

WHAT MOTIVATES AND DISCOURAGES DESIGNERS TO USE DIGITAL SKETCHING? COMPARING ITS USE TO EXTERNALISE IDEAS VERSUS COMMUNICATING WITH EXTERNAL STAKEHOLDERS

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ABSTRACT

Digital design tools have dominated engineering and design practice offering many advantages that ultimately improve efficiency in the design process. Digital sketching is one such example of these tools yet, its current use is primarily to present work to stakeholders (External Communication). It is relatively underused to externalise ideas (Externalisation) where sketching on paper is still favoured. This paper aims to understand the characteristics of digital sketching that motivate or discourage designers to use the tool. Semi-structured interviews were undertaken with 12 designers to gain insights on the tool's use in External Communication and Externalisation. Results highlight a trade-off between fidelity of visualisations and time and effort expended to achieve visualisations. The key difference between the use scenarios is the way in which this trade-off is connected to managing stakeholder involvement. While designers acknowledge advantages that digital sketching can offer in externalisation, it is viewed as requiring a level of detail to begin use. In conclusion we suggest segmenting roles of digital sketching in terms of the characteristics identified in this study would help to motivate use in Externalisation.

Keywords: Sketching, Computer Aided Design (CAD), Visualisation, Communication, Characteristics

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1 INTRODUCTION

Since the birth of widespread computing (and subsequent demise of drawing boards) digital design tools have dominated engineering and design practice. They facilitate a wide range of advantages that ultimately improve efficiency in the design process. Advantages include (but are not limited to); increased accuracy, the ability to create hyper realistic visualisation of concepts, opportunities for virtual analysis and simulation, and improved version control (Aldoy and Evans 2011).

At the same time the format or media of design tools is known to influence resulting designs and designer's practice in terms of idea development (Chu et al. 2017), ideation and idea fluency (Ranscombe et al. 2020) design fixation (Robertson and Radcliffe 2009; Viswanathan et al. 2014) and stakeholder judgements and decision making (Reid et al. 2013). Furthermore, researchers have for some time flagged the rate at which digital design tools advance is reaching a point where their associated practices and methodologies are outpacing our understanding of best practices with traditional design tools (Lee and Yan 2016). The research presented in this paper forms a kind of user research, expanding our understanding of how designers use digital design tools (in this case digital sketching) and to inform future practices and development of digital design tools.

Digital sketching is of interest for a number of reasons. Firstly, there is a relative lack of literature researching its use compared with literature on topics of traditional pen/paper sketching, CAD and prototyping. Secondly examples of its use in industry and key literature on design visualisation suggest that it tends to be used in a relatively limited capacity for presenting work to stakeholders (Eissen and Steur 2008; Pei et al. 2011; Camba et al. 2018). Yet, Design research literature has and continues to cite sketch-based visualisation as integral in designerly thinking (Cross 1982; Goldschmidt 1991; Schon and Wiggins 1992) and has advantages over computer modelling (CAD) (Lee and Yan 2016). So, given the advantages that digital tools offer, and now widespread availability of tablet computing combined with recognition of the importance of sketching, it is surprising that digital sketching does not see more widespread application in engineering and industrial design. As set out in (Camba et al. 2018) there is growing desire to understand this relative underuse of digital sketching and better capitalise on the advantages that it theoretically offers.

The paper proceeds as follows. First background (Section 2) to this research is given starting with a definition of digital sketching and contextualising its use in the design process and elaborating on the goals of the study and presenting the precise aim of the study. Next methods are described in Section 3, with findings presented in Section 4. These are discussed in Section 5 with respect to characteristics that motivate designers to use digital sketching in different scenarios and the implication of findings for further use of digital sketching. Finally, conclusions drawn in Section 6 along with an outline of expected further research on the topic.

2 BACKGROUND

2.1 Defining Digital Sketching

For the purposes of this study digital sketching is defined as a form of sketching where sketches are realised using 2D design software. Typically, this uses a stylus input however we do not exclude the use of a computer mouse input in the definition. The major distinction to other digital design and visualisation tools is that visualisation is created in digital 2D space rather than digital 3D space such as solid or surface modelling software. As such the input is sketch-like, i.e. visualisation is created by drawing lines/marks not creation of 3D objects. While the means to create visualisation (sketching) is similar to traditional sketching on paper, its application with digital design software offers a wide range of capabilities. For example, the ability to edit, undo, resize and duplicate sketches at any stage, sketch at scale and using layers to separate different components of sketches. The digital platform also affords easy sharing of work across distributed teams, live annotation and mark-up, version control and somewhat easier migration of sketches into 3D modelling software.

Although we view digital sketching as a relatively new design tool, it has existed in various forms since the first invention of the graphics tablet in the 60's. The rationale for referring to it as new/emergent stems from the relatively recent widespread availability of hardware (suitably sensitive touchscreens) and software to support its use over the last 10-12 years that make it a truly viable

alternative to sketching on paper (Camba et al. 2018). In addition to widespread availability, digital sketching is also of interest from a research perspective in light of the recent invention of digital sketching in immersive VR/AR/XR environments. While this more recent iteration of digital sketching is newer, it is yet to see widespread use in industry. As such this paper focuses only on digital sketching however the research method is devised in a way that findings could be relevant to these new/emerging forms of digital sketch.

2.2 Understanding current uses of digital Sketching: External Communication versus Externalisation

Referring to the taxonomic classification of visual design representations by Pei et al. (2011) used by industrial designers and engineering designers, we see the use of digital sketching in visualisations defined as; “Sketch Rendering – Clearly defined proposal produced by controlled sketching and use of colour/tonne to enhance detail and realism”, “Layout Rendering – Defines product proposal as a third angle orthographic projection with precise line and colour”. These applications are both classed in the development phase of the design process primarily focusing on overall form of the design. Typically, they occur after a range of more rough sketches (Idea, Study, Referential and Memory sketches) created with pen and paper, that occur in the concept stage (prior to development), and before the start of digital 3D modelling and physical modelling of prototypes. As such these representations are used to visualise a more refined design to others involved in the project. For the remainder of this paper, we define this use of digital sketching for the purpose presentation as ‘External Communication’.

The activity of sketching has long been cited as a key ingredient in engineering and design practices and designerly thinking ever since they have been researched in academic literature (Alexander 1964) cited in (Cross 1982), (Goldschmidt 1991; Schon and Wiggins 1992). Specifically, sketching is cited as key to designer’s being able to externalise thoughts and emergent designs, to reflect and communicate their merit before further developing the design. For the purpose of this paper, we define this wider application of sketching as “Externalisation”. Compared to Externalisation scenarios, the External Communication scenario of use is relatively limited. Identifying that sketching on a digital platform offers all kinds of advantages (as stated above), it is curious that digital sketching seems only to be primarily in the External Communication scenario and not in in the Externalisation scenario. It is this pattern of use that leads to the specific aim of the paper, to understand what characteristics of digital sketching motivate or discourage designers to use the tool. Understanding how these characteristics dictate its use could thus help practitioners to better capitalise on the advantages that sketching on a digital platform offers if its use could be expanded beyond External Communication. More broadly, understanding these characteristics also has implications for the development of new and emerging digital design tools too.

3 METHOD

A semi-structured interview method is adopted to understand designers' motivation to use digital sketching. Participants were recruited from engineering and design consultancies in Melbourne Australia. Consultancies were targeted as employees within were more likely to have worked on a diverse range of products and been exposed to a broader range of the design process and visualisation tools (traditional sketching, digital sketching and CAD). A total of 12 industrial designers from 3 firms and one freelance industrial designer were interviewed. Of the 12 participants, 8 are designers, 2 described their role as project leader and 1 described their role as manager. 8 respondents had more than 5 years' experience while 4 had less than 5 years' experience. In terms of the tools used, 10 of the 12 have experience with digital sketching while all have experience with traditional sketching and CAD.

3.1 Interview structure

Open ended questions were posed to each designer over the course of a 60-80 minute interview. Preliminary questions posed capture basic information about the participants' current role within the industrial design firm, years of experience in the industry and whether they currently use or have used digital sketching within their practice. Then a series of open-ended questions are posed designed to reveal references to different characteristics of digital sketching. The 22 questions and prompts posed are summarised for brevity in the following categories. The first category covers the tools typically

used within their design process, when, and for how long. The next category goes into further detail of how tools are applied covering use of tools to ideate a breadth of ideas, iterate or add detail, and switch between design tasks within a project. A series of follow up prompts were used encourage participants to rationalise their responses in terms of skill, time, and phase in the design process. The final category of questions is more closely related to generalised characteristics of design tools. These are posed to encourage designers to explain their preferences and motivations outlined in the earlier questions in terms of design tool characteristics. These are explained further in the following Section describing the coding scheme used to analyse interviews.

3.2 Interview coding scheme

Interview transcriptions are coded in terms design tool characteristics (DTCs) drawn from Zhang et al. (2019). This framework is selected as to date it represents an exhaustive and generalisable list of design tool characteristics. Exhaustiveness is important to ensure a wide breadth of characteristics can be captured. Generalisability of terms provides a means to describe digital sketching and patterns of use without using inherent qualities of digital sketching. Its generalisability is also important to ensure that findings from this study where digital sketching is the focus can be interpreted in the future with respect to other emerging digital tools. For brevity, the reader is directed to Zhang et al. (2019) for complete definitions of the characteristics. An abbreviated list of key characteristics and their definitions described in the results is included as an appendix.

The application of the DTC framework to code responses is now described and illustrated in Figure 1. The coding process begins by analysing statements for the scenarios in which designers are using digital sketching (step 1: Use Case). As stated in the Section 2.2, the present use of digital sketching tends to be for presenting work to stakeholders or clients (defined as External Communication scenarios) and a reason for this study is exploring the utility of digital sketching in broader Externalisation scenarios. Hence, statements are coded as to whether they are referring to External Communication or Externalisation use scenarios. Next statements are coded to interpret statements in terms of DTCs (step 2: Tool Characteristics). This involves identifying statements where participants describe their use of digital sketching or rationalise certain patterns of use, then categorising statements by the tool characteristics cited as defined in the DTCs framework. Coded responses are analysed by counting the number of designers that mention DTCs in each use condition. This value highlights for each use condition (Externalisation or External Communication), which DTCs are considered most. The third step (step 3: Sentiment) analyses whether identified DTCs are mentioned with a positive or negative sentiment. The goal of this step is to provide explanation as to whether the mentioned characteristic is a motivation (positive sentiment) or demotivation (negative sentiment) to use digital sketching. The final step in coding is analysing statements to identify any associations between DTCs that are coded (step 4: Associations). These are defined as instances where two or more DTCs are mentioned within the same statement. This analysis of associations is designed to give further explanation of motivations by looking at how one characteristic may support others or embody a trade-off or compromise.

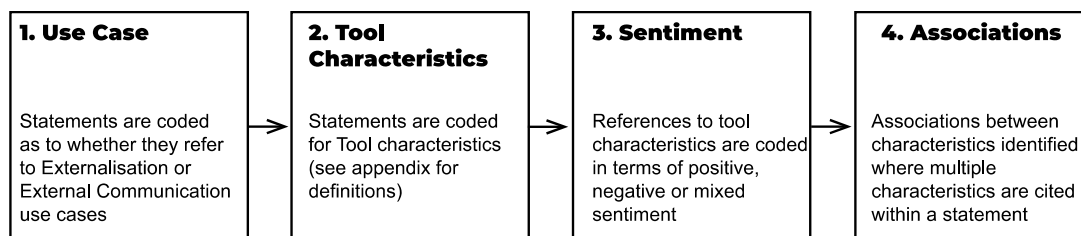


Figure 1. Approach to coding interviews

4 RESULTS

First an overview of characteristics cited by participants in both Externalisation and External Communication use cases is presented in Figure 2 (data arising from steps 1 and 2 of the coding process illustrated in Figure 1). This highlights how certain characteristics (Level of Aesthetics, Flexibility, Accessibility, Ambiguity and Level of Commitment) are referred to differently when describing Externalisation versus External Communication activities. These differences are likely at

the root of the different patterns of use and hence further analysed in subsequent Sections 4.1- 4.4 for associations and sentiments (steps 3 and 4 of the coding process illustrated in Figure 1).

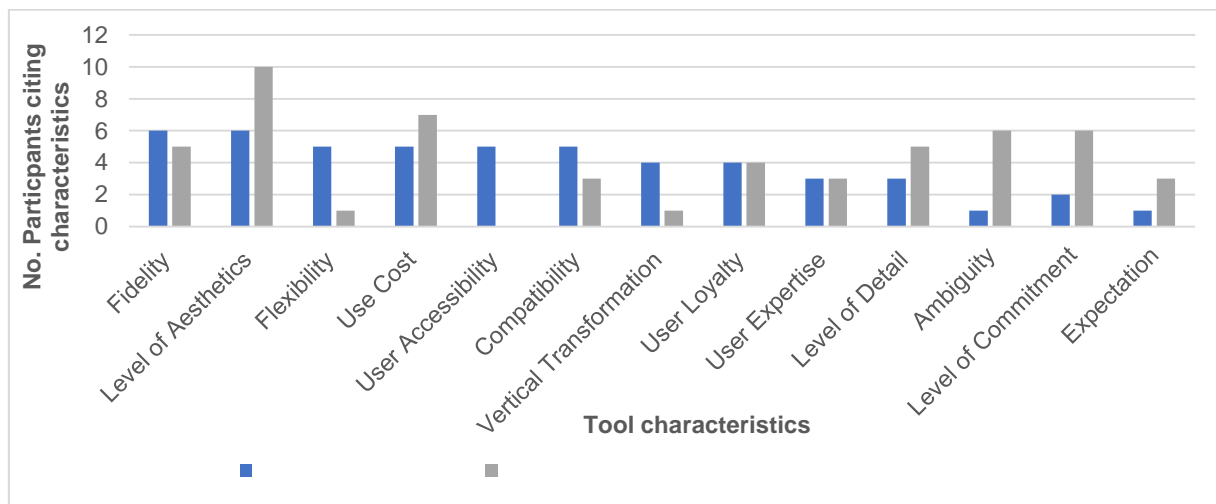


Figure 2. Comparing the number of participants referencing design tool characteristics in the Externalisation versus External Communication use cases.

4.1 Design Tool Characteristics cited with respect to Externalisation

Figure 3 elaborates on the data presented in Figure 2 illustrating the sentiments that accompany the characteristics cited by participants. DTCs: Level of Aesthetic, Flexibility and Vertical Transformation are mentioned in an entirely positive way. Loyalty and Accessibility are predominantly negative when mentioned, and Fidelity, Use Cost and Compatibility are mentioned with mixed sentiments.

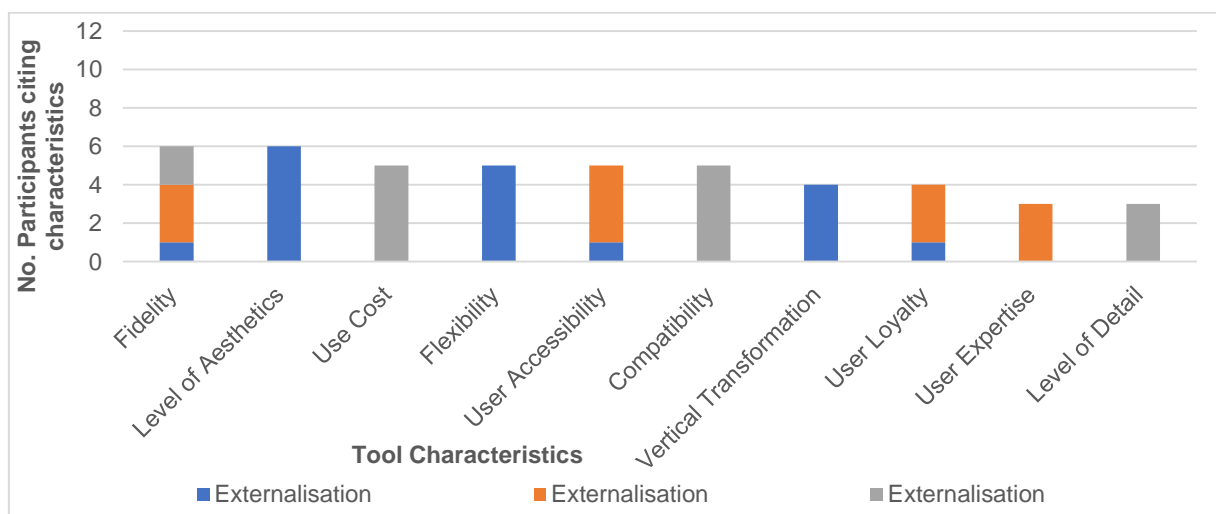


Figure 3. Number of participants referencing DTCs and their sentiments in the Externalisation use case

4.2 Associations between design tool characteristics with respect to Externalisation

Analysing statements for associations between the DTCs reveal three clusters of DTCs that are related when describing motivations for tool use. The first cluster of characteristics comprise of Fidelity, Use Cost and Level of Aesthetics. As can be seen in Figure 3, Use Cost is mentioned with mixed sentiment as judgements on whether Use Cost is suitable is contingent on Fidelity. For example, “I generally will still start by hand and then once I've got a more fleshed out idea is when I move into digital (sketching). I think for quicker generation of ideas, I go with paper” (P12).

Level of aesthetics is cited as a positive characteristic of digital sketching. However, accompanying the positive view of the aesthetic qualities, respondents also cite Fidelity with negative or mixed

sentiments. For example, designers suggest the design concept should “already be done on paper” (P3) or be a “relatively well-developed concept” (P10) “have a more fleshed out idea” (P12).

The second group of associations describes how Flexibility of using the tool is interconnected positively with adding detail and Vertical Transformation in terms of the design activity. Here Flexibility (viewed positively) is connected to Use Cost and Vertical Transformation. This suggests the tool’s Flexibility affords efficient Vertical Transformation when designing. For example, “we take screenshots and then put them on the Wacom and just sketch different variations of the finer detailing the battery cover over the top” (P11), and “With digital sketches, I probably start with one base like have my hand sketched outlines and produce variations based on that, so keeping the form the same but playing around with colours or certain line work.” (P9).

The Final cluster centres around the practical logistics of using digital sketching. Specifically, the associations between accessibility of the tool and how that is associated with its use. Accessibility is cited with negative sentiment explaining how little or no access is connected to the users’ expertise which in turn is related to the loyalty towards the tool. For example, P1 stated: “In most of my roles, I haven’t had one [Digital Sketching tablet] available to me and you really have to want to use it a lot to commit to buying one.”

4.3 Design Tool Characteristics cited with respect to External Communication

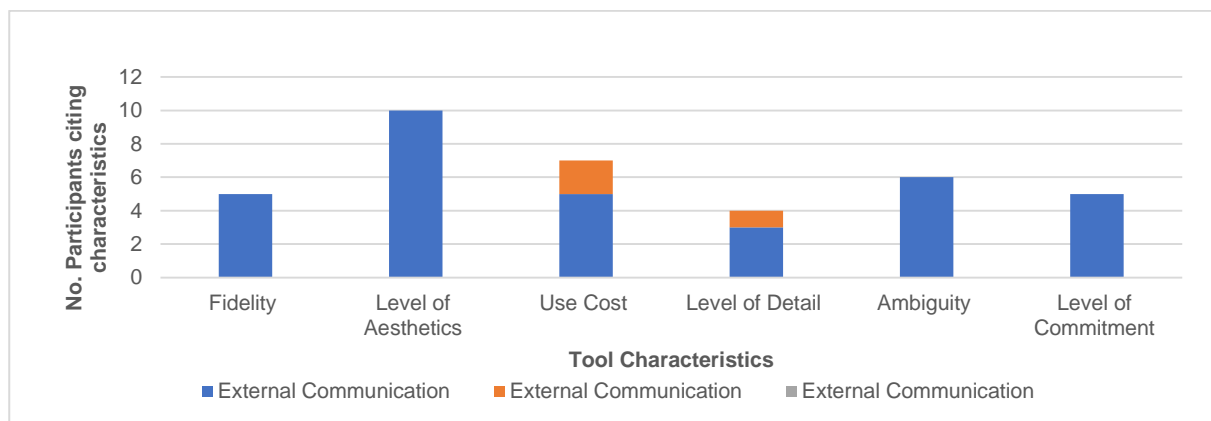


Figure 4. Number of participants referencing DTCs and their sentiments in the External Communication use case

Figure 4 elaborates on the data presented in Figure 2 illustrating the sentiments that accompany the characteristics cited by participants. Unlike Externalisation, in External Communication, there is a more positive sentiment towards characteristics compared with the mixed and negative sentiments in Externalisation.

4.4 Associations between DTCs with respect to External Communication

As in the previous Section, the associations between DTCs are given to reveal clusters of DTCs that are connected when describing motivations/tool use. The first cluster is Level of Aesthetic, Level of Detail, and Use Cost. This illustrates the characteristics that explain present use (as described in 2.2). Namely the quality of resulting visualisations and level of detail that can be achieved in a time efficient manner (Use Cost).

The second cluster of characteristics centres on Fidelity, Commitment, Ambiguity. This cluster gives some insight on the first cluster in this use scenario. Specifically, it gives a glimpse of the purpose behind the above-mentioned cluster as managing clients or external stakeholders in the design process. The designers get value from a tool that can balance Fidelity and Ambiguity so as to get optimal feedback from the stakeholders as explained by participant P11: “To make it clear to [the client] what it is that you are talking about, we usually try to keep it consciously more sketch focused rather than CAD and rendering at that point, partially because it's faster to do it that way than working it out in CAD, and partially because it looks more conceptual to the client so they know it's not finished product yet.”

5 DISCUSSION

Results of the study are now discussed. First the DTCs that motivate or discourage designers to use digital sketching are compared between the two use cases discussed. This is followed by a discussion of key implications of these findings on the use of digital sketching.

Within the use of digital sketching there is fundamental motivation related to the trade-off between creating representation that closely match the designer's mental model (Fidelity) versus the time and effort expended to achieve the visualisation (Use Cost). In other words, this is the desire for representation aligned to the designer's mental model but acknowledging this can come at a cost if greater effort is required to produce the representations at high fidelity. This alone is not surprising but is important to point out as a common underlying consideration in motivating or discouraging designers in both use cases. In Externalisation this trade-off is viewed less positively than in External Communication (see proportion of positive sentiments towards Use Cost and Fidelity in Figure 4 versus those in Figure 3). The difference in view of this underlying compromise is explained by the other DTCs that motivate the use of digital sketching. Figure 5 gives an illustration of the key differences in the way DTCs are viewed in each case to motivate or discourage the use of digital sketching.

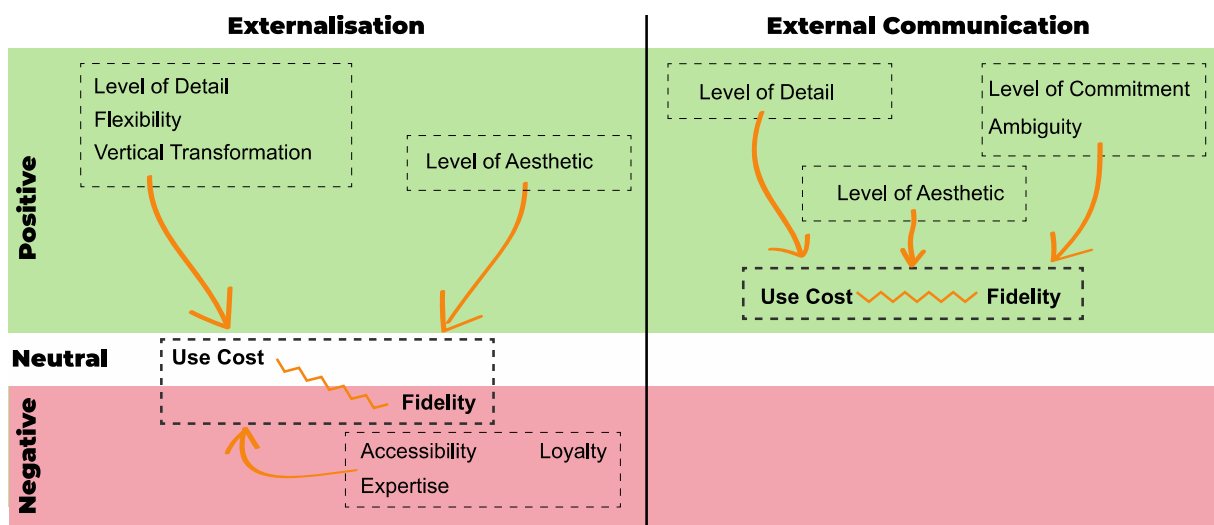


Figure 5. Illustrating the different motivations in terms of DTCs that motivate use digital sketching in Externalisation and External Communication use scenarios

In Externalisation there are DTCs that are viewed more positively that suggest a motivation to use digital sketching. They relate to the tool's affordances for adding detail and developing a given idea in a flexible and hence efficient manner (See Level of Detail, Flexibility and Vertical transformation in the top left quadrant in Figure 5). These are aligned to the characteristic Level of Detail that motivate use in External communication (see top right quadrant in Figure 5). Likewise, we also observe similarity in the positive view of Level of Aesthetics in both use cases.

The major difference in the way these motivate and discourage the use of digital sketching stems from Level of Detail and Level of Aesthetics connecting to the Use Cost Fidelity trade off. In the case of Externalisation, responses indicate a threshold of detail needed for the positive characteristics around detail and Flexibility to be time effective (see quotes by participants P3, P10 and P12 4.2). In other words, these DTCs only motivate designers to use digital sketching once the design reaches a level of detail or development. Once met, the time and effort required for digital sketching is worthwhile. Alternately this can be viewed as the perceived level of time and effort involved in using digital sketching not being worthwhile when ideas are very ambiguous. Similarly, although in Externalisation Level of Aesthetic is viewed positively, it is connected to a substantial Use Cost (viewed with mixed sentiments). In other words, designers view the Level of Aesthetic as being positive. However, the expectation of a high Level of Aesthetic comes with an expectation of time and effort to produce it, which discourages designers.

Looking to the other characteristics that discourage the use of digital sketching in Externalisation, we can see the cluster of negative characteristics around practical logistics of using digital sketching. Namely

that a lack of access and expertise relate closely to a preference for other tools (low User Loyalty). This in turn feeds into the threshold level of detail or development where Use Cost becomes worthwhile. Simply put, without good access to digital sketching facilities and a level of expertise, the time and effort to use digital sketching becomes even greater and hence less likely to be viewed as worthwhile.

In External Communication the positive view of Use Cost Fidelity trade-off is also connected to DTCs concerning adding detail or development of a given idea and Level of Aesthetic. However, in this scenario DTCs with negative sentiments towards practical logistics are barely mentioned. Instead, there is a cluster of DTCs cited with positive sentiments related to stakeholder engagement with designs. These reflect a motivation being to provide stakeholders with a balance of ambiguity and detail which helps manage commitment towards designs when seeking feedback or decision making. This can equally be explained as wanting to show stakeholders a level of progress in the project while not giving a false representation of completeness.

The differences in motivation have some key implications when considering expanding the use of digital sketching in Externalisation, and potentially other emerging digital tools. The first is noting that designers consider the way that stakeholders will engage with their visualisations and the subsequent impact they have on the design process. Returning to the motivations for this study (the relative underuse of digital sketching despite potential advantages) it is clear there are opportunities to better capitalise on digital sketching. Results in the Externalisation scenario indicate that there are gains to be made when using digital sketching to add detail or further iterate within a concept (as described by positive views of Level of Detail and Vertical Transformation). Presently these positives are curbed by logistical issues around access to digital sketching facilities, but also designers' views of the Use Cost Fidelity trade-off and expectations around levels of detail and aesthetic. As stated in the introduction accessibility of digital sketching is already changing greatly. The availability of cheap yet sensitive tablets will no doubt go a long way in removing this barrier in the near future. The more pertinent barrier to greater adoption of digital sketching is associated with expectations of level of detail and aesthetics. Here the implication is if designers have a different view of detail and aesthetics to be produced, then the barrier can be overcome, and advantageous aspects of the tool come to the fore. Changing these expectations would likely occur by further highlighting potential gains with respect to Use Cost. Use Cost is already viewed with mixed sentiments (i.e., there are some positive attitudes within). Hence in addition to lowering expectations around aesthetic, highlighting the goals of Externalisation and how these align with the positively viewed DTCs could further persuade a change in the way the tool is used and thus greater adoption.

Considerations of stakeholder (being the major difference between scenarios) are central in motivating designers to use digital sketching for external communication. This aligns with a body of literature that indicates stakeholder judgements and preferences are influenced by presentation style (Macomber and Yang 2011; Reid et al. 2013). The implication that arises is that this motivation is something to be considered alongside established theories on the use of sketching for Externalisation. The research community in digital design tools might look to work published in the domain of prototyping and frameworks describing their possible uses (Menold et al. 2017; Lauff et al. 2019). There, prototyping approach is defined not just in terms of the designer's development of ideas but also those who will engage with the prototype/idea. A similar framework for digital design tools might persuade designers to view digital sketching differently by using tool characteristics to explain opportunities for more efficient uses of tools. Likewise, this type of framework could also be persuasive in encouraging designers to lower expectations of aesthetic when using the tool in Externalisation. Hence further research into the adoption of digital sketching would likely be the creation of such a framework or canvas, and its implementation assessed in terms of impacting the adoption and use of digital sketching and possibly other emerging digital tools too.

6 CONCLUSION

This paper set out to investigate the different characteristics of digital sketching that motivate or discourage designers to use the tool. Presently the tool is used primarily in scenario of creating visualisations to present to external stakeholders (External Communication). Yet, it is relatively underused in favour of traditional pen paper sketching to more broadly externalise ideas throughout the design process (Externalisation) despite the advantages that adopting a digital version of sketching

offers. Hence one of the goals of the research is to understand opportunities to better capitalise on the tool beyond the External Communication use scenario. Semi-structured interviews were undertaken with 12 industrial designers from 3 firms to gain insights on the tool's use in External Communication and Externalisation. Insights were collected in the form of key characteristics of digital sketching which motivate or discourage its use which are compared between the two scenarios

Results show the trade-off between the tool characteristics of Fidelity of visualisations (Fidelity) and time and effort expended to achieve visualisations (Use Cost) underlies motivations in both External Communication and Externalisation. The key difference between the use scenarios is the way in which this trade-off is connected to stakeholder involvement. In External Communication, considerations of how the tool facilitates a balance of detail and ambiguity are beneficial in seeking stakeholder feedback mean the trade-off is viewed positively, and the use of digital sketching is worthwhile. In Externalisation, participants perceive a threshold of design detail/development before which they find the tool inefficient. This is despite designers identifying positive characteristics of the tool for creating level of detail and aesthetic qualities.

In conclusion we have highlighted how considering the purpose and stakeholders interacting with visualisations is the major point of difference between use scenarios. With respect to this paper's goal to understand and identify opportunities to better capitalise on digital sketching, we contend that better segmenting roles of digital sketching in terms of the characteristics identified in this study would help to educate designers of benefits of its use in the Externalisation case.

Further research on this topic is thus to develop such a segmentation, most likely following examples from research in the field of prototyping. This would be aligned with conducting case studies that would help to validate the segmentation but also provide examples of using digital sketching for externalisation and thus persuade designers to extend their use of digital sketching. We acknowledge some limitations in the study presented. Namely that the sample size is limited and more respondents from different design firms would further validate our findings. Likewise, a richer understanding of the way designers use digital sketching could be achieved through alternative research methods such as observations and lab-based studies to trial new approaches to using digital sketching would also embody further work.

APPENDIX

Abbreviated definitions of design tool characteristics referenced in results and discussion

Fidelity: Accuracy of communicating the inner Ideas or the resemblance of an idea in one mind compared with the idea visualised.

Level of Aesthetics: The aesthetic appeal of representations that created with the design tools. Could be related to the style/type/amount of the renderings.

Flexibility: The freedom of changing/developing ideas with design tools.

Use Cost: The time and effort invested and/or cognitive demand of creating a visualisation.

User Accessibility: The general accessibility of design tools.

Compatibility: The compatibility of visualisation media with other design tools or media. E.g. transitioning from 2D to 3D, or from digital visualisation to physical prototype/production.

Vertical Transformation: The development or variation of an idea. Lateral Transformation refers to ideation of a new idea.

User Loyalty: Attitudinal and behavioural tendency of designers to favour a design tool.

User Expertise: The experience/skills/knowledge that designers already have design tools.

Level of Detail: The extent of detail as well as the amount and display of information in visual representations.

Ambiguity: The extent of ambiguous and unambiguous representation of ideas

Level of Commitment: The extent designers or stakeholders are committed to pursuing a design.

Expectation: The Expectation of how resulting visualisation should be.

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