THE STUDY OF COGNITIVE DIFFERENCES BETWEEN DESIGNERS AND USERS BASED ON SCHEMA THEORY

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ABSTRACT

This study is grounded upon the cognitive process and knowledge representation, analyzes the differences in perceptions between designers and users by applying schema theory. Per design process, we disassembled the semantic words that represent the design concept, and re-construct the representative visual imagery library. We experimented the imagery library with selective designers and users, and through their selections of the images, we uncovered: 1. The differences largely exist in concept interpretation and imagery selection between designers and users, which has strong relationship with their different schema; 2. The experiment revealed the fact that designers are inclined to understand the concept by disassembling the elements, and have obvious tendency of professionalism, while users' interpretation prefers complete forms and life-oriented; 3. As compared with users, designers relatively prefer brand-new, creative elements in selecting visualized representation.

Keywords: Design cognition, Design learning, Conceptual design, Conceptual schema

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Cite this article: Guo, S., Fan, S., Meng, Y. (2023) 'The Study of Cognitive Differences between Designers and Users Based on Schema Theory', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.352

1 INTRODUCTION

The previous studies have shown that there is difference existed between what the product designer is intended to express and what actually the end user feels out of the designed product (Marglin, 1997; Hsu, et al, 2000; Luo and Zhu, 2005; Cilly, et al, 2008; Khalaj and Pedgley, 2019; Luo, et al., 2021). In the design process, the designer forms the mental and behavioral intention, thus meets the expectations of users via designing (Zeisel, 1984). Very often there's deviation on interpretation of design intention and cognition between designer and users, which brings obstacles of communication in the conversation. Marglin asserted the difference exists between the aesthetics of designers and the taste of users (Marglin, 1997). Hsu, et al (2000) thought the difference exists in the descriptive words of how the designers and users express their feelings to the same product. In fact, as sitting in one end of the conversation, both designers and users have a certain level of asymmetry in the design knowledge. They are not only the cognitive subjects respectively, but also co-creators of achieving the objectives via communication (Zhao, 2013). The designers apply the unique cognitive thinking while understanding objects and designing artifacts, to build and represent the knowledge. Thus, between the designers and users, there might exist different schema framework about the world.

This study is through the lens of design conceptual schema to look into the difference between designers and users at the cognitive level to a designed product, and try to obtain the difference of how the knowledge is acquired via semantic disassembly of design conceptual words, and the match-up of the conceptual imagery. This study is hoping to solve following problems:

- Does the difference exist when designers and users are selecting the representational images?
- If yes, where does this difference reflect to?
- Is this difference impacted by conceptual schema?

2 THEORETICAL OVERVIEW

2.1 The cognitive difference between designers and users

Hsu, et al (2000) thought the difference exists in perceiving the product forms and meanings between designers and users. They have misaligned perceptions to the same object, and misaligned understanding to the same adjective. For instance, if the intention of the designer is about to express "vintage" out of the product form in respondent to market needs, but the impressions to the product form from the majority of users are "modernized", then we say there is semantic discontinuity existed (Khalaj & Pedgley, 2019).The difference between designers and users also reflects in their product perception model. Based on design objectives and user needs, designers explicitly express the form and function of a given product by application of symbolic information, semantic information, and imagery information. But the perception model of users is relatively ambiguous and influenced by previous experiences. Users can only leverage general adjectives to describe what they perceive, e.g. beautiful, niche (Luo and Zhou, 2005). In addition, the previous study also uncovers that designers pay attention to the aesthetics of the product form, and externalize it via visual symbols (Marglin, 1997; Luo, et al, 2021). The cognitive difference between designers and users also reflects in their different knowledge base and aesthetics experiences (Cilly, et al, 2008). Marglin (1997) thought sometimes the cognitive difference comes from the fact that the functions designed by designers exceeds the knowledge base of users. The gap of knowledge base between designers and users reflects in the fact that their product information collected in different time and space, on which they build up their respective understanding to a given product, thus shape up their respective conceptual schema to the product. In fact, the understanding level to a given product reflects their knowledge level between designers and users (Anay and Özten, 2018). Disassembling the knowledge and experiences through how the schema forms and the represented elements (semantics and images), can scale the variation analysis at product level to the broader knowledge structure and the thinking process.

2.2 The conceptual schema formation process

The schema is a framework of knowledge representation (Bartlett, 1995; Steinberg, 2005). People feel the objects via perception, match the received representations with the concrete and abstract knowledge stored in brain, seek for resemble characteristics, and stabilize the concepts that represent

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the aspects. The schema is the framework and regulation that repetitively occur during perceiving and thinking. A human's schema of world and all kinds of objects is from his/her personal life and cognitive experiences, and is closely related to how his/her visuals stored in brain, feelings or abstract elements are sorted and searched.The schema of a vehicle in user's head, is actually the summary of what he/she saw or experienced previously. It contains the common essence, core signatures and attributes of those vehicles. The process of forming the conceptual schema for users is a process of classifying and seeking for representatives, which puts more attention to define the characteristics of the objects in the same type. Perceiving vehicles from a user, is the process of organizing and extracting the knowledge towards the concept of vehicle in the brain. How to establish the connection to this concept, depends on how much relevant knowledge is stored in the brain.

In the process of forming the conceptual schema for designers, there are identical aspects, as well as different aspects. After forming the schema of regular objects, the primary work of designers is to break down the artificial objects, encode all kinds of products in the world in a way they're good at with, and decipher the form of objects as essential elements (Douglas and Isherwood, 1979). Designers break down and re-construct the artifacts via dimensions of form, function, materials and manner (Buchanan, 2007). Designers of different occupations focus on different artifacts, and collect a huge amount of information characteristics of artifacts in one kind. In the process of designer knowing and learning, the classic precedent or creative design cases were stored in their brains as design knowledge thus form as schema (Akin, 2010). The construction of designer schema starts from the problem, intentionally interpretates the artifacts and breaks down into elements, re-synthesizes and creates new objects (Figure 1).

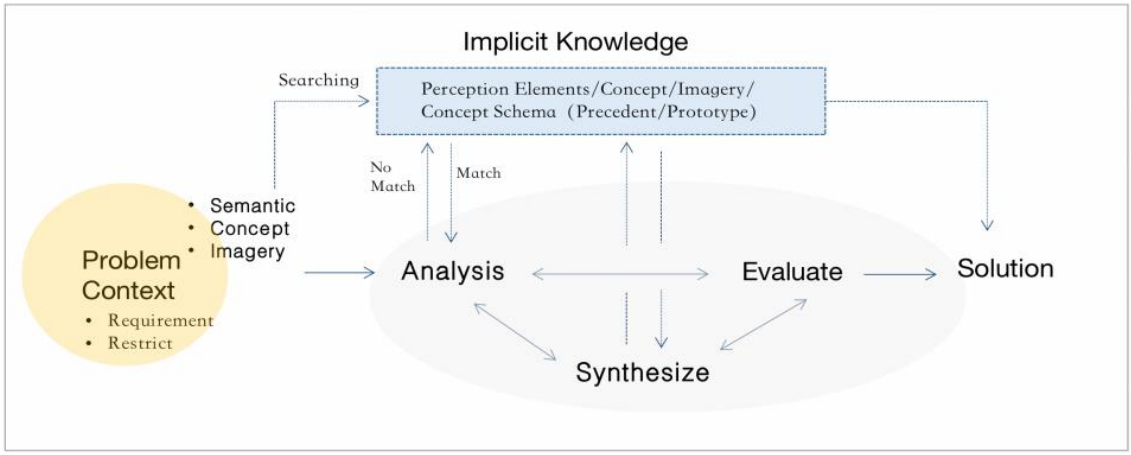

Figure 1. The process of extracting knowledge in problem-solving for designers

2.3 The methodology of studying the representations of product conceptual schema

As an implicit knowledge, the conceptual schema is usually stored in long-term memory. Designers search, extract, and use the relevant schema information during problem-solving to complete the representations of design intention. But when users see the product, they extract their relevant knowledge to complete the understanding to it. The conceptual schema contains abstract semantic concepts as well as concrete imagery. In the previous studies, the researchers compared the extent of perception to a product via product form imagery and descriptive semantic words, and used the semantic differential method to conduct quantitative research (Hsu, 2000; Khalaj and Pedgley, 2019). Hsu, et al asked users to semantically evaluate 24 telephones, then analyzed the cognitive differences to products by collecting users' subjective evaluation. Anay and Özten (2018) took design precedents as research materials, leveraged oral analysis as method, and investigated the level of schema of domain expertise of students majored in Architecture. They uncovered the difference existed in extractable knowledge by students in different grades. Some researchers think there should be differences in cognition of design conceptual schema prior to the differences of product cognition, as currently the design requirements sometimes do not directly come from consumers, but instead, is based on the design concept summarized by commercial market (Khalaj and Pedgley, 2019; Gonzalez, Val, Justel & Iriarte, 2017).

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This study is through the lens of design conceptual schema, looks into the differences of product cognition wise between designers and users, and obtains differences existed in extracting their respective knowledge by semantically disassembling the design conceptual words and matching them up with images. The designers' conceptual schema is relevant to the design precedents they're aware of, the design problem they're processing, and the design elements they're using to express the design intention. The users' conceptual schema is relevant to their experiences in life and the synthesized knowledge. The following questions were expected for a deep dive:

- Does the difference exist when designers and users are selecting the representational images?
- If yes, where does this difference reflect to?
- Is the representations of a design concept by designers influenced by conceptual schema?
- Is the representations of a design concept by users influenced by conceptual schema?

3 EXPERIMENT DESIGN

3.1 Semantic disassembly of design keywords

The three keywords of this study came from the research results of Design Keywords Study of Chang'An Automotives in 2021. The design keywords study leveraged the method of image perception research (Luo, 2005), provided images of the top 10 best-selling vehicles of the year (logo masked) and asked designers and users to subjectively evaluate the forms, materials, colors and conveyed emotions of the vehicles respectively. The researchers conducted oral analysis to the descriptions by participants, selected 10 keywords based on the frequency of mentions. This study chose the top 3 keywords as the subject: "fluid", "robust", "hi-tech". In order to ensure the best accuracy and comprehensiveness of the library of keyword and image, we formed groups to embark on semantic disassembly. The 13-person research group includes 3 experts (professors of semantics, aesthetics, and design), 5 users (2 males, and 3 females), and 5 designers (3 males and 2 females, 2 product designers, 2 architects, 1 graphic designer). We firstly invited three experts to analyze the keywords from perspectives of semantics, aesthetics, and design, for obtaining the diverging dimensions of the keywords, and making the outline of semantic disassembly interview. Then we asked designers and users to explain the keywords, synthesized via oral analysis, and eventually obtained the 6-dimensioned semantic disassembly of the keywords and their characteristic description. The Table 1 is the characteristic description of semantic disassembly to the keyword of "hi-tech" between designers and users.

Table 1. The characteristic description of semantic disassembly to the keyword of "hi-tech"

	Designer semantic disassemble		User semantic disassemble	
Disassemble dimension	Feature	Per of person-time (η/%)	Feature	Per of person-time (η/%)
Meaning Interpretation	Advanced Something about future Unknown mystery	40 80 40	Efficient assistant Powerful technology Good product	40 40 80
Synonym	Future sense Science fiction	100 40	Intelligent Complex	60 60
Antonym	Outdated Normal	60 80	Outdated Original ecology	80 20
Scope of word application	Industrial product Architectural space Science fiction film	80 40 20	Daily necessity Automobile Film News event	60 60 20 20
Visual imagery	White lines style Metallic glossy material Neon lines with light Smooth angular object Silvery luminous material	60 40 60 40 80	Metallic object Interface of an electronic product	60 60 20

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Represent object	Spacecraft	40	ChatGPT	20
	ChatGPT	80	Tesla	60
	Warcraft	20	Residence	40
	Tesla	80	Sneaker	20
	I phone	60	Heated clothing	20
	Zaha's design work	20		

3.2 The establishment of image library

We asked 10 participants to collect imagery based on their understanding to the keywords and the dimension of semantic disassembly, 15 images per participant, try best to visually represent the keywords. Then we asked the participants to explain the relevant characteristics to "hi-tech" in the images, e.g. "I think the colors in this image gives me the feeling of hi-tech". Initially we obtained 150 images per keyword. We removed duplicated, alike images in semantic dimension and visual dimension, then voted out 50 final images by the research group.

3.3 The implementation of research

We asked the designers and users to select out 20 images that are best representing the keywords out of the 50 images filtered in the above section. The concepts and images are presented in the form of questionnaire. The participants were asked to answer the question of "Which of the following images that you think can best represent the word of fluid?". The 50 images were presented in sequence. The participants picked up 20 images they saw fit out of 50. The questionnaire was distributed as web app via internet. The participants filled the questionnaire on mobile devices or desktop PCs.

3.4 The participants

The participants included 10 designers and 200 users. The designer group was consisted of 4 males and 6 females, 23-45 years old, with the educational background from undergraduate to post-graduate. The user group represented the consumer base of cars, including 140 males and 60 females, aged from 25 to 60, with the educational background from high school to post-graduate.

4 RESULTS

4.1 The difference generally exists in the selected group

Based on their respective understandings to the three conceptual keywords, users and designers selected 20 images out of 50, see the Table 2 for the sequence of the selection frequency of images from high to low. The image to the keyword of "Fluid" that users selected the most was lc_45, with 71.5% selection rate, and lc_102 was the least selected image, with 50.5% selection rate. The image to the keyword of "Robust" that users selectd the most was YL_55, with 72% selection rate, and YL_5 was the least selected image, with 50.5% selection rate. The image to the keyword of "Hi-tech" that users selected the most was kj_136, with 70.5% selection rate, and kj_102 was the least selected image, with 52% selection rate.What designers selected was greatly differed from users. First of all, for the most selected and least selected images to the three keywords, they were totally different. Then in the selected 20 images, the respective amount of identical selections to "Fluid", "Robust", "Hi-tech" are 9, 4, and 5, overlap ratios are 45%, 25% and 30%.

Table 2. The statistics of image selections between designers and users

Users						Designers					
Fluid		Robust		Hi-tech		Fluid		Robust		Hi-tech	
Pic.	Pct of vam(%)	Pic.	Pct of vam(%)	Pic.	Pct of vam(%)	Pic.	Pct of vam(%)	Pic.	Pct of vam(%)	Pic.	Pct of vam(%)
lc_45	71.5	YL_55	72.0	kj_136	70.5	lc_65	90	YL_6	90	kj_102**	100
lc_7	70.5	YL_128	70.5	kj_128	66.5	lc_126**	90	YL_31	90	kj_10	90
lc_13	66.0	YL_68	68.5	kj_135	66.5	lc_80	80	YL_9	90	kj_13**	90
lc_54	63.0	YL_121	66.5	kj_133	65.5	lc_45	80	YL_129**	80	kj_15	90
lc_147	59.5	YL_129	64.0	kj_130	64.0	lc_54**	70	YL_56	80	kj_126	80
lc_110	58.5	YL_135	63.5	kj_26	64.0	lc_35**	70	YL_37	70	kj_113**	80
lc_35	57.0	YL_42	61.0	kj_6	61.0	lc_118	60	YL_135**	70	kj_20	80
lc_148	56.0	YL_134	60.5	kj_113	60.0	lc_95	60	YL_22	70	kj_39	80

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lc_142	54.5	YL_132	58.5	kj_132	60.0	lc_25**	60	YL_38	70	kj_101	70
lc_70	54.0	YL_60	58.0	kj_54	60.0	lc_24	60	YL_128**	60	kj_115	70
lc_25	53.0	YL_31	57.5	kj_13	57.5	lc_13**	60	YL_71	60	kj_88**	60
lc_130	52.5	YL_51	56.5	kj_98	57.0	lc_85	50	YL_36	60	kj_67	60
lc_145	52.5	YL_140	55.0	kj_134	56.0	lc_145**	50	YL_44	50	kj_136**	60
lc_75	52.5	YL_3	54.0	kj_21	56.0	lc_5	50	YL_29	50	kj_99	60
lc_26	51.5	YL_8	53.5	kj_124	54.0	lc_35	50	YL_32	50	kj_26	60
lc_30	51.5	YL_138	53.0	kj_97	54.0	lc_75**	50	YL_79	40	kj_47	50
lc_76	51.5	YL_130	51.5	kj_88	53.5	lc_142**	50	YL_41	40	kj_53	50
lc_126	51.0	YL_133	51.0	kj_18	53.0	lc_94	40	YL_8**	40	kj_84	50
lc_143	51.0	YL_5	51.0	kj_37	52.0	lc_121	40	YL_15	40	kj_48	50
lc_102	50.5	YL_6	50.5	kj_102	52.0	lc_147**	40	YL_89	40	kj_105	50
**represents the image selected both by the user and the designer											

4.2 The characteristic description of the selections between designers and users

In the selected images that can best represent the three concepts, there's huge difference existed. For instance, regarding the images that can best represent "Robust", users selected YL_55, a helmet, as opposed to what designers selected, YL_6, a workstation. Regarding the images that can best represent "Hi-tech", users selected kj_128, but designers selected kj_10. What users selected was an image with storytelling, which is a user is using gaming console to experience VR technology. But what designers selected was a certain part of a vehicle, which is the front/rear light consisted by multiple diamond-shaped light stripes. In the rest of the images that have differences, the images that designers selected to represent "Fluid" was inclined to the conceptual arts of vehicle or airplane. The images for "Hi-tech" to designers was inclined to new technology, new materials, new forms, and new ways of manufacturing. And the images for "Robust" was inclined to forms with shapes of squares or rectangles, geometric forms, with straight lines and apparent right angles, materials with metallic glossy in colors of silver, grey, or black. What users selected for "Fluid" can be identified what the main object is. For instance, the main objects of lc_54, lc_35, lc_130, lc_30 are architectures. The same as the 20 images for "Robust", in which the main objects include vehicles, computers, tools, humans. In specific, the main objects in YL_134, YL_130, YL_133 are clearly human characters. Also, we can see the obvious connections in forms, lines, and functions of the main objects from the images that represent "Fluid" and "Robust". The selected images of "Hi-tech" consistently convey the concept by rendered scene or storytelling, for instance, ky_136, kj_128, kj_130. Interestingly, the image of kj_102 was what designers selected can best represent "Hi-tech", it was also selected by users, but sequenced as the last one out of 20 images.

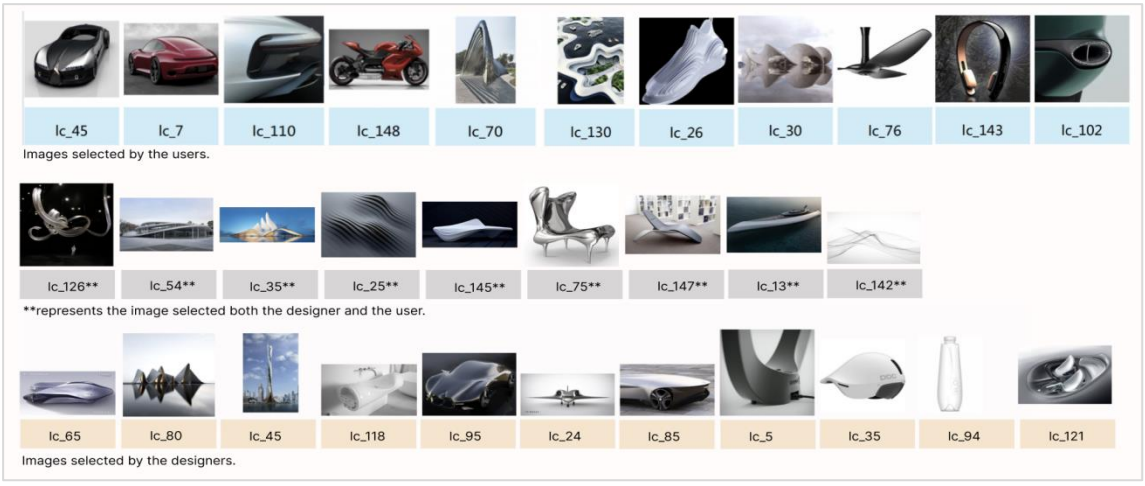

Figure 2. Images of "Fluid" selected by user and designers

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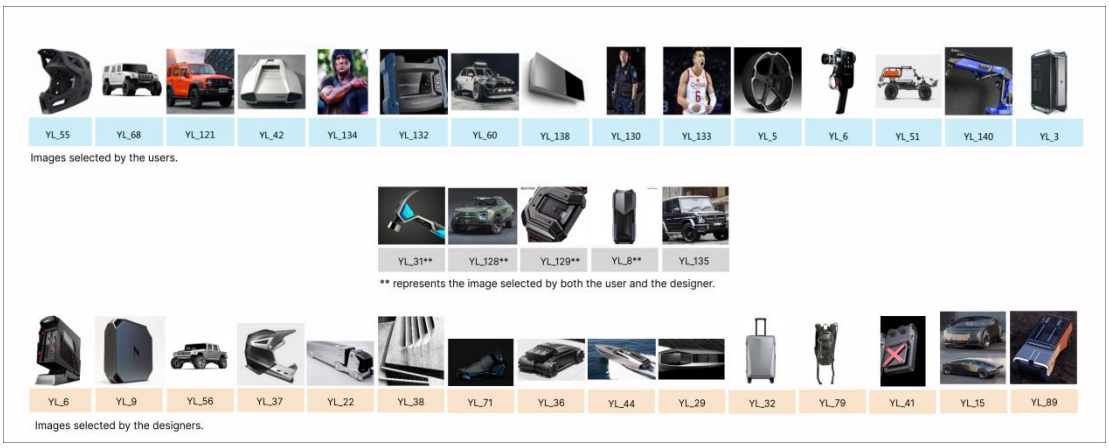

Figure 3. Images of "Robust" selected by user and designers

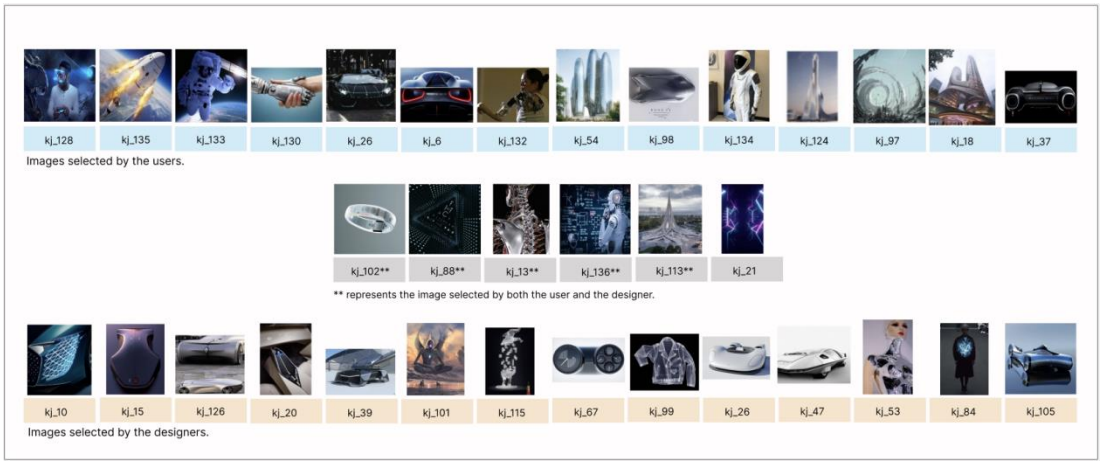

Figure 4. Images of "Hi-tech" selected by user and designers

4.3 The in-group differences on the selected images by users

Inside of the users group, there were differences in age, gender to image selection. What females selected has noticeable difference vs. males and in general. For instance,

- the selection rate of YL_6 for "Robust" was the lowest in top 20 for general, but actually high in female, which was 60%.
- Both YL_130 and YL_133 are male character images, which are police officer and basketball player , also have relatively high selection rate in female, as 60% and 45%.
- The highest ranked image for "Hi-tech" was kj_136. The selection rate of this image in users aged in 20-35 was pretty high – 73.8%.
- For image kj_128, 74.7% female selected, and image kj_102, 41.8% female selected, both images have noticeable difference to what male selected.

Alongside the distinctive selection between the groups of designers and users, we obtained the insights that selection differs in gender, age within the group, which needs more investigations to deeper dimensions to unveil the root cause.

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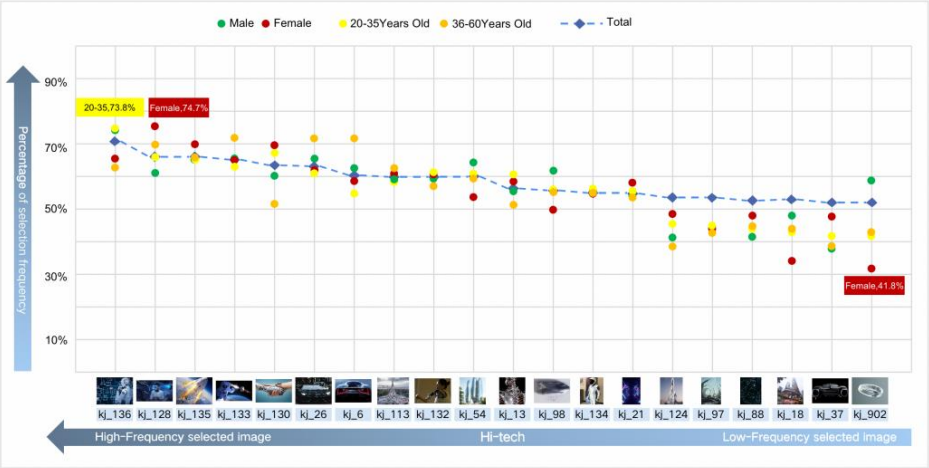

Figure 5. In-group differences of "Hi-tech" Images

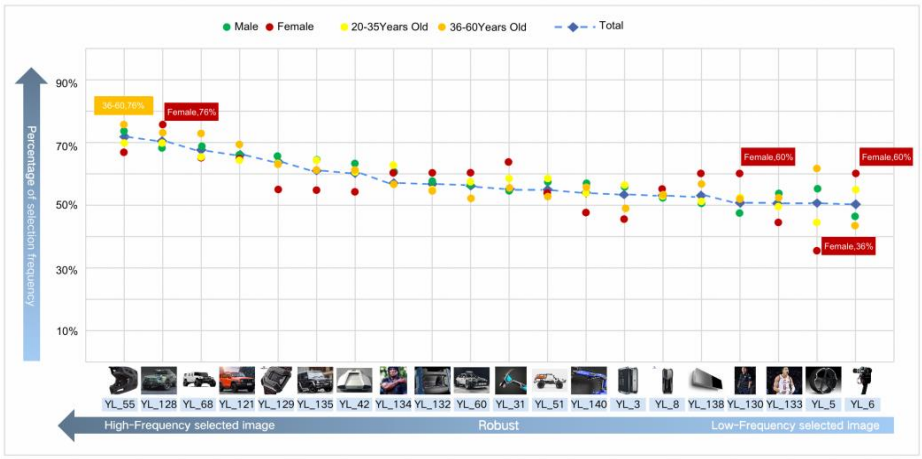

Figure 6. In-group differences of "Robust" Images

5 DISCUSSION

5.1 The differences in image selection between users and designers

Through the image selection in this study, we found out the difference exists in the image selection to the same concept between designers and users. This difference firstly reflects in the best representative images and overlap images. Secondly the difference sits in the image type, style, and the key object of what designers selected as compared with users. For instance, lc_45 and lc_65 are what users and designers think most representative for "Fluid" respectively, lc_45 has obvious characteristic of vehicles, but lc-65 is more like an aircraft or conceptual art for cars. lc_65, lc_85, lc_95, lc_121 are all vehicle-alike, which were selected by designers, but all get rid of the typical character of vehicles, and instead, incorporate new elements to the form. The difference like this might be relevant to the motivations of innovation for problem-solving. The designer schema does not persist, but always changes from time to time. Sometimes it re-organizes the information and elements within a given conceptual scope, to achieve the change of form or material. Sometimes it defines a new artifact by walking out of the original conceptual scope (Gero, 1990). What users selected are reflectively richer in image types, including architectures, vehicles, characters, etc. The images more likely refers to real life, with obvious tendency to narratives or storytelling. For instance, the image selection to "Hi-tech" includes the visual imagery that is often seen in news, ads, which matches the interpretation to the oral analysis in the semantic disassembly. How individuals identify the product, understand and obtain the meaning of the product is highly relevant to their knowledge base, life experiences, and aesthetic experiences (Zhao. 2003).

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5.2 The relationship between image selection and conceptual schema

There were obvious tendency to image selection by designers, which laid in their attentions to design works that are related to their major, as well as the influence by precedents. 44 selected images out of 60 for the three concepts were product images, involving vehicles, electronic products, tools, etc. The imagery was more likely the conceptual art for products, which represents the future trend or possible directions. This is highly relevant to what designers learned and get influenced by precedents in their education, as observing/analyzing the classic design works and collecting creative design solutions are approaches of how they learned to design (Lawson, 2005). Aside from that, designers pay more attention to aspects of a given product like the forms, lines, styles, materials, and patterns, etc. They are likely to break down the product into pieces for analysis respectively, that was why we saw a lot of the details or just a part of the whole object in selected images by designers. Designers proactively collect and build up all sorts of information that is relevant to product design, including classic, current, futuristic, to architecture the understanding to its form, function and value. Their conceptual schema alters based on different requirements and innovation, in which designers may constantly change their understanding to the subject. Users passively accept the information that is relevant to design product, and extract their available knowledge or experiences to shape up the understanding to the product. There's non-equivalence existed at knowledge wise between designers and users, which can be testified by the differences in image selections in the research, as well as the overl.

5.3 The correlation analysis between semantic understanding and imagery

Very often the design project starts by requirements expressed by words or concept, followed by the process of analysis and synthesis, in which the designers will convert the semantics to visualized elements for composition, and eventually express in forms of visualization. When this study was disassembling the design concept semantically, as opposed to users, what designers express was more concrete and clear, which paid more attentions to visualized elements, materials, etc. For instance, the style with white lines, metallic glossy material, etc. What designers selected also matches the characteristics from the semantic disassembly. We often say that designers think visually, by which we mean that representations that serve designers to think with are not only verbal but largely consist of shapes and forms (Goldschmidt, 2006). As compared with designers, the semantic disassembly by users was simpler and broader. There was not much reference to extract in the conversion from semantics to imagery. For users, if the knowledge to object is limited, the perception and evaluation to products might be fuzzy. From the lens of conceptual schema to analyze the accumulation of the product-relevant knowledge, there's huge difference existed in breadth and depth of the knowledge base between designers and users.

6 CONCLUSION

The cognitive difference between designers and users is relevant to their ways of thinking, knowledge base and experiences. Through the analysis and research, we found out the difference also laid in the structure and formation of the knowledge. The designers, who have been educated with professionalism, forms unique way of thinking during the design process. What they interprets the artificial objects is a way of disassembling. To the same conceptual semantics, designers tend to interpret from perspectives of forms, materials, etc. They have obvious tendency in collecting and selecting the elements that shape up the artificial objects, which pay more attention to the product itself. But how users perceive the artificial objects is aiming at classification and synthesis, without overly pay attention to the details of a certain concept. Aside from the above, we can see a lot of conceptual design ideas, new tech, new materials, and non-realistic solutions in the selection by designers, which is relevant to their future-oriented thinking during the process of learning design. This study didn't extend the correlation analysis on semantic disassembly of conceptual words, which could be going deeper in the further research, to flesh out the whole result.

ACKNOWLEDGEMENTS

This study couldn't been completed without the support of the Behavioral Cognition Studio of the College of Innovation & Design, Tongji University, and is based upon the project of design keywords

https://doi.org/10.1017/pds.2023.352 Published online by Cambridge University Press

study partnered with ChangAn Automobile Modeling Design Institute. I’m grateful to the materials and testing samples that are provided by ChangAn Automobile Modeling Design Institute, as well as the inspirations out of the discussions with the designers in it. I’m thankful to folks at Behavioral Cognition Studio who generously supported the data synthesis and analysis, namely Bibo Deng, Yecheng Wang, Ma Zhang. Last but not least, shout out to Professor Wenqing Yang of Leo Design who helped me a lot on conducting the experiment and the precious suggestions to this study.

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