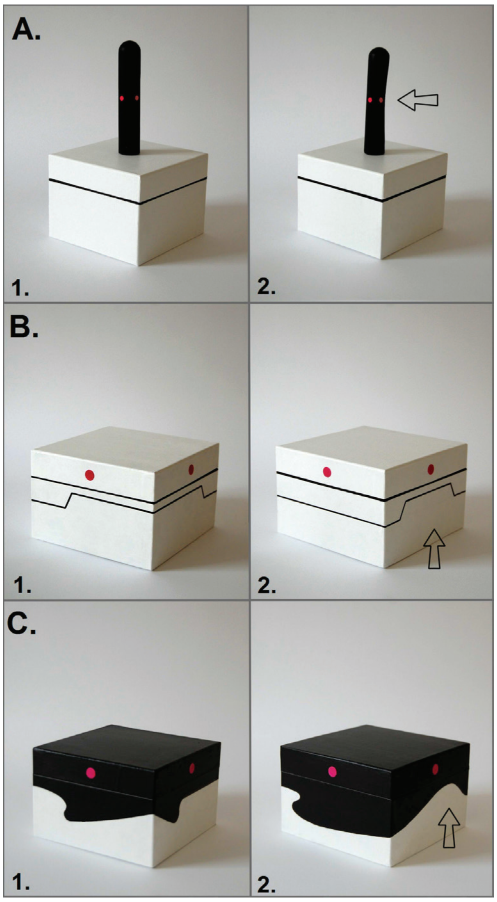

Fig. 3. Arrows show places where shape variable was integrated. Participants were asked to push the red side marker to open the box.

The data is processed statistically and average of attempts is determined for each and total of sets. 37 people (homogeneous by age and education) participated in the experiment, and the results strongly support the variable's positive effect (Fig. 4).

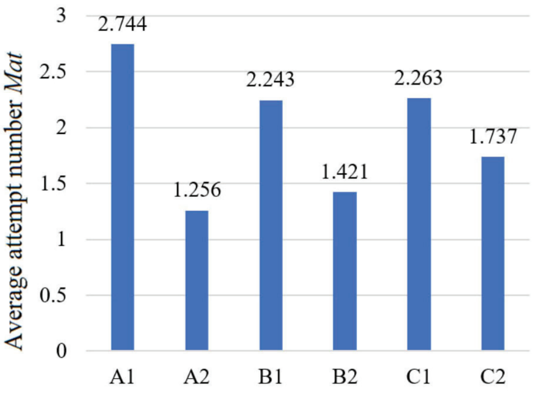

Fig. 4. Quantitative data show that the designs with the integrated shape variable are more functionally effective and communicate (teach) interaction.

Immediately after the interaction experiment, 30 participants carried out MaxDiff test of the same models. The aim of the test was to determine qualitative aesthetic properties of the models. The results show that models of the same design with integrated variable are aesthetically more appealing (Fig. 5).

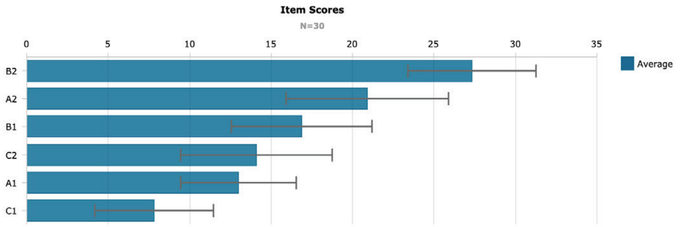

Fig. 5. MaxDiff analysis results.

IV. Discussion of the Results

The experiment data show that the proposed shapes are strongly embodied in cognition and are evaluated on an intuitive level. The survey of car body split-line model reveals that the shape, which reflects method of use, can be effectively modeled and integrated into the object. The box experimental models confirm integrated shape variable's harmonizing effect and demonstrate a strong correlation between the established methodical tools and universal harmonization of the intuitive design factors. The most effective model to complement function and teach interaction is A2 (positive), which requires the least number of attempts to open the box. Since all the conceptual models are based on author's interpretation, MaxDiff analysis allows to evaluate aesthetic quality of designs and shows preferences among the same pair of models. It can be noted, that in all evaluated pairs positive shape expression is more preferable. Nonetheless, the most appealing design was pair B.

The study explored and confirmed experimental methods of shape conditioning, decomposition, and modeling. Applied qualitative and quantitative methods validate practical possibility to monitor and test the object's shape effectiveness on intuitive level.

It is concluded that human is intuitively sensitive to mechanical causality of environment and the proposed methodology allows to purposefully manipulate shape to enhance quality of the spatial design. Shape expression elements can be effectively organized for the user by creating a suggestive, intuitive, psychologically fluent, energy efficient and secure interaction scenario. Shape gestalt can be analyzed as interrelated physical elements in a particular context. Linking the shape's mechanical expression with human cognitive abilities provides a creative tool to universally improve the quality of social, cultural and functional interaction and achieve more precise added value measurement.

Applied use of intuitive harmonization methodology allows to determine shape design constraints by addressing various functional contexts (physical, cultural, social, psychological, etc.) and mechanical interaction peculiarities. To monitor shape intuitive design effectiveness, various quantitative criteria or a set of criteria, such as time, distance, amount of force, number of attempts, etc., can be employed. Applied functional and interaction value analysis allows to define such criteria values. MaxDiff qualitative analysis is a viable option to evaluate feelings and subconscious reactions. Practical application of the methodology can be implemented in a wide range of spatial design solutions. Architectural elements may be developed to create a zone barrier by directing the shape's mechanical force towards the agent or create a movement layout for particular interest of people. For example, in the design of medical product an invasive tool can obtain more amorphous (less sharp / structured) contact shape to reduce stress on patient. In landscape design, it is possible to alter large spatial shapes according to their function (shelter, communication, privacy zone, etc.) and human physical interaction mechanics [21]. Analysis of user interaction with the object or spatial function provides creative tools that are not limited to human physical actions and utilitarian function. The study reveals possibilities of evaluating spatial cultural content of an object as functional. Various methods can be used for the functional analysis of cultural content: typological, historical-chronological, iconological, hermeneutic, or others. Intuitive perception of the cultural functionality can be modeled through the mechanical expression of the shape. Intuitive interaction is a synergy of sensory stimulus and a particular context. As a result, it generates sensations and emotional responses. Uncontrolled emotions are disruptive force. To establish socio-cultural and functional criteria and conditions for the landscape harmonization, it is necessary to involve community members and professionals on participatory democratic grounds.

General conclusions

This study provides a new insight to enhance the interaction quality of human and environment in a variety of spatial design fields. The research has confirmed that human ability to simulate Newtonian physics is embodied into cognition and allows to intuitively perceive and anticipate the interaction with environment. It is concluded that material environment shape's intuitive communication can be universally harmonized by utilizing principles of the mechanical causality. The established methods of shape conditioning, modeling and experimental techniques enable to create the conceptual models and to monitor intuitive interaction effectiveness.

The developed methodology contributes to the interdisciplinary design research field and provides a scientific support for further studies of the universal design optimization, intuitive design principles, their innovative application and evaluation. As a further development of the research the author is planning to carry out applied collaborative investigation of the shape intuitive harmonization methods in various spatial design fields.

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