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New Design Heuristics Compared with Existing Ones

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Abstract: Design Heuristics (DHS) as a tool helps boost designers' creativity in the early design phases. Since the middle of the 20th Century, different DHS have been developed, e.g. general ones such as SCAMPER and 77 DHS; and specific ones such as DHSfX (design for one-handed use) and DHS for additive manufacturing. With rapid technological developments, an increasing number of products now incorporate technological platforms and services. There is a lack of new DHS relating to such service-based information products. Based on RedDot Concept Design Award entries (2013-2017), we have extracted ten DHS that focus on service-based information products. We compared our newly derived DHS with existing design heuristics and discovered that although some of our DHS overlapped with existing ones, the new DHS10 were more specific and useful for digital solutions. The preliminary evaluation of the new DHS suggested its potential in helping generate concepts in the early design phase.

Keywords: design heuristics; methodological review; service-based information products

1. Introduction

Design Heuristics (DHS) are defined as a context-dependent directive, based on intuition, tacit knowledge or experiential understanding which provides design process direction to increase the chance of reaching a satisfactory, but not necessarily optimal, solution (Fu, Yang, & Wood, 2016). Different DHS have been developed for different purposes, such as DHS for additive manufacturing (Bloesch-Paidosh & Shea, 2019), DHS for assistive (one-handed) products (Hwang & Park, 2018), and DHS for technological innovations, e.g. TRIZ (Ilevbare, Probert, & Phaal, 2013).

DHS are evidenced to help generate ideas effectively in the conceptual design phase and play an important role in addressing issues with design fixation. However, existing DHS have some shortcomings: 1) The datasets utilised are not up to date (with the majority originating before 2009); 2) Most of DHS are structural design heuristics for industrial design, with little relevance to service-based information products; 3) Technical advances have triggered an

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opportunity for design innovation to generate a wealth of new products (Dove, Halskov, Forlizzi, & Zimmerman, 2017), but few DHS are generated for the digital era.

The nature of product design appears to be experiencing significant changes as evidenced by activities in design schools. A comparison of keywords appearing in final year design students' degree show books (based on two UK universities best known for their product design and industrial design student employability) has revealed the changes in the last ten years (Table 1).

Table 1 Keywords in Design Degree Show books compared, 2009 vs 2018

Words appearing 10 or more times in 2009		Words appearing 10 or more times in 2018	
Interactive	15	App	40
Experience	12	Environment	27
Portable	12	Personalization	16
Multifunctional	11	Experience/User experience	15
Encourage	11	Smart/Intelligent	15
Environment	10	Modular	14
		Customisable	13
		Interaction/ User interaction	11

With rapid technology changes, DHS have the potential to support designers and this study presents ten new DHS for the digital era. While developing the new DHS, we found there was a lack of comparative evaluation between existing DHS. Our hypothesis is that there are overlaps between different DHS. The objective of this study is to compare existing DHS and then compare them with our new DHS to identify whether there is added value offered by the new DHS.

2. Design Heuristics

'Design heuristics' are defined as cognitive 'shortcuts' that point toward useful design patterns (Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012; Seda Yilmaz, Daly, Seifert, & Gonzalez, 2016; Seda Yilmaz & Seifert, 2011; S. Yilmaz, Seifert, & Gonzalez, 2010).

2.1 Existing Design Heuristic for Ideation

SCAMPER is an acronym for (S) Substitute, (C) Combine, (A) Adapt, (M)Modify, (P) Put to other uses, (E) Eliminate, and (R) Reverse/Rearrange (Serrat, 2017) which provides a structured method of assisting students to think divergently and enhance their design knowledge (Michalko, 2010). SCAMPER was proposed by Alex Faickney Osborn in 1953 and was further developed by Bob Eberle in 1971 in his book SCAMPER: Games for Imagination Development (Eberle, 1971) .

TRIZ 40 Principles was developed by Altshuller in 1969 through reviewing 40,000 patent

abstracts. It provides 40 principles (design heuristics) for helping technological innovations with particular relevance in solving complicated technical problems (Gadd, 2011). TRIZ has been widely utilized to enhance creativity in addressing technical problems. However, there is a degree of confusion with TRIZ on how to approach it and what exactly it embodies, which makes it difficult to fully employ (Ilevbare et al., 2013). Often people need training before using TRIZ.

77 Design Heuristics (77 DHS) was developed by analysing 400 award-winning designs from which 40 DHS were identified (Seda Yilmaz, Seifert, Daly, & Gonzalez, 2016); 218 sequential concepts created by an expert industrial designer over two years for a single design project (a universal access bath within an existing home); and 179 followed by 68 concepts generated via two studies using Think-aloud protocols. The 77 Design Heuristics have proved to associate with effective innovation in both engineering and industrial design domains (Seda Yilmaz, Daly, Seifert, & Gonzalez, 2015). However, the datasets are mainly from 2001 to 2009 (not up-to-date), with most being structural design heuristics for the industrial design area.

Design Heuristics set for X (DHSfX) was developed by analysing a total of 139 products (100 manufactured and 39 patents) by Hwang & Park in 2018. DHSfX provides 13 Design Heuristics as a design aid for assistive product concept generation (Hwang & Park, 2018) focussing on assistive products for one-handed users. An empirical evaluation indicated that DHSfX could enhance the outcome of assistive product concept generation (Hwang & Park, 2018).

Design Heuristics for Additive Manufacturing (DHSfAM) was developed by analysing a total of 275 artefacts (datasets including academic/industry literature, popular media, and industry/hobby websites). DHSfAM provides 29 Design Heuristics for additive manufacturing which were found to positively influence the designs generated and were more effective in communicating DfAM concepts (Bloesch-Paidosh & Shea, 2019).

Table 2 summaries the comparison of the existing DHS.

Table 2 Comparison of the existing DHS.

Reference	DHS Name	Data Source	Purpose	Limitations
(Eberle, 1996)	SCAMPER (1953)	Not specified	A structured way of assisting students to think out of the box and enhance their knowledge.	Can be quite abstract

(Gadd, 2011)	TRIZ 40 Principles (1969)	40,000 patent abstracts	To help technological innovations especially in solving technical contradictions.	Great confusion on how to approach it and what exactly it embodies.
(Seda Yilmaz, Daly, et al., 2016)	77 Design Heuristics (2016)	Study 1: 400 award-winning products. Study 2: 218 sequential concepts created by an expert industrial designer over two years. Study 3: 179 concepts generated from 36 engineers. Study 4: 68 concepts generated from 12 industrial designers.	To help designers to generate more, and more varied, candidate concepts to consider in the early phases of design.	1) The datasets are mainly from 2001 to 2009, and most are structural design heuristics for the industrial design area. 2) service-based products are rarely included.
(Seda Yilmaz, Seifert, et al., 2016)	40 Design Heuristics (2016)	400 award-winning products.	The same as above (77 DHS).	The same as above (77 DHS).
(Hwang & Park, 2018)	DHSfX (13 design heuristics) (2018)	139 examples (100 existing products and 39 patents).	A design aid for assistive product concept generation.	It does not support other phases of the assistive product design process.
(Bloesch-Paidosh & Shea, 2019)	DHS for Additive Manufacturing (29 Design Heuristics) (2019)	275 artefacts (datasets including academic and industry literature, the popular media, and industry and hobby websites).	A design aid for Additive Manufacturing.	The heuristics are meant to represent what is possible at a conceptual level, not what is currently feasible or makes economic sense.

2.2 Research Gaps

Research gaps were identified through analysing existing DHS:

- New technology applications are rarely mentioned and the datasets are not up to date (i.e. lacking data from 2009 onwards), with the exception of DHS for additive manufacturing.
- Most of DHS are structural design heuristics for industrial design, and service-based information products are rarely included. Few studies consider DHS for the digital era.
- Many DHS are difficult to understand, remember and apply, due to extensiveness and abstract descriptions (Ilevbare et al., 2013).

New Design Heuristics are needed for the fast-developing digital era. It becomes necessary to add service-based products and new technology applications to the development of design heuristics. DHS descriptions should also be easy to understand so that designers can remember and utilise them effectively.

2.3 New Design Heuristics for Service-based Information Products (DHS10)

Our DHS, called DHS10, were extracted from 998 award-winning designs covering the period between 2013 and 2017 and aimed to plug the research gap. The data source is RedDot that has been identified as the most credible international design award (Self, 2014). Two researchers (both with masters' degrees in industrial design and winners of RedDot awards) undertook data extraction, following a 5-step process (Figure 1). Details about the extraction of the DHS10 can be found from (Jin & Dong, 2020).

Figure 1 The 5-Step process of extracting design heuristics.

To make the design heuristics easy to understand and easy to remember, we illustrated the new DHS10 not only in textual descriptions but also images. Card-based design tools have been widely utilized (Roy & Warren, 2019) and each design heuristics is presented on one card.

Figure 2 shows the ten cards (Jin & Dong, 2020).

Design Heuristics 10

Figure 2 DHS10 for service-based information products.

3. Methods

Four typical DHS were selected for comparison, i.e. SCAMPER, TRIZ, 77DHS and DHSfX. To compare the DHS, two design researchers undertook the role of analysts. One analyst had a bachelor's degree of English and was a postgraduate student in design. The other analyst was a professional designer with bachelor and master degrees in industrial design. The three-step analysis procedure is as follows (illustrated in Figure 3).

Step 1: Familiarising with the design heuristics including SCAMPER, TRIZ 40 Principles, 77DHS, DHSfX, and the DHS10 developed.

Step 2: Analysing the design heuristics independently. Because the 77 Design Heuristics are general and contain the large numbers of DHS, they were used as a datum (shown in capital letters in Table 3) and other DHS were compared with the 77DHS. If the two analysts identified similarity or overlap between different sets of DHS, they made notes independently.

Step 3: Discussing to reach consensus. Once the comparison was completed by each analyst, they compared the results with each other. When they had different opinions, they discussed to achieve agreement.

Figure 3 a, b: Independent review by two analysts; c: comparison; d: discussion

The comparison outcome was further verified by a design professor (Figure 4).

Figure 4 Further verification of the comparison outcome of the DHS.

4. Results

The verified outcome was then visualised (Figures 5-7).

4.1 Overlapping between the Four Sets of Existing DHS

Figure 5 indicates that there is a high overlap between the 77 DHS and TRIZ 40 principles. All the SCAMPER design heuristics are covered by the 77 DHS, and its DHS 'Adapt' and 'Put to other uses' correspond to many DHS in the 77 DHS (Figure 6). In the figures, '0' suggests no matching items.

Figure 5 The overlaps of the four selected DHS.

Figure 6 The overlaps between SCAMPER and 77 DHS.

Interestingly, although the DHSfX (Hwang & Park, 2018) is developed specifically for generating designs for one-handed use, it overlaps with the generic design heuristics 77 DHS apart from only one item, i.e. 'Integrate one-hand gesture control to the product'.

4.2 Comparison between our DHS10 and the Existing DHS

Figure 7 shows the overlap between our DHS10 and the 77 DHS, TRIZ and SCAMPER (DHSfX was excluded as it is specific for one-handed use design, and overlapped a lot with 77 DHS). As show in Figure 7, our DHS10 overlapped one of the TRIZ 40 Principles (i.e. 13. Inversion), two of the 77 DHS (i.e. 11 ALLOW USER TO REORIENT, and 36 FOLD), and five out of the seven 7 SCAMPER DHS (i.e. 'Put to Another Use', 'Adapt', 'Modify', 'Substitute', and 'Combine').

Figure 7 Comparison between DHS10 and 77 DHS, TRIZ and SCAMPER.

Although it appears that there is a high overlap between our DHS10 and SCAMPER, our DHS10 is much more detailed, and specific to the digital design context.

5. Preliminary Evaluation

To assess the usefulness of the DHS10 in helping generate concepts for digital design, we conducted a preliminary evaluation. We asked a volunteer studying for a master's design degree to answer the following brief (Figure 8, adopted from IF 2019): firstly using his existing knowledge and any conceptual design tools he knew; and then using the DHS10. The whole session took 60 minutes in total.

3. SAMSUNG DESIGN PRIZE 2019 by iF: Design for Collaboration – new concept of collaboration tools and solutions for the augmented workplace

We live in a world where the digital and real life overlap – especially in the workplace. A good communication is needed more than ever to maintain effortless communication and effective collaboration.

Your task: Design a practical smart solution or concept that helps people to communicate and collaborate easily in the daily business – be that digital or physical.

Figure 8 The design brief.

The volunteer was able to develop several concepts within 60 minutes (see sketches in Figure 9) and his feedback was as follows,

In the beginning, I saw this design task and I thought it is very hard for me. I use brainstorming to think this design task. Unfortunately, I still can't think of any good ideas. But when I saw these design heuristics, in 10 mins I understood them. Then, I could quickly come out ideas for tackling this design problem.

Figure 9 The concept sketches by the volunteer.

The analysis of his design text description suggests that seven out of the 10 DHS10 were effectively applied, as follows (the DHS utilised were numbered in brackets starting with #).

The W-Drone is an integrated Drone meeting system (#1 Adding Drone technology), which addresses the teleconference's low efficiency, especially in architecture and industrial design area. The W-Drone can control the Drone remotely and intelligently (#8 Allowing the user to manage and control remotely, #7 Adding smart functions), so as to help stakeholders to watch

the whole design and detail design work through different angles and heights. The W-Drone also owns a sound and light system (#4 Utilizing lights and Sounds), which can allow users to send themselves voice to the opposite side. The W-Drone has a foldable structure (#5 Utilizing foldable structure) so that it can be stored in a small space. W-Drone also provides Sharing Function (#6 Adding Sharing Service). Every company's staff can use the W-Drone if it is available. Besides, W-Drone provides projection display technology (#3 Utilizing the display technology), which can display images opposite. For example, stakeholders draw sketches and give reference images to designers. Most importantly, these functions will enhance the experience in collaboration and communication. W-Drone will save costs and time significantly.

This preliminary evaluation suggests DHS10 is effective in supporting conceptual design of service-based information product in the early design stage.

6. Discussion, Conclusions and Future work

In this study, we reviewed existing design heuristics and compared them with our new DHS10, and found some of DHS10 overlapped with existing design heuristics, but our DHS were more specific and relevant to the emerging technological context (i.e. digital design, service-based information product). The preliminary evaluation suggests great potential of DHS10 in helping generate concepts in the early design phase.

The comparison and visualisation of existing DHS is the first study of this kind. In addition, the DHS10 is originally developed by us, and it is the first time that the three 'traditional' DHS (i.e. TRIZ, 77 DHS and SCAMPER) were compared with the DHS10 which was derived from 'digital design' examples.

By analysing the existing DHS, we gain a better understanding of how DHS work and their purpose and limitations. For example, SCAMPER uses the acronyms of the seven design heuristics as its name, which helps the users to remember and recall them easily. TRIZ 40 principles tend to be highly abstract, so detailed description, examples and applications (with images) are often required to help users to grasp the principles. The 77 DHS are comprehensive, but too difficult to remember all. Many design heuristics can be grouped in the same category at a higher level. Although the DHSfX is developed specifically for assistive design, it shares a lot of principles with generic design heuristics (e.g. 77 DHS).

DHSfAM deals with new technology (i.e. additive manufacturing), similar to our DHS10. It is interesting to know that DHSfAM has proved to be very useful in communicating Design for Additive Manufacturing concepts (Bloesch-Paidosh & Shea, 2019). This inspires us to consider whether DHS10 will be effective in communicating digital design and service-based information product design concepts, as an objective for our future evaluation of DHS10. For future work, we are planning an evaluation study which will involve 60+ design students (divided into the control and experimental groups), to test how effective the DHS10 is in helping generate digital design concepts compared with other methods (e.g. Brainstorming). The preliminary evaluation suggests concept sketches and text descriptions can be effective, and these will be incorporated into the future evaluation study.

We also plan to optimise the presentation of the DHS10. The existing DHS take different forms, some are short textual phrases (e.g. TRIZ); some are a combination of texts and images (e.g. 77 DHS), and some are short text followed by a number of probing questions for inspiration (e.g. SCAMPER). Short, abstract text may inspire imagination but sometimes can be difficult to understand; examples and images are effective in explaining the heuristics but might restrain imagination. An optimal form of representing DHS10 will be explored in our future study.

In summary, this study has compared existing DHS sets and the new design heuristics (DHS10). The DHS10 has been extracted from more recent data which address emerging service-based information products in the digital era. We are using the insights gained from the comparison to refine DHS10. The significance of the research is two folds: the visualised comparison of existing DHS has revealed ‘unseen’ overlaps and gaps, which may give direction of the future development of DHS; and the DHS10’s relevance to the contemporary design context, which will make it a useful tool to design students and design professionals.

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