DETERMINATION OF CHARACTERISTICS AND ATTRIBUTES THAT ALLOW THE EFFICIENCY OF TECHNOLOGICAL TOOLS FOR THE CREATIVE STAGE OF DESIGN PROCESS

Alejandro ACUNA
Department of Industrial Design of Tecnologico de Monterrey, Queretaro, Mexico

ABSTRACT
The main objective of this research is to analyze the performance of design software to support the first stage of the product design process. To achieve this, a pilot study was developed to evaluate the efficiency of three design software commonly used in the creative phase of the design process, through an exercise of representation and conceptual exploration. Due to that this problem has been poorly studied, the study was exploratory, focusing on the ability to represent the first ideas in the selected software, leaving aside everything related to the mental activity of the designer. Based on the study, we can say that there are a number of features and attributes that allow certain technological tools to be efficient for representation and development of the first ideas in the creative stage of product design.

Keywords: Sketching, creative stage, design software.

1 INTRODUCTION

Nowadays there is a vast range of technological tools regarding processing software and devices that are created to make drawings quickly and easily [1]. But it should be noted that many of these technological developments may not be necessarily effective to support the creative stage of product design. This is due to the focus on the rapid three-dimensional representation, either through solids, surfaces or frames. This volumetric display is not the best way to represent the first ideas when it comes to designing a product. This is because the sketches, with its high degree of abstraction, allow the designer to reinterpret the shape and develop new ideas from previous sketches [2], [3]. We can say that there are software and devices that allow sketching, understood as a process [4] and others that allow the mere representation of ideas (centred in three-dimensional virtual drawing). That is, it is favoured in many occasions fast and easy three-dimensional representation of shapes, which limits the re-interpretation and mental re-processing.
The phenomenon of sketching has been studied from different perspectives and approaches [5], [6], [7], [8] but little evidence of research has been found on the role of design software in the first stage of the product design process [9]. Therefore, it is pertinent and relevant to conduct a pilot study to help us to identify and describe the properties of some software that allow quick representation of ideas, through figures and shapes with a high degree of ambiguity.

2 PILOT STUDY

2.1 Objective

To analyze the efficiency of processes and possibilities of representation of three of the most common design software, this through an exercise of representation and conceptual exploration. This study involved industrial three design students (novices) and three design professionals (experts), with reference to previous research [2], [10], [11].

2.2 Activity

The primary intention of the study was to lead three novice designers in performing freehand sketches of figures with high level of abstraction, plus to design proposals for a kettle. Secondly, novice

replicated the sketches made by hand, but now in the corresponding software. Finally, experts in a design software replicated the same sketches in the respective software, this with the intention of observing and comparing the processes of representation in computer interface. The sections of the pilot study are explained:

Section 1: The first part of the study consisted in performing sketches of basic volumes (sphere, cone, pyramid, cube and cylinder) with modifications of visualization (rotation in 3 dimensions) and transformation of the form (stretch, slice and compression). Auxiliary lines were used to better represent the volume.

Section 2: In the second stage of the study, the novice developed different design proposals of a kettle, which would consist only of four components: body, water outlet, lid and handle. The intent of this stage was to develop different proposals of a kettle, in side view, based on lateral transformations [3], considering the basic volumes of section 1 as the bodies. This limited the design possibilities, getting more homogeneous and equivalent formal solutions, which gave greater validity to the results of the pilot study.

Section 3: At the end of section 2 novice was requested to identify the proposals which in his/her opinion seemed the most innovative and/or attractive ones. This with the intention of taking them as a basis for the development of vertical transformations [3] in the section 3 of the study.

Section 4: At the final of section 3 novice chose the proposal that seemed the best, and then, drew it in 3 dimensions. The novice had the opportunity to sketch the object in perspective with support of auxiliary lines, shadows and texture effects.

Section 5: Novice replied all the sketches made by hand (sections 1-4), but now in the corresponding software: SketchBook Pro (Study A), SketchUp (Study B) and Illustrator (Study C).

Section 6: Experts replied all the sketches made by hand by the novice (sections 1-4) in the corresponding software. In addition to this, the expert of SketchBook Pro was requested to perform sections 1-4 of the study directly in the mentioned software, this previously to replicate the sketches made by the novice. That is, he was asked to perform the same sketches that novice in sections 1-4, but directly in mentioned software.

2.3 Variables

Independent variables: The independent variables include the software to compare (SketchBook Pro, SketchUp and Illustrator). The choice of computer programs for the development of this study was based on three aspects: popularity, accessibility and differentiation. The hardware selected was a laptop and input devices were chosen by the participants (a Wacom tablet for SketchBook Pro and mouse for SketchUp and Illustrator).

Dependent variable: A dependent variable was determined and called "efficiency", which considers runtime and quality. The runtime refers to the amount of seconds in the development of a sketch. Quality is defined as the fidelity of copying the personal sketches [12] on the selected software and on a scale of 1-2-3 (bad-regular-good respectively).

Extraneous variables: The extraneous variables correspond to the creative capacity, individual development of mental imagery [13] and skill in representing ideas through sketches of novice, as well as the degree of mastery in handling of software by novices and experts.

2.4 Subjects

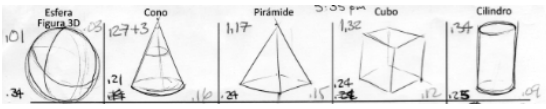
The novices are three undergraduate Industrial Design students, which had an average domain of each software. In relation to the three experts, the choice was based on years of professional experience using the corresponding software (at least 3 years).

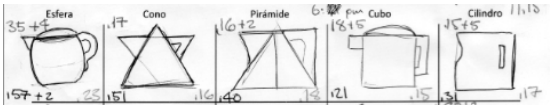
2.5 Contextual conditions

Novice and expert designers performed their exercises under equivalent conditions of work and in two schedules to choose: 10:00 am or 5:00 pm. The intent of this was to minimize the risk of fatigue and hunger. The sessions were conducted in offices of 2 x 3 meters , which had a desk and chair, and good natural lighting. The duration of the work sessions did not have a time limit.

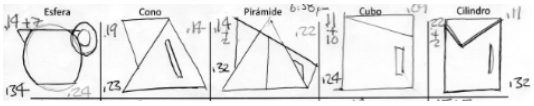
3 RESULTS

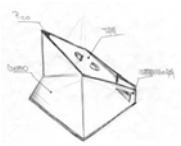
Below are presented, as examples, sketches performed in sections 1-4 of the Study A:





Figures 1-2. Personal sketches performed in sections 1-2 of the Study A

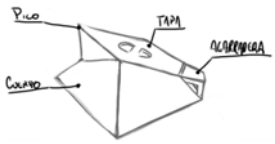




Figures 3-4. Personal sketches sketches performed in sections 3-4 of the Study A

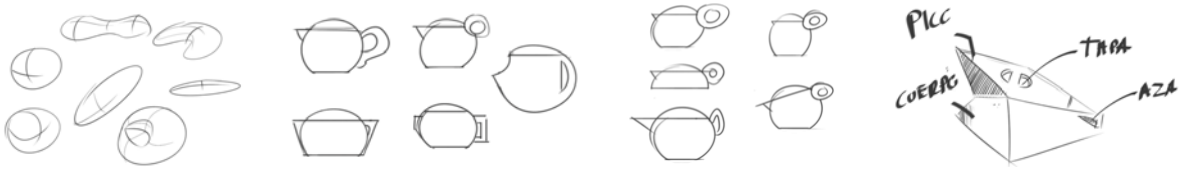
In Figures 5-8 can see some of the sketches replicated by the novice in SketchBook Pro (section 5 of Study A).

Figures 5-6. Section 5 of Study A: Some sketches of sections 1-2, that were replicated in SketchBook Pro



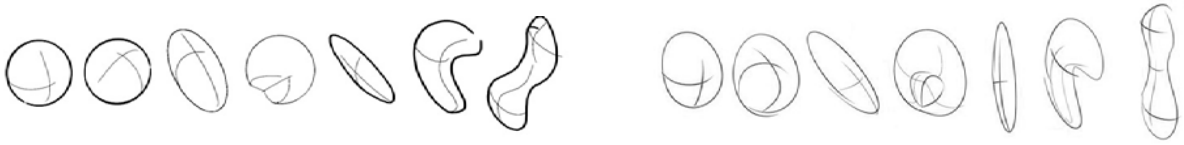
Figures 7-8 Section 5 of Study A: Some sketches of sections 3-4 replicated in SketchBook Pro

Some of the sketches replicated by the expert in SketchBook Pro can see in figures 9-12 (Study A).



Figures 9-12. Some sketches replicated by the expert in SketchBook Pro (sections 1-4 of Study A)

In figures 13-14, on the other hand, we can see sketches performed by the expert in SketchBook Pro:



Figures 13-14. Sketches performed directly in SketchBook Pro and sketches replicated, based on sketches previously performed by the novice

On the other hand, table 1 shows the runtimes and assessments of quality reproduction of sketches of the pilot study (Studies A, B and C):

Table 1. Averages, percentages y time-quality sketches performing factors of pilot study.

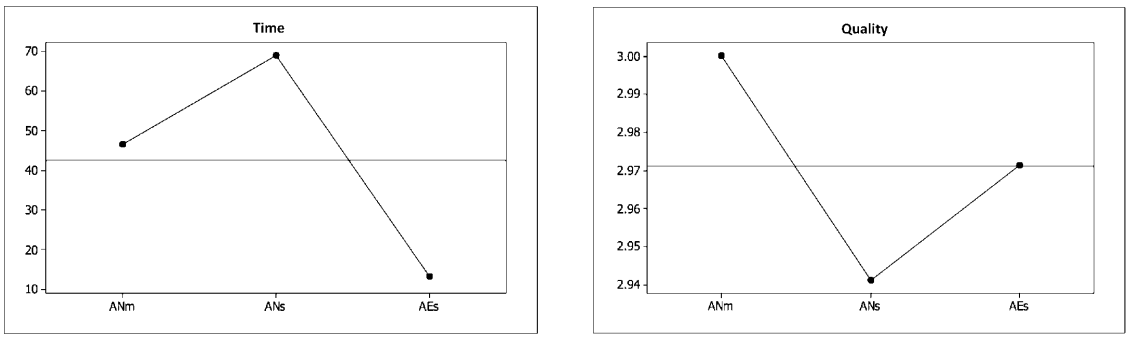
Averages-percentage-performing factors/Study	Study A SketchBook Pro	Study B SketchUp	Study C Illustrator
Time average (in seconds) in performing handmade sketches by the novice	142.1	145.4	164.4
Time average (in seconds) in sketches replicated in software by the novice	190	584.4	1068
Time percentage (in seconds) in sketches replicated in software by the expert	40.5	250.4	308.4
Time average in sketches replicated in software by the novice vs. expert	+ 369%	+ 133%	+ 246%
Time efficiency factor by novice	1.34	4.02	6.5
Time efficiency factor by expert	0.29	1.72	1.88
Quality average of replicated of sketches in software by the novice	2.78	2.37	2.93
Quality average of replicated of sketches in software by the expert	2.96	2.79	2.87
Quality average of replicated of sketches by the novice vs. expert	- 0.06%	- 0.15%	+ 0.02%

Table 2, meanwhile, shows the average of runtimes of sketching by the expert of SketchBook Pro directly in the software (Study 0) vs. the average of handmade sketches performed by the novices (Studies A-B-C):

Table 2. Average of runtimes of sketches performing by novice vs expert of SketchBook Pro

Studio A (handmade sketches)	Studio B (handmade sketches)	Studio C (handmade sketches)	Studio O (sketches performed in SketchBook Pro)
142.1	145.4	164.4	156

Finally, in figures 15-16 we can see two charts of time and quality averages of section A of Study A, where **ANm** means Study A-Novice-Handmade sketches, **ANs** means Studio A-Novice- sketches in software and **AEs** means Study A-Expert-in sketches in software):



Figures 15-16. Charts of time and quality averages (section A of Study A)

4 DISCUSSION AND FUTURE WORK

Based on the results of the study, three separate analyzes were conducted:

Analysis 1: The analysis 1 performs a comparative of time-quality among handmade sketches made by the novice vs. those sketches replicated in software by the novice vs. those sketches replicated in software by the expert. This for Studies A, B and C.

Analysis 2: Analysis 2 considered comparing time-quality among the three novices and experts (sketches replicated in software). The intention of this analysis is to find the software that allows faster and better quality performance (replicating sketches). The fact that there are no significant differences between the various figures and kettle proposals made by novice designers, allows us to make this comparison.

Analysis 3: Analysis 3 aimed to compare the time-quality of representation vs. replication of sketches by the expert in SketchBook Pro. As mentioned, this expert was asked to conduct the study sections 1-4 directly into the software mentioned, previously to replicate the sketches made by the novice.

Based on the results of these analyzes, it was observed that the SketchBook Pro software supports better the representation of the first ideas on the creative stage. This is possible precisely because, compared with Illustrator and SketchUp, SketchBook Pro enables the representation of figures with a high degree of ambiguity, through the free manipulation of a drawing instrument. If we look at the averages of runtime of the sketches performed by the expert directly in SketchBook Pro, in comparison with the handmade sketches performed by novices, we can see that the times are similar. This shows that the sketch on paper, or directly on SketchBook Pro, can be the same.

SketchUp, meanwhile, is emerging as an interesting way to represent objects and constructs 3D models. But it is precisely this possibility of three-dimensional representation only a way to represent ideas, but not to generate them. In fact, this software is more appropriate for the architecture, the above for its “constructive” character.

About Illustrator, we can say that is a software better than SketchUp, this respect to the representation of the first ideas on the creative stage. Illustrator is undoubtedly a design software that allows the representation of almost any shape, although runtimes are considerably larger than those used in SketchBook Pro.

Moreover, it is true that the three studied computer programs allow the representation of most geometries made by hand, but it is important to distinguish that SketchUp and Illustrator allow only the representation of ideas, but do not allow the “process of sketching" . This is due to, just to mention three characteristics, the speed of execution, high degree of ambiguity capacity and the free trace. In its favour, we can say that these programs can apply colours, textures and other effects, important issues for the communication of design proposals, but not important in the first stage of product design.

It is also important to mention that the possibility of copy / paste, in Illustrator and SketchUp, allows vertical transformations can be performed in a faster way. This was observed at the time of execution of the sketches in the software (Section 3), this in novices and experts.

As for the design of the study, we can say that although it is perfectible, it is considered that the design of the pilot studio is a good starting point for future research. In this sense, the general recommendations for further experiments consist of the following:

- Ensure equal working conditions for study subjects (eg: use the same space and the same time, in complete silence and without allowing music).
- Incorporate new software. The use of Paint and CorelDRAW, similar to SketchBook Pro and Illustrator respectively, certainly would allow more enriching results.
- Consider variations in terms of processing devices (such as tablets and smart phones).
- Measuring the efficiency of a software considering the use of different input devices (eg: mouse vs. Wacom tablet vs. touchpad).
- Investigate if a software interface promotes / inhibits the generation of design proposals, that with respect to sketching on paper.
- Based on the Analysis 3, we could ask the expert in software to perform their figures without line quality and without templates. This would reduce the execution times of the original sketches, which result in a greater validity of results.
- Incorporate, as far as possible, the missing components sketching: vision and mental processing (ability to reinterpretation and reprocessing of the already drawn).

REFERENCES

[1] Oh J., Stuerzlinger W. and Danahy J. Comparing SESAME and Sketching on paper for conceptual 3D Design. *Eurographics Workshop on Sketch-Based Interfaces and Modeling*, 2005.

[2] Prats M. and Garner S. Observations on ambiguity in design sketches. *Tracey the online journal of contemporary drawing research*, 2006.

[3] Goel V. *Sketches of thought*, 1995 (MIT Press).
[4] Gross M. D. and Do E. Y. L. Three R's of Drawing and Design Computation. In *Design Computing and Cognition'04*, 2004, pp.613-632 (Springer Netherlands).
[5] Kavakli M. and Gero J. S. Sketching as Mental Imagery Processing. *Design Studies*, 2001, 22(4), 347-364.
[6] Verstijnen I. M., van Leeuwen C., Goldschmidt G. Hamel, R. and Hennessey J. M. Sketching and creative discovery. *Design Studies*, 1998, 19(4), 519-546.
[7] Cross N., Christiaans H. and Dorst K. *Analysing design activity*, 1996 (John Wiley & Sons, Chichester).
[8] Acuna A. and Sosa R. The Complementary Role of Representations in Design Creativity: Sketches and Models. In *Design Creativity*, 2010, pp. 265-270 (Springer London).
[9] Bilda Z. & Demirkan H. An insight on designers' sketching activities in traditional versus digital media, *Design Studies*, 2003, 24(1), 27-50.
[10] Kavakli M. and Gero J. S. The structure of concurrent cognitive actions: a case study on novice and expert designers. *Design Studies*, 2002, 23(1), 25-40.
[11] Kavakli M. and Gero J. S. Strategic knowledge differences between an expert and a novice designer. In *Human behaviour in design. Individuals, teams, tools*, 2003 (Springer Berlin Heidelberg).
[12] Evans M.A., Pei E. and Campbell R.I. Extending Sketches, Drawing, Models and Prototypes to Define a Taxonomy of 35 Design Representations for Improved Communication during New Product Development. *IDSA 2009 International Conference "Project Infusion"*, Miami, September 2009.
[13] Finke R. and Freyd J. Imagery. In *R. Stenberg (Ed.) Encyclopedia of Intelligence*, 1994, pp. 561-563 (New York: Macmillan Publishing Company).
[14] Buxton B. *Sketching User Experiences*, 2007 (Morgan Kaufmann).
[15] Ohira T. *Computer Designics*, 1995 (Graphic-sha Publishing).