Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference
IDETC/CIE 2011
August 28-31, 2011, Washington, DC, USA

DETC2011-48714

THE ROLE OF SKETCH FINISH AND STYLE IN USER RESPONSES TO EARLY STAGE DESIGN CONCEPTS

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ABSTRACT

Conceptual sketches of design alternatives are often employed as a tool for eliciting feedback from design stakeholders, including potential end-users. However, such sketches can vary widely in their level of finish and style, thus potentially affecting how users respond to a concept. This paper presents a study of user responses to three objects drawn in styles ranging from rough hand sketches to CAD drawings. This study also considers the amount of design time required to create the sketches. Results show that respondents generally ranked realistic, "clean" hand sketches the highest over other types of sketches, particularly "rough" sketches. These types of sketches took longer than other types of hand sketches to create, but were still much faster than CAD renderings. Results also suggest that the complexity and familiarity of an object can influence how users respond to a sketch.

1 INTRODUCTION

Early stage product design process is marked by a continuing interplay between divergent and convergent design activities [1, 2] in an effort to generate appropriate design solutions. One common strategy in this process of generating and winnowing design concepts is to elicit feedback on potential design concepts from end users or customers, or from external design stakeholders such as engineers, manufacturers, or managers. This feedback can then be used to inform the design process by helping designers decide which concepts to pursue, suggesting how current concepts may be modified, or inspiring new concepts altogether [3, 4]. Such feedback may be obtained through a number of means such as focus groups, interviews, observations of use [5], or participatory design [6], and often involves the use of drawings or physical prototypes to prod commentary [7].

This paper examines the use of drawings as a prompt in eliciting feedback and specifically considers the role that the style of a sketch plays in influencing how a user may respond. The goal of the designer should be to create a drawing to elicit information from the user that will be useful in driving the design forward. However, drawing characteristics such as sketch style and level of finish may affect how the drawing is received [8]. Given the same concept drawn with varying levels of finish, which do users prefer?

In tension with this issue of the level of finish of a sketch is the design effort necessary to generate sketches. The goal of the designer working under a deadline is to create drawings to elicit the maximum amount of useful design information with the minimum amount of time and effort. A simple 2D line sketch may require minimal sketching skill and only a few minutes to create, while a highly rendered CAD model of the same concept may take a designer experienced in CAD hours to generate. However, a rough sketch created quickly may not generate as much useful feedback from a user as a more finished, realistic sketch.

Intertwined with this is a third issue, that of design effort breeding commitment of the designer to a specific design. More highly finished drawings require the designer to make more choices about a design that may lead the designer to buy-into a design, potentially closing off exploration prematurely.

The broader goal of this work is to formulate frameworks that can guide the designer in the judicious use of sketches and prototypes to support decision-making during the early stage of the design process. This paper focuses specifically on the role of sketches, and explores the responses of individuals to objects

drawn in varying levels of finish, including CAD. This study further links sketch style to the amount of time needed to create sketches. Knowledge of the levels of sketch finish that are preferred by users can help designers and teams decide what type of sketches are more effective at eliciting useful feedback.

The paper seeks to examine the following hypotheses about sketch finish and user response:

- More realistic, finished drawings are regarded more highly by potential end users.
- More realistic, finished drawings take more time to create

2 RELATED WORK

2.1 Sketching in design

The act of sketching during the design process is considered to be a fundamental activity by which designers think about a design [9-11]. Sketching captures ambiguity in design [12] and provides an alternative strategy for exploring various aspects of a design [13].

2.2 Types of design sketches

Sketches may be categorized in a multitude of ways. McGown et al. [14] and Rodgers et al. [15] have set forth categories for sketches that emphasize their basic physical elements:

- Level 1: Simple monochrome line drawing that does not include shading or annotations
- Level 2: Detailed monochrome line drawing with annotations but no shading
- Level 3: Level 2 drawing with shading to suggest 3D form
- Level 4: Level 3 drawing with more gradations of shading and possibly color to emphasize 3D form
- Level 5: The most ‘‘realistic’’ type of sketch includes extensive shading and annotation

Ferguson [16] defines sketches by the purpose they are meant to serve: the thinking sketch acts as a mechanism for design reflection, the prescriptive sketch serves as a set of instructions for design work, and the talking sketch supports design collaboration. Schenk [17, 18] describes a taxonomy of sketches based on their purpose, including such categories as "Drawing for the initiation of ideas" and "Drawing for presentation" to a client or other stakeholders.

2.3 Sketch style and fidelity

2.3.1. Role of sketch style in a design

There is research in both product and user interaction design that consider the potential influence of the style of sketches and outcome. Kurosu [19] and later Tractinsky, et al. [20] found that a user interface's aesthetic appeal had a stronger influence on an interface's perceived usability than the interface's actual usability. Yang and Cham [21] explored the role of a designer's sketching skill in design outcome and found a broad range of realism in the sketches that engineers produced, though this did not relate to the quality of design outcome. However, Yang [22] examined sketch quantity and timing and found the exploration of dimensioned drawings early on in the design cycle correlated with design outcome. Dimensioned drawings are notable because they likely represent a more concrete level of thought regarding a design concept. Song and Agogino [23] found a relationship between both 3D and shaded sketching and design outcome.

2.3.2 Sketching and commitment to a design

A prototype may be described by its resolution, or fidelity. In general, higher fidelity, more realistic prototypes require time and design skill to produce. Ideally, designers should opt for the "cheapest" prototype that still provides the desired information [24, 25]. However, it has been observed that the act of sketching at a higher resolution may engender higher commitment to that sketch on the part of the sketcher [12, 26]. In particular, Gerber [4] notes the value of incremental prototyping ("small wins") in reinforcing a designer's commitment to a project.

2.3.3 Sketch and user feedback

User interface designers utilize sketches and prototypes of varying levels of resolution to elicit user feedback [27]. The goal may be to garner feedback on a prototype's function, role, or form [28]. In the context of engineering design, Hannah, et al. [29] examined the role of fidelity of engineering sketches, solid models, and functional prototypes in helping designers determine the likelihood a design will meet various design requirements, and in general found that higher fidelity prototypes provided designers with more confidence in making such determinations.

2.4 Research gap

There is a rich body of research that examines the value of design sketching for supporting the design process and design outcome. Furthermore, literature has considered the importance of sketch and prototype fidelity in eliciting feedback from stakeholders. The work presented in this paper seeks to further add to this work by considering sketching style from an industrial design perspective [30] rather than from a more engineering-centric view. This is of particular relevance for user feedback from individuals who may not be familiar with technical drawing.

3 METHODS

Participants were asked to rank four different sketches of one object from 1 to 4, 1 being the image they liked the least and 4 being the image they liked the most. This question was intentionally left open to interpretation by respondents in order to obtain their immediate, visceral response to the question. This study examined three different objects: a cube, a chair (the Amoebe chair by Verner Panton, Figure 1) and a cell phone (the Motorola RAZR, Figure 2), each sketched in four styles. Participants were presented only with images, without any text description of what the sketch represented. The three objects were selected because they provided a range of complexity and form. The baseline cube was chosen because it is a neutral building block in sketches across engineering, product, and

industrial design, and has few of the preconceived notions associated with it that an image of a more familiar product might [31]. The "Amoebe" chair was selected as a counterpoint to the cube because of its organic form. The RAZR cell phone was used as it was a relatively more complex geometric form and was easily recognized as a product.

Figure 1 Verner Panton Amoebe chair [32]

Figure 2 Motorola RAZR phone [33]

Sketches were divided into two broad categories: hand sketched wireframe-style line drawings (a Level 2 drawing) and "shaded" drawings (a Level 4 drawing). Sketches were of varying levels of finish. The goal of these styles was to get a range of commonly used sketching styles by professionals in industrial and product design and engineering.

Line drawings (Figure 3)

A. Unfinished - a rough sketch. This style might be used to represent preliminary, exploratory ideas.
B. In progress - a sketch with construction lines, in the style of a partially completed industrial design sketch
C. Finished - a clean sketch that is a more finished version of B.
D. Stylized - a sketch drawn with heavy lines intended to be a graphic interpretation of the object.

Shaded drawings (Figure 4)

E. Unfinished - a rough sketch. This style might be used to represent preliminary, exploratory ideas.
F. In progress - a sketch with construction lines, in the style of a partially completed industrial design sketch
G. Finished - a clean sketch that is a more finished version of F.
H. CAD - a computer generated solid model.

All sketches were created by the same individual, an undergraduate mechanical engineering student with coursework in art, drafting, and CAD rendering. Sketches were made using pencil, pen and assorted shades of gray markers. The time to create each sketch was recorded. For each hand sketch, an underlay was used to keep the size and shape of the objects consistent across all drawing styles. The time taken to draw the underlay was not reflected in the overall time to draw each image. If the sketches had been made without an underlay, it is estimated that they would have taken on the order of seconds longer to produce, though there would likely be more variation in net shape across each set of drawings.

In total, six sets of drawings were presented to six different sets of respondents of approximately 100 people each. Surveys were conducted using Amazon Mechanical Turk, an online crowdsourcing service for labor for various tasks, including responding to surveys. Mechanical Turk has been found to be comparable in quality to traditional methods for recruiting survey respondents for social science experiments [34]. The six surveys were made available via Mechanical Turk from December 2010 to January 2011. Each survey was completed by 100 respondents. Of the 600 possible surveys that could be completed, 584 were approved for use in this study. Surveys were discarded only if they contained errors such as giving two drawings the identical rank.

Table 1 Number of responses to line drawing survey

LINE	Number of Responses Counted
Cube	99
Chair	97
Phone	100

Table 2 Number of responses to shaded drawing survey

SHADED	Number of Responses Counted
Cube	97
Chair	94
Phone	97

Payment for the first of these experiments, the line drawing of the cube, was $0.20 per survey. This amount was increased to $0.30 per survey to encourage responses. This calculates to an hourly wage of $5.22 for evaluating the line drawing of a cube, and an hourly wage between $7.30 and $7.88 for the remaining surveys. Respondents were all adults living in the US who had an approval rating from previous surveys of 90% or higher.

Finally, participants were asked to give two adjectives describing both their least favorite image and favorite image in order to further assess reasoning for their rankings.

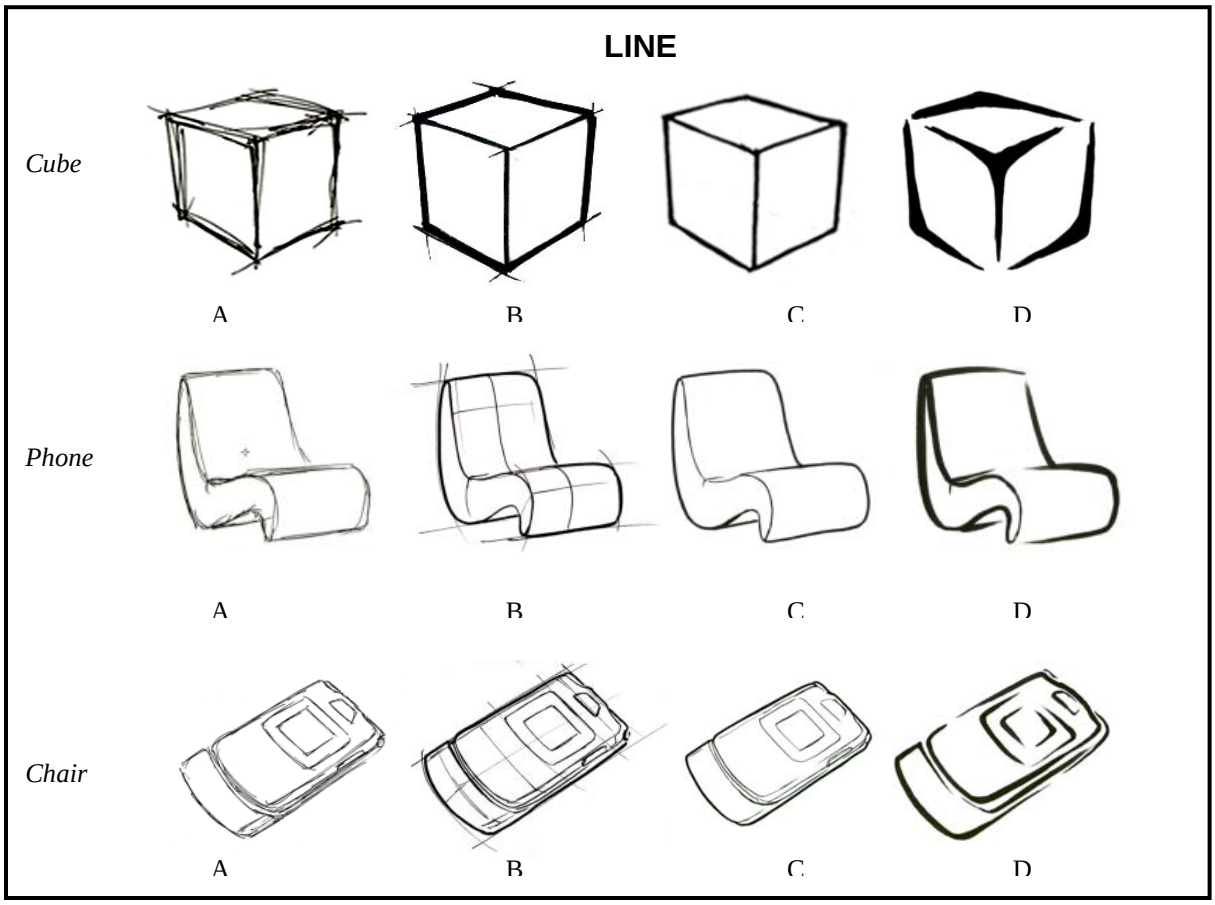

Figure 3 Line drawings of cube, chair, and cell phone

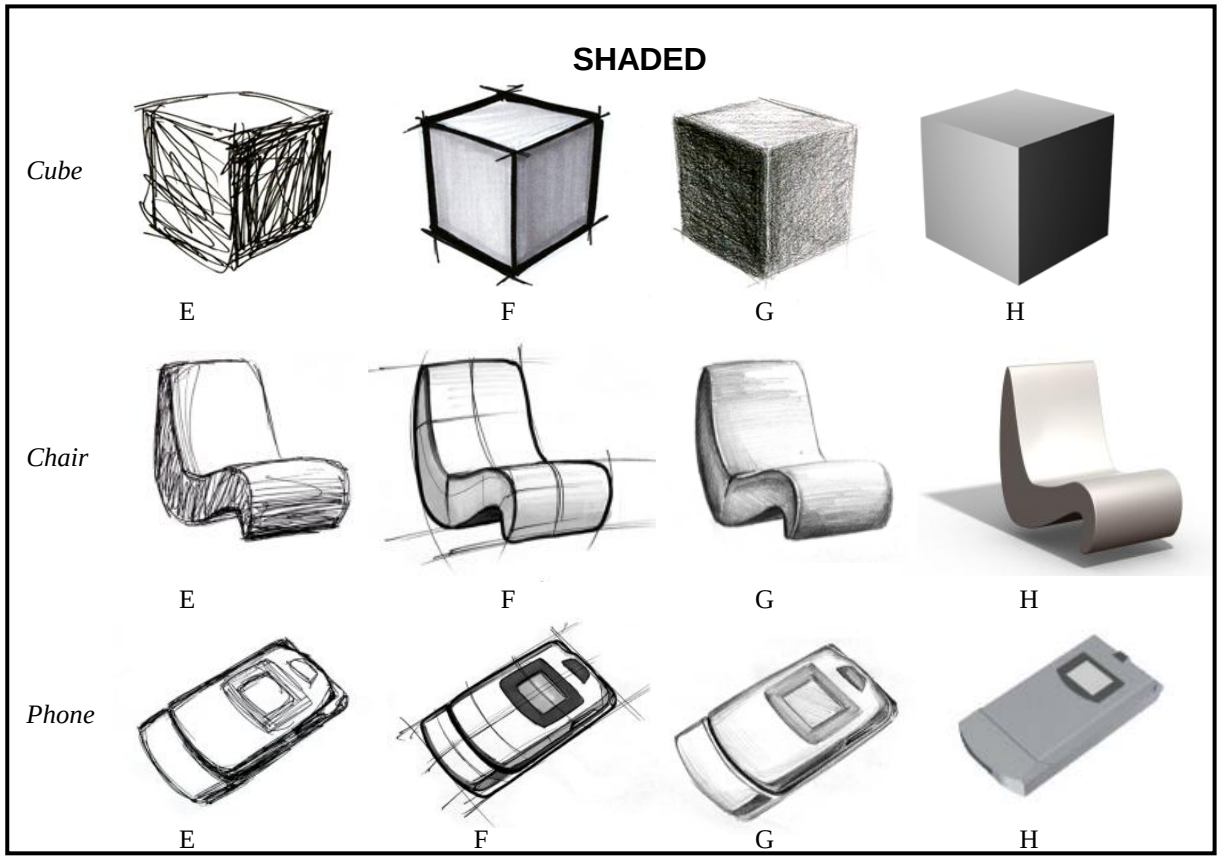

Figure 4 Shaded drawings of cube, chair, and cell phone.

4 RESULTS AND DISCUSSION

Table 3 Line drawn cube: Average rankings, standard deviations, time to create, and normalized time

CUBE	A	B	C	D
ranking	2.01	2.71	2.66	2.63
std dev	1.16	0.84	1.09	1.23
time (sec)	10	30	15	10
time (%)	33	100	50	33

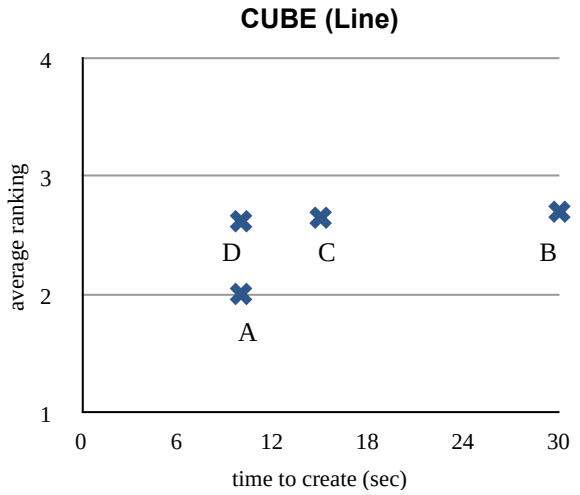

Figure 5 Plot of average rankings and time to create line drawing of cube

Table 4 Line drawn chair: Average rankings, standard deviations, time to create, and normalized time

CHAIR	A	B	C	D
ranking	1.73	2.11	2.9	3.26
std dev	0.87	1.05	0.94	0.9
time (sec)	30	50	60	30
time (%)	50	83	100	50

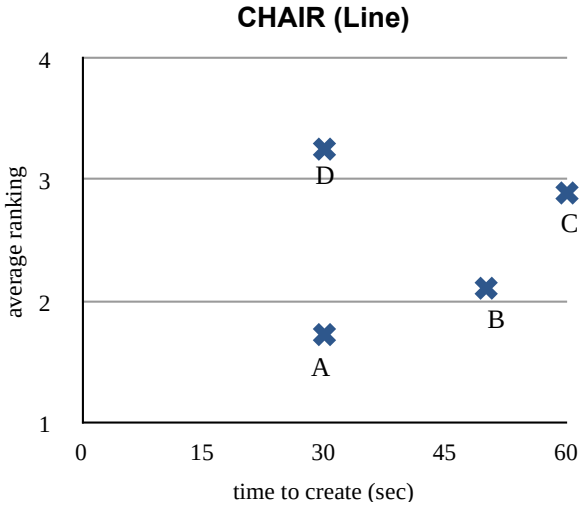

Figure 6 Plot of average rankings and time to create line drawing of chair

Table 5 Line drawn phone: Average rankings, standard deviations, time to create, and normalized time

PHONE	A	B	C	D
ranking	2.21	2.31	3.01	2.47
std dev	0.92	1.15	0.95	1.25
time (sec)	60	105	180	45
time (%)	33	58	100	25

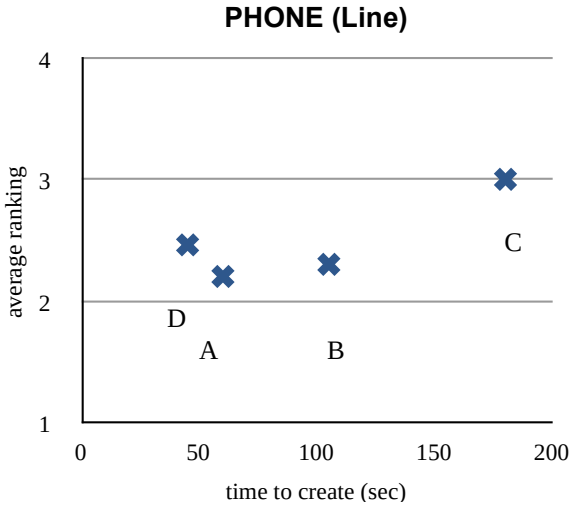

Figure 7 Plot of average rankings and time to create line drawing of cell phone

Tables 3 through 5 list the average rankings and standard deviations of each of the line drawings, along with the time required to create each one. The table also includes a normalized percentage of time with the longest time equal to 1 in order to give a better relative sense of the time allotment. These values are plotted in Figures 5 through 7. The rough

sketches (A) were in all the cases the lowest ranked style. Common adjectives used to describe this style included "rushed," "messy," "sloppy," and "rough." For the cube, the styles B, C, and D were all given virtually the same ranking. However, for the chair, the stylized version (D) was clearly preferred over the other styles, and for the cell phone, the finished style (C) was also rated more highly.

To assess the statistical significance of these results, they were further analyzed by applying the Mann Whitney U test to the raw ranking values given by all respondents to the original surveys. In the case of the line drawing of the cube, A < D <= C <= B, where "<" means that the inequality relationship is statistically significant for $p < 0.05$, and "<=" means that the relationship is not statistically significant. For the line drawing of the chair, A <= B < C < D, and for the line drawing of the phone, A <= B <= D <= C. Tables listing the raw p-values can be found in Appendix A.

In all cases, the rough drawings were less preferred to the more finished drawing in a statistically significant way, though no one style (B, C, or D) was clearly preferred over the others, We suspect this has to do with the particular objects that were drawn. The cube consists of only 9 lines, and because of this simplicity, the visual differences among the three line drawing styles (B, C, and D) are relatively minor and likely more difficult for a viewer to differentiate. Prior associations with the object may play a role in the user perceptions of the other two objects. The survey presented images to the respondents without any textual description of what the image represented. In the case of the cell phone, it was likely clear to most respondents that the drawing was of a cell phone. Respondents in fact preferred the more finished (C) sketch of the cell phone. Of the four sketches, this sketch was arguably the most "realistic" and clean looking. However, in the case of the chair, the design was probably unfamiliar to most of the survey respondents, and the particular style of the chair is almost graphical in nature. It is possible that respondents had no preconceived notions about what the chair should look like, and instead responded to it in a purely visual way, thus preferring the more stylized version (D) over the others.

Table 6 Shaded cube: Average rankings, standard deviations, time to create, and normalized time

CUBE	E	F	G	H
ranking	1.54	2.62	3.09	2.75
std dev	0.94	0.98	0.8	1.09
time (min)	0.50	1.33	1.67	5.00
time (%)	10	27	33	100

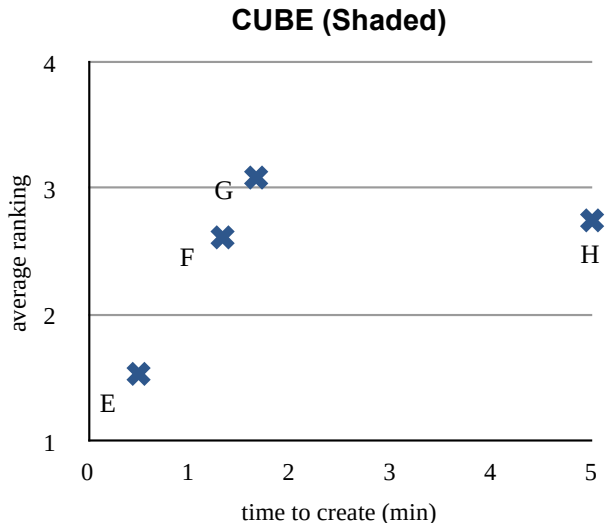

Figure 8 Plot of average rankings and time to create shaded drawing of a cube

Table 7 Shaded chair: Average rankings, standard deviations, time to create, and normalized time

CHAIR	E	F	G	H
ranking	1.81	1.9	3.28	3.01
std dev	0.86	0.82	0.71	1.2
time (min)	1.0	3.0	5.0	15.0
time (%)	6.6	20	33	100

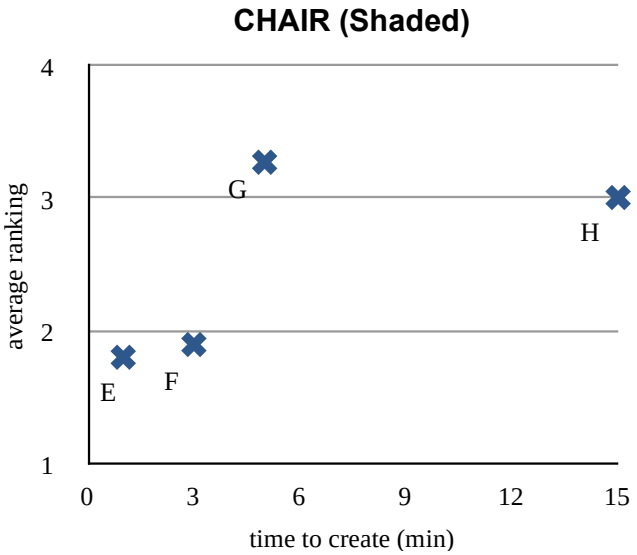

Figure 9 Plot of average rankings and time to create shaded drawing of chair

Table 8 Shaded phone: Average rankings, standard deviations, time to create, and normalized time

PHONE	E	F	G	H
ranking	2.02	2.39	3.47	2.11
std dev	0.95	1.01	0.74	1.12
time (min)	1.0	6.0	7.0	120
time (%)	0.8	5	6	100

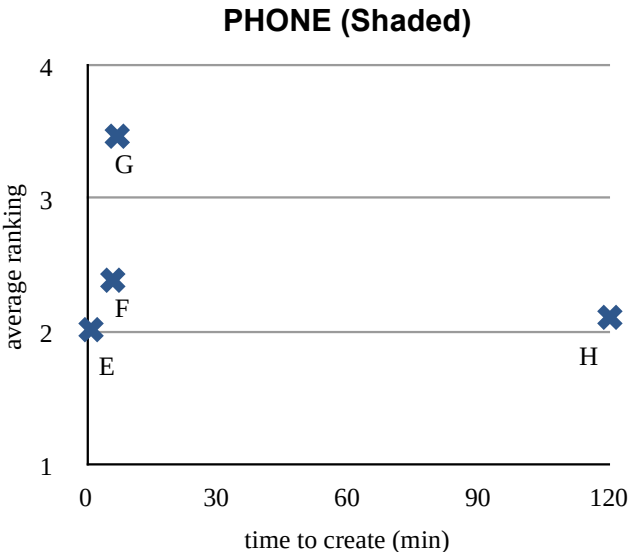

Figure 10 Plot of average rankings and time to create shaded drawing of cell phone

Tables 6 through 8 list the average rankings and standard deviations of each of the shaded drawings, along with the raw time required to create each one and a normalized time percentage. These values are plotted in Figures 8 through 10. In all cases of the shaded drawings, the finished hand sketch (G) was ranked the highest, and the rough sketch (E) the lowest. This is a notable result because of the relative speed with which it was created with respect to the CAD drawings (H). In the case of the cube and chair, the finished hand sketch (G) was only slightly more preferred over CAD (H), but the time to create the hand drawing was 3 to 4 times less. For the phone, however, the finished hand sketch was more clearly preferred though the time to create it was 19 times less.

In order to establish statistical significance, the Mann Whitney U test was applied to the raw ranking values given by all respondents to the original surveys. In the case of the shaded drawing of the cube, E < F <= H < G, where "<" means that the ranking is statistically significant for $p < 0.05$, and "<=" means that the relationship is not statistically significant. For the shaded drawing of the chair, E <= F < H < G, and for the shaded drawing of the phone, E <= H <= F < G. It should be noted again, as for the line drawings, in all cases, the "rough" drawings were less preferred than the "finished" drawings in a statistically significant way. Tables listing the actual p-values can be found in Appendix A.

4.1 Descriptions For Drawings

Tables 9 and 10 show the most frequently occurring adjectives provided by the respondents for each of the drawings. For drawings A, C, E, and G, comments tended to skew only positive or negative.

Table 9 Most commonly used adjectives given by respondents to describe most- and least liked line drawings

A	*negative*	rushed	messy	rough
B	*positive*	professional	detailed	clean
	negative	busy	confusing	incomplete
C	*positive*	clean	precise	simple
D	*positive*	bold	simple	creative
	negative	cartoonish	boring	incomplete

Table 10 Most commonly used adjectives given by respondents to describe most- and least liked shaded drawings

E	*negative*	rough	messy	incomplete
F	*positive*	modern	attractive	professional
	negative	messy	incomplete	unsure
G	*positive*	realistic	clear	detailed
H	*positive*	clean	solid	smooth
	negative	boring	bland	predictable

Why did respondents consistently prefer the finished sketch style for the shaded drawings (G) but not for the line drawings (C)? One possible reason is that the shaded finished drawings were, in general, more realistic than the other shaded drawings. Based on the positive adjectives ("clear," "detailed," and "realistic") given by the respondents for (G), realism appeared to be a desirable quality. In contrast, the finished line drawings (C) were not described as "realistic," except in the case of the chair.

If "realism" was a desirable quality, then, why were the CAD drawings not the most preferred? On the face of it, CAD drawings could be more realistic than hand sketches. However, "realism" was not an adjective used to describe the CAD drawings (H). The CAD drawings also had negative connotations associated with them, as evidenced by terms such as "boring," "bland," and "predictable."

4.2 Design effort and time

In this study, the time required to create line drawings ranged from seconds (for the cube) to minutes (for the phone). Note that this time did not include the time necessary to design the object, only to create a 2D representation of it. The most

time consuming drawings (C) took approximately 2-3 times longer to draw than the simplest ones (A). For the shaded drawings, the time to create sketches by hand ranged from under a minute to 7 minutes. The most finished-looking shaded, hand drawings took 4 to 7 times longer to create. The CAD drawings took 5 minutes to 2 hours to generate, or 3 to 19 times longer than the most finished hand sketches.

The engineering student who created the drawings noted that creating these CAD drawings in particular required making many additional choices about a design that did not arise when sketching by hand, such as the material for the object, its complexity, the quality of rendering, and the style of rendering.

5 CONCLUSIONS

This study grew from the following observation: When used early on in the design process, concept sketches may have the power to elicit feedback from users that will help designers make design decisions, and that the style or finish of that sketch may influence how users respond.

Given the same design concept, this study found that the perception of cleanliness, simplicity, and realism in a drawing was valued by respondents, while the appearance of roughness or messiness was viewed negatively. In fact, for both line and shaded drawings, "rough" sketches were always ranked lower than the "finished" sketches in a statistically significant way. For the line drawings, there was no single, universal style that respondents all favored. Realism in sketching was not as important for objects that were more stylized or less familiar, including the chair. For the shaded drawings, a clean, realistic hand drawing was the consistent preference among respondents.

The hypotheses proposed at the beginning of this paper may thus be addressed in the following way:

- More realistic, finished drawings are regarded more highly by potential end users.

It was anticipated that respondents would generally find the most finished, realistic sketches the most appealing. For the line drawings, this appeared to be true for the one object (cell phone) that looked most like a real product, but not true for the other two, more stylized objects (a cube and the Amoebe chair). For the shaded drawings, this was also true in some sense. For all three objects, the most preferred style was the hand drawing with the highest level of finish. Surprisingly, this was preferred over the rendered CAD drawings.

- More realistic, finished drawings take more time to create.

It was assumed that the most realistic, finished drawings would be the rendered CAD drawings, and these types of drawings did take the longest to complete. However, the highest fidelity hand drawings were the most favored, and these took much less time to create than CAD drawings.

The cases explored in this study imply that designers wishing to obtain user feedback on drawings are advised to create clean, finished, and realistic sketches by hand. Moreover, such drawings are preferred over CAD drawings for eliciting feedback. In general, for the designer who wishes to get feedback on relatively simple concepts, hand drawings of any kind have a distinct advantage over CAD drawings in that they are far faster to produce. In the time it takes to create a CAD drawing, a designer can generate many detailed hand sketches of various concepts or aspects of concepts. This makes for efficient exploration of design space.

It is hoped that this work might have value for design education, particularly in guiding novice designers during the early stages of design. Students have a range of sketch tools available to them, from traditional hand sketches to vector graphics editors such as Adobe Illustrator to modeling packages like Rhino to solid modeling in CAD systems. Many of these computer-based tools are capable of producing highly finished, photorealistic conceptions of products that are very appealing, but it is important for students to understand that the role of a drawing can vary with the stage in the process. In this case, this study suggests that clean sketches done by hand generally achieve the same level of appreciation by outside users as CAD drawings which take more time to create.

6 FUTURE WORK

Future work should consider a number of aspects of design sketching. First, the drawings included in this study were of relatively simple objects, and future work might examine how results might scale for drawings of more complex products. This may have particular ramifications for CAD models which likely will take longer to complete. Second, future work might also consider other key visual elements of sketches, such as the use of color, texture, and lighting and the role that these have on user perceptions of the object being drawn. Finally, this study asked respondents to rank drawings by how much they liked them, though there might be other, more specific criteria that could be used to value sketches in future research.

ACKNOWLEDGMENTS

The work described in this paper was supported in part by the National Science Foundation under Award CMMI-0830134. The authors would also like to thank Dr. Tomonori Honda for his insightful thoughts and suggestions. The opinions, findings, conclusions and recommendations expressed are those of the authors and do not necessarily reflect the views of the sponsors.

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APPENDIX A

Tables 11 through 16 list p-values calculated for using the Mann Whitney U Test for each set of rankings from all respondents for drawings included in this study. P-values that are both in **bold** and *italicized* are statistically significant.

Table 11 P-values for line drawing of cube

Line	A	B	C	D
A		***4.86E-13***	***3.96E-04***	***0.0029***
B			0.3217	0.6716
C				0.8884
D				

Table 12 P-values for line drawing of chair

Line	A	B	C	D
A		1.16E-01	***1.30E-20***	***1.41E-25***
B			***4.34E-09***	***1.17E-10***
C				***3.30E-05***
D				

Table 13 P-values for line drawing of phone

Line	A	B	C	D
A		1.00E+00	***8.72E-11***	2.41E-02
B			***1.69E-08***	7.79E-01
C				1.12E-02
D				

Table 14 P-values for shaded drawing of cube

Shaded	E	F	G	H
E		***2.44E-18***	***1.41E-25***	***3.22E-14***
F			***3.30E-05***	0.1979
G				0.0628
H				

Table 15 P-values for shaded drawing of chair

Shaded	E	F	G	H
E		2.45E-01	***8.51E-33***	***5.97E-09***
F			***5.11E-27***	***2.23E-11***
G				0.1462
H				

Table 16 P-values for shaded drawing of cube

Shaded	E	F	G	H
E		***6.50E-03***	***1.41E-25***	8.87E-01
F			***3.22E-14***	6.28E-02
G				***1.86E-19***
H				