Final Report: 2D Drawing Evaluation

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Abstract

Starting from the SketchPad in 1963, many tools have been invented to help 2D artists create their graphics. Our experiment aims to perform a case study, comparing the performance of artists and non-artists using different tasks (trace-rating, line-tracing, dot-connecting). We conducted the experiment on 5 different participants, and learned (1) for artists, “area under curve” impacts their judgment on accuracy the most; (2) some directions are harder to draw (3) people are pushed into speed-precision tradeoff when facing different tasks; (4) the pressure is consistent within an individual no matter what the task is.

Introduction

History

Drawing programs have been a prominent feature of computer systems since the beginning of the computer age. Drawing inputs are primarily the same input devices as a simple pointing device, but rather than the act of pointing users do the act of drawing. For example, the very first such a device, Sketchpad, has its light pen as an input device in the form of a light-sensitive wand used in conjunction with a computer's cathode-ray tube (CRT) display (Ivan Edward, 1963). It allowed the user to point to displayed objects or draw on the screen in a similar way to a touchscreen but with greater positional accuracy. This was replaced by the mouse, a more successful pointing device through measures of Fitts Law, comfort, etc. With the development of mobile devices, resistive touch screens accompanied by an analog stylus began to make their way into mobile products like PDAs. Resistive touch screens are made of several layers that respond to the hard pressure of a finger or stylus. The outer layer flexes under pressure and pushes back onto a layer behind it. This completes a circuit and telling the device which part of the screen is being pressed. Although capacitive touch screens were invented earlier, progresses in their technology made them the primary touch screen for mobile devices. A capacitive screen has four electrodes placed at each corner of the touchscreen, which maintain a level voltage over the entire conductive layer. When a user’s finger, which is naturally conductive, comes in contact with any part of the screen, a current flow is initiated between those electrodes and your finger. Sensors under the screen sense the change in voltage and the location of that change. (Lecture Notes, 2019)

Table 1: A comparison between different styluses

	Direct V. Indirect	Compatible Devices	Price	Connection	Pressure Sensitive	Tilt Support	Palm Rejection	Lag
Adonit Pixel	Direct	iPhone 5, 5c, 5s, SE, 6, 6 Plus, 6s, 6s Plus, 7, 7 Plus iPad Mini, iPad Mini 2, iPad Mini 3, iPad Mini 4, iPad 4, iPad Air, iPad Air 2 and iPad 2017 (5th generation)	$74.99	Bluetooth	Yes	No	Yes	Yes
Apple Pencil 2	Direct	iPad Pro 12.9‑inch (3rd generation) and iPad Pro 11‑inch	$99.00	Bluetooth	Yes	Yes	Yes	No
Bamboo Fineline	Direct	"Most iOS Touch Devices" Except 9.7 inch iPad Pro	$59.95	Bluetooth	Yes	Yes	Yes	Yes & No
Google Pixelbook Pen	Direct	Google Pixel Slate or Google Pixelbook	$99.00	Bluetooth	Yes	Yes	Yes	No
Huion INSPIROY Q11K	Indirect	Windows 7 or later, macOS 10.12 or later	$139.00	USB 2.4 G	Yes	Yes	Yes	No
Logitech Crayon	Direct	iPad Pro 12.9-inch (3rd gen), iPad Pro 11-inch, iPad Air (3rd gen), iPad mini (5th gen), iPad (6th gen)	$69.99	Wireless Frequency	No	Yes	Yes	No
Ugee M708	Indirect	Windows 7 or later, macOS 10.08 or later	$59.99	USB	Yes	No	No	No
Wacom Intuos Pro	Indirect	Windows 7 or later, macOS 10.12 or later	$329.95 - $399.95	USB, Bluetooth 4.2	Yes	Yes	Yes	No
XP-Pen Deco 01 Drawing Tablet	Indirect	Windows 7 or later, macOS 10.10 or later	$72.99	USB	Yes	No	Yes	No

Styluses are becoming more popular as pointing devices among creatives, as it allows one to draw digitally in similar physical motions as hand drawing. Some are direct pointing devices and are connected to a device by Bluetooth, so users can "draw" directly on top of the touchscreen of the device. Some examples of this are Logitech Crayon, Apple Pencil, Google Pixelbook Pen, Adonit Pixel (and other models), and Bamboo Fineline, among others. There are also indirect drawing devices. These use a graphics tablet (also known as a pen tablet, drawing tablet or digitizer), essentially a touchpad, and a corresponding pointing device. Some examples of this method are Wacom Intuos Pro, Huion INSPIROY Q11K, XP-Pen Deco 01 Drawing Tablet and Ugee M708, among others. (See Table 1 for a detailed comparison; Armstrong, 2019; secretasianman.com, 2019)

We did a comparative analysis of the input devices used for drawing and other creative digital activities that are currently on the market. We chose to narrow our choices down to the devices we will be testing listed in the experiment design below, due to factors including the comparative analysis, interview insights, and accessibility to specific devices.

Interviews

Before designing an experiment we did research interviews. We interviewed professors and students in creative disciplines. There were three categories of questions: demographic, technology, and interaction technique, to get a well-rounded view of the person and their digital drawings methods. The question outline is attached in the appendix.

The first professor interviewed was Doug Cooper, a prolific free-hand renderer and a professor in Carnegie Mellon's College of Fine Arts and the School of Architecture.

The second professor interviewed was Eddy Man Kim, the Digital Media Professor for first-year students in undergraduate and graduate architecture programs.

We also interviewed two students who are both in the College of Fine Arts and consider themselves artists. Student 1 is a junior in the School of Design with a concentration in Communication Design.

Student 2 is a third-year student in the School of Architecture with an IDeATe Minor in Design for Learning.

Interview Insights

We gathered some interesting insights about specific pain points in digital drawing as well as more abstract ideas around the digitization of drawing.

We learned from all three interviewees that the lightweight caused by a pressure sensitive tip is incredibly important. This is an important factor in creating a more realistic digital drawing experience. Similarly, the less lag there is between where the user's pen is and where the line is being drawn on the digital interface is creates a more realistic feel; this appeared to be slightly more important for direct drawing methods rather than indirect.

There will always be trade-offs between technology, especially with the wide range of variables in these devices. The biggest tradeoff for a long time was the difference between indirect and direct drawing methods. For a long time, the indirect styluses were more powerful in terms of accuracy and pressure sensitivity, so artists gravitated towards that technique. However, indirect techniques have a long learning period due to the lack of seamless translation; one interviewee noted it took around four years before they felt their drawing skills on the graphics tablet method were as fluent as their hand drawing. Now direct devices are becoming more prevalent. The issue with these is usually compatibility with devices. For example, the newest Apple Pencil is only compatible with two Apple products (iPad Pro 12.9-inch and iPad Pro 11-inch), whereas the indirect methods are typically able to connect most computers with up to date operating systems via USB. Each pointing device also has limits with which software are compatible. Though the majority of the industry-leading creative softwares are now compatible.

One professor, Doug Cooper, in particular, thought that computers can be "too good at being too precise". By this, he was referencing to the "auto-neatening" of wiggly lines to straight lines or uniforming subtly varying pressure in line weight to a constant line weight, though he noted this is typically the result of the graphics software or operating system a user is using rather than directly the stylus. He thinks that it is important for lines to have character and vagueness, especially in early stages of sketches and projects, and through digitization, you often lose this and the dimensionality can become flattened. Another professor, Eddy Man Kim, noted that though digital drawings are immensely important in this new media age, students should learn analog drawing skills first to have a deft hand and then translate to digital, rather than start with digital. We think this will show in the tests in the comparison of artists drawings who were trained to hand draw to people who were not trained to hand draw.

We took some of these insights, especially the importance of pressure sensitivity, in consideration of the design of the experiment.

Experiment Design

Set up

Figure 1: A participant sitting in front of the computer, using the Wacom stylus for the drawing task.

Initially, we planned to test three different input methods: the Wacom tablet, Apple Pencil, and mouse. However, due to the availability of technologies, as well as the scope of this assignment, we narrowed down to use only Wacom tablet on a chrome browser. The participant is instructed to sit on a chair, with the laptop on the table facing them (Figure 1). They will be instructed to use their dominant hand in their favored hand position.

Participants

We plan on testing our software with people who consider themselves artists and are familiar with drawing, both analog and digital. This includes both students and professors. We also plan on testing on people who are not artists as a way of comparison.

We tested our software with 3 artists (2 art students, 1 art professor) and 2 non-artists (1 computer scientist, 1 professional writer), all recruited by personal networks. Although we only tested on five participants, we planned for a participants pool with a wide diversity to compare the results between artists and non-artists.

All the participants happened to be right-handed with no major injuries on their dominant hand.

Participant 1, Artist

Participant 1 is an Architecture student in the College of Fine Arts. They have over 5 years of art education. They render, illustrate and hand sketch daily. They regularly use an iPad Pro and Apple Pencil for both academic and personal drawings. Before using the Apple Pencil, a direct input method, they used a Wacom Tablet, an indirect input method similar to the one we are testing.

Participant 2, Artist / Professor

Participant 2 is a professor in the undergraduate and graduate Architecture programs. They have over 20 years of art education and consider themselves a generalist (use a wide range of creative technologies). They render or hand sketch daily. They have used an indirect drawing technique similar to the one we will be using for about 10 years. They typically use it for online annotations and sketching rather than illustration.

Participant 3, Artist

Participant 3 is a student in the College of Fine Arts and the School of Computer Science. They have over 4 years of art education. They used to render, illustrate and hand sketch daily, but now only about once every week or two. They infrequently use an iPad Mini and Adonit Pixel for both academic and personal drawings.

Participant 4, Non-Artist

Participant 4 has been a computer scientist for 40 years. They have never done any visual art before, nor does he have any experience using a stylus for visual arts.

Participant 5, Casual Artist

Participant 5 has been a professional writer/editor for more than 35 years. They use paper, film, clay, metal, and iPad to do visual sketching as a hobby for 5 months. They use Day One (a journal app) daily to create sketches and photo albums.

Since she is not professionally trained, we count her as a non-artist in this report.

Steps

1. First, we will introduce participants to the experiment to explain the intent and go over the process. (Script will be attached in the appendix)
2. Next, we will show participants samples of the trace line and a test line, and have them rate how well they think the line is traced, assuming the line was for a professional drawing.
3. Then we will run the computer tests with the stylus. For each participants' test session, we will:
    a. Run a practice session to familiarize participants with the testing software and interaction technique.

   b. Have participants perform the tracing task.
   c. Have participants perform the “connecting-the-dots” drawing task.
4. After the computer tests have concluded we will interview participants with the demographic questionnaire.
5. Finally, we will debrief the participants on the purpose of the study.

Tasks and Metrics

There are three major tasks in the experiment: trace rating, line tracing, and dot connecting.

Task 1: Trace Rating

At the beginning of the experiment, the participants will be given some tracing samples (see Appendix: Trace Rating Task). The samples will differ in qualities such as their smoothness, maximum distance off the given trace line, etc. The participants will then be asked to rate each sample tracings based on their tracing accuracies and explain their rationales.

We recorded their ratings and generalized how artists perceive a line as being accurate.

Task 2: Line Tracing

Next, the participants will be instructed to do the line tracings tasks (Figure 2). The trace line varies in length, slope, and direction. Each participant will complete the line tracing task in 10 runs of the eight directions of lines, totaling to 80 lines drawn. A test run will be conducted at the beginning of each session to familiarize the participant with the interaction technique. The participants are instructed to draw the lines as quickly and accurately as possible while staying within the proper pressure. The participant will see the line they are supposed to follow (trace line) as well as the line they are drawing (user line) so they have instant feedback on how far they have deviated from the trace line. Similarly, the users will have a green circle to show the desired pressure (50% of maximum pressure registered by the device), and a grey circle that shows the users actual pressure. They can use this as instant feedback to correct their pressure if necessary.

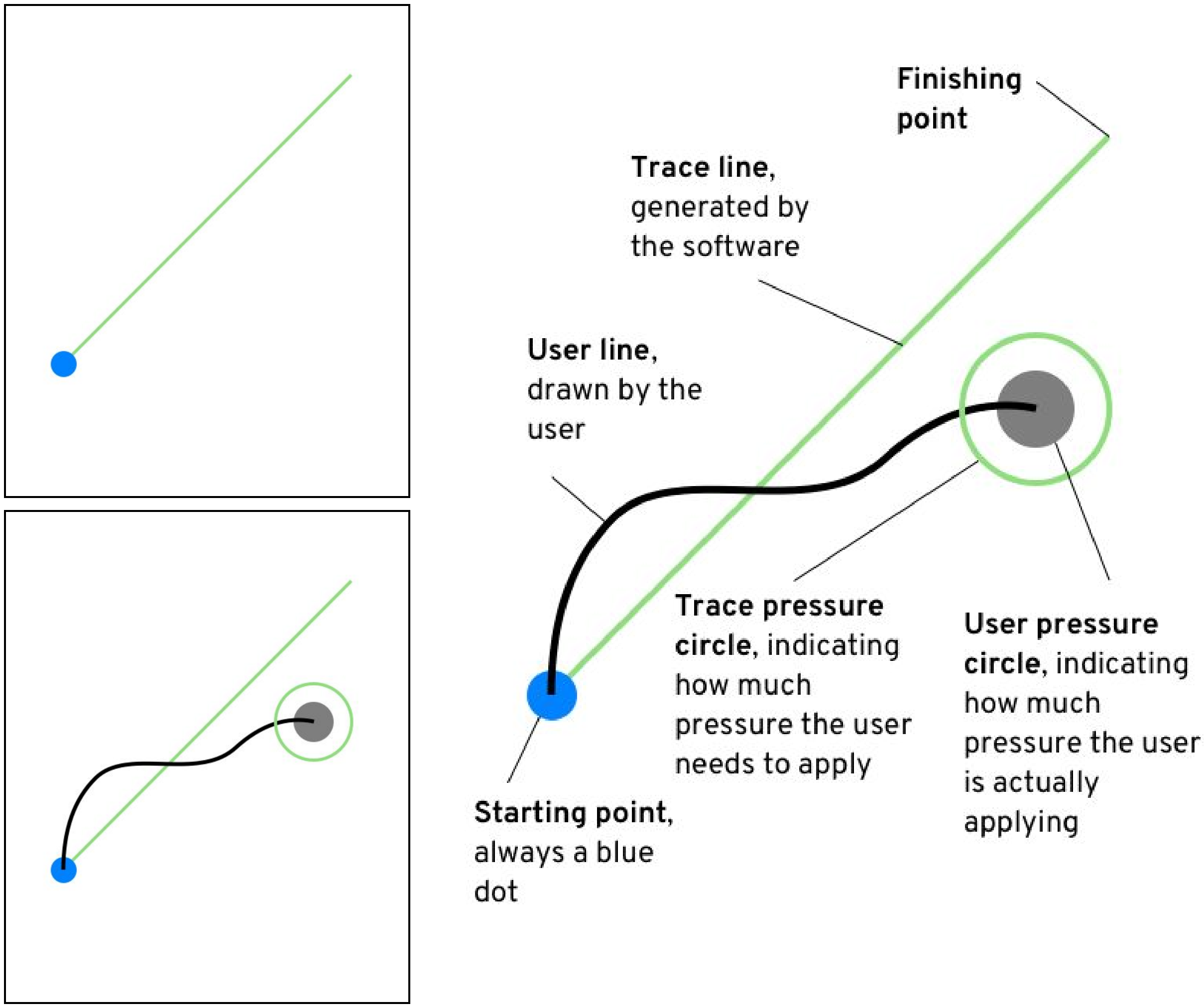


Figure 2: software interface during Task 2: Line Tracing. Top left: Before the participant starts to stroke. Bottom left: while the participant is stroking. Right:while the participant is stroking, annotated.

We will measure the speed, which can be calculated relative to the length of the trace line, and the amount of time the user spent on finishing a single test line. We will also measure the accuracy, which is determined by the distance between the test line coordinate and the trace line coordinate. Lastly, we will measure the pen-tip pressure for the devices that are pressure-sensitive.

Task 3: Dot Connecting

Finally, we would like to test our participants' ability to draw straight lines. This differs from the line tracing task. In the dot connecting task, we remove the trace line and instead specify a beginning and end point of the line segment (Figure 3) for the participants to draw a line between on their own. The participants are instructed to draw the lines as quickly and accurately as possible while staying within the proper pressure. While they will not have the trace line as a reference, the users will still have a green circle to show the desired pressure (50% of maximum pressure registered by the device), and a grey circle that shows the users actual pressure. They can use this as instant feedback to correct their pressure if necessary.

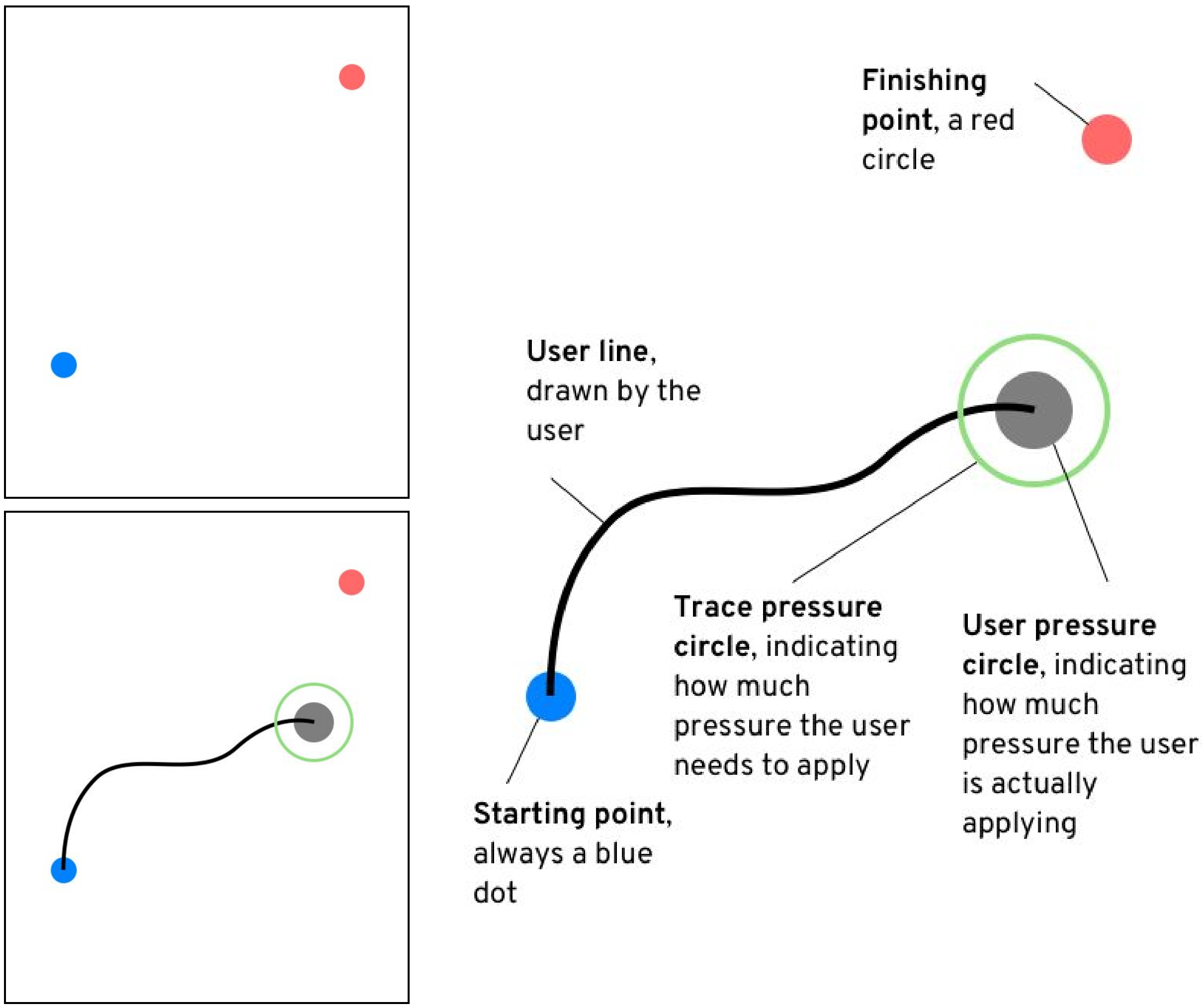


Figure 3: software interface during Task 3: Dot Connecting. Top left: Before the participant starts to stroke. Bottom left: while the participant is stroking. Right:while the participant is stroking, annotated.

During our interview with a psychology professor, we realized that compared to Line-Tracing, Dot-Connecting closely resembles what an artist might be actually doing while creating their 2D drawings. Instead of having a trace line where they would be able to make "local corrections", this task forces people to aim at their target carefully.

Each participant will complete the dot connecting task in 10 runs of the eight directions of lines, totaling to 80 lines drawn, also We would use the same metric for quantifying data as specified in the line tracing task.

Test Software

We developed our own test software as a web application (Figure 4). Using some basic algebra knowledge, we are able to implement the line-tracing task and the dot-connecting task using the html `<canvas>` tag. A link to the software code is attached in the Appendix: Assets.

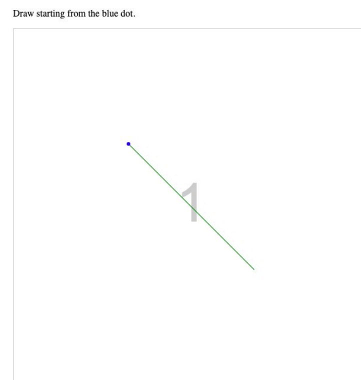


Figure 4: a screenshot of the software. The number at the center serves as an indicator of the participants' progress.

Questionnaire

We will end our experiment by asking our participants about demographics and their experiences with the interaction techniques in the past. We will ask them to evaluate the trade-offs between each interaction technique tested during the experiment. A sample questionnaire is attached at the end of the report (Appendix: Experiment Questionnaire).

Result & Discussion

Using Numbers, Apple's equivalent of Microsoft Excel, we performed several data visualizations on the data we gathered, which resulted in some interesting findings: [1]

1. "Area under curve" impacts an artist's judgment on accuracy the most.
2. Some Directions Are Harder To Draw
3. For some people, the pressure is consistent within an individual no matter what the task is
4. Speed-precision tradeoff

Insight 1: "Area under curve" impacts an artist's judgment on accuracy the most.

During task 1: Trace Rating, artists tend to rate those with a higher "area under curve" (Figure 5) with a lower score. That is, the further the user line deviates from the trace line, the worse the artists think the line is traced. However, artists disagree with each other when it comes to the smoothness of the curve. Some artists factor smoothness a lot into their ratings, while other artists appear to be not heavily influenced by it.

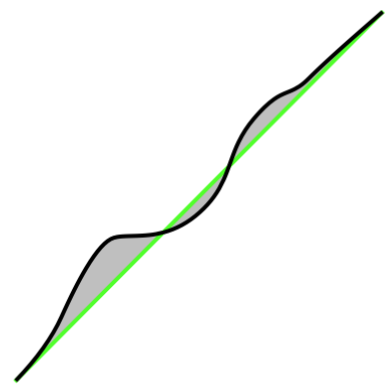


Figure 5: "Area under curve". The dark line denotes the user line, the green line denotes the trace line. The grey area in between them is the "area-under curve".

[1] During the class we also talked about "Artists' accuracies are fairly stable across time." However, a more careful examination of the data revealed that it was not significant enough to conclude it.

Insight 2: Some Directions Are Harder To Draw

During the data analysis phase, we found that some certain directions are harder to draw. Participants drawing in direction #4, #5, and #7 (Figure 6) either took longer time to finish their stroke, deviate a lot from the given trace line, or both.

How do we measure their performance in each direction? For a given participant and a given direction, we calculate the average time it takes to finish a line stroke and the average distance between the user line and the trace line. Multiplying the time and distance together, we were able to obtain a rough estimate of their **performance score**. The higher the performance score is, longer and more inaccurate participants stroked in the experiment, and the worse they draw.

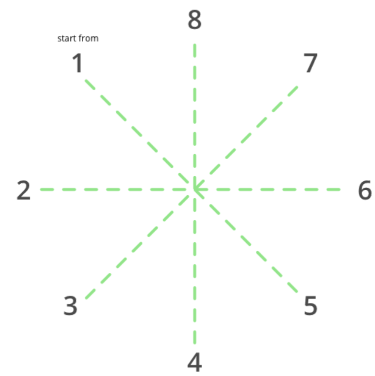


Figure 6: Eight directions the participants drew during the experiment.

Table 2: The direction in which the participant has the highest performance score
* Note that participant 4 performed equally bad on direction #4, #5, #7, with only a 1% difference between their performance scores. (Other directions listed in this table differ from their second-to-worst by 6% ~ 23% in their performance score)

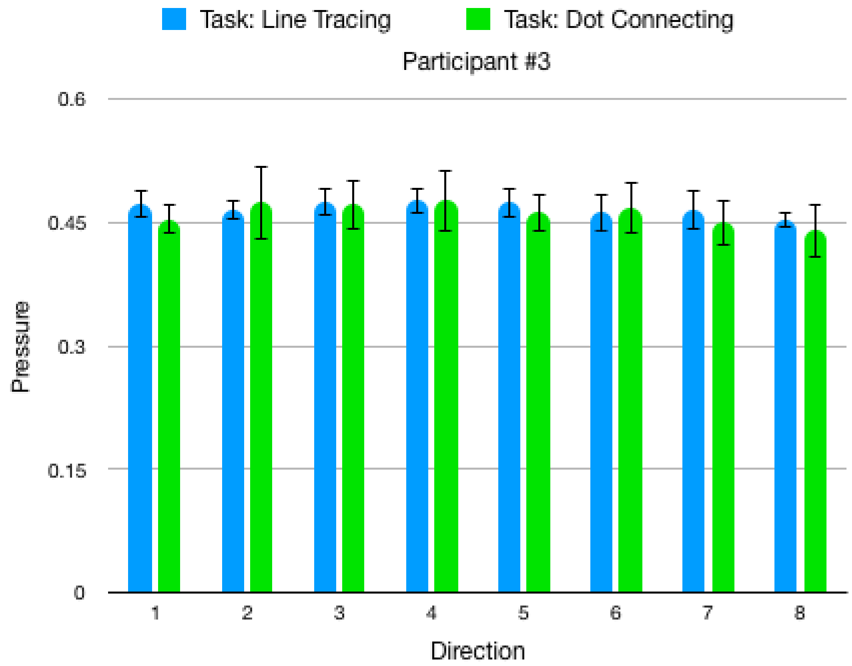
	Participant 1	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
Task 2: Line-tracing	4	5	4	4,5,7 *	8
Task 3: Dot-connecting	7	8	5	7	3

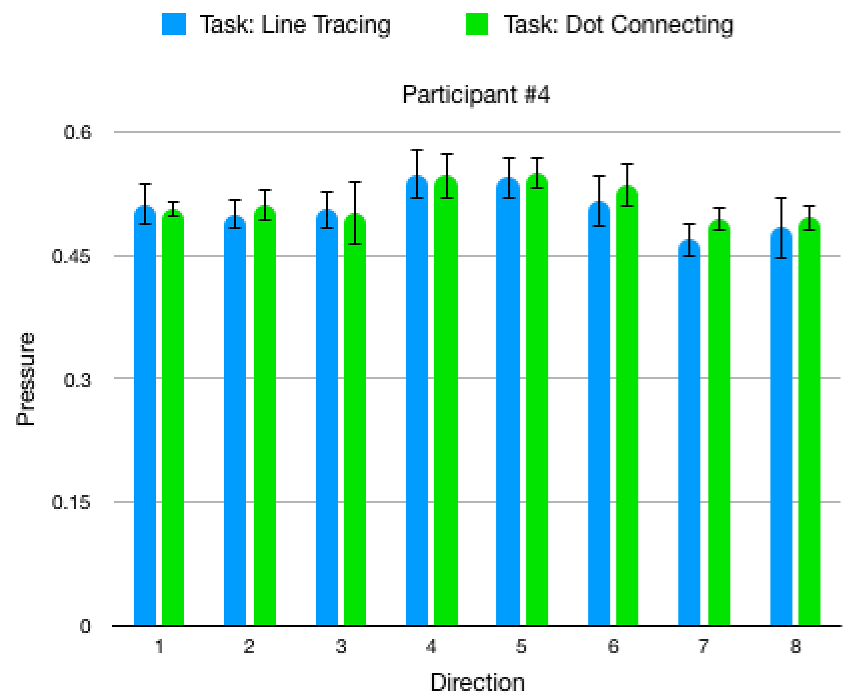
As we can see in the Table 2, direction #4, #5 and #7 occur more frequently. This is suggesting that #4, #5, #7 have a higher performance score, and thus are harder to draw.

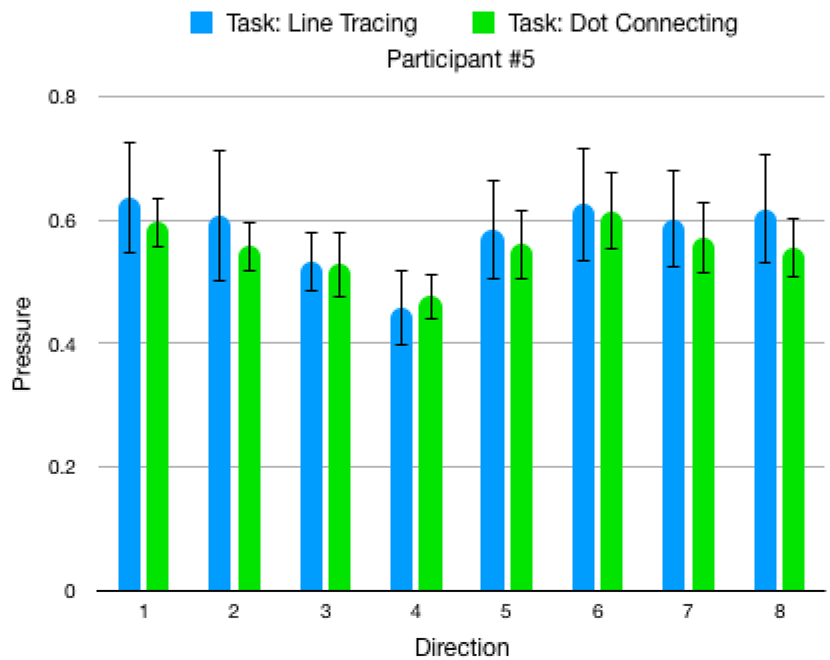
Insight 3: The pressure is consistent within a individual no matter what the task is

Due to some technical problems with JavaScript, we were only able to collect the pressure tracing data from participant #3, #4 and #5. Among all of them, we found that they tend to apply the same amount of pressure in a given direction (Figure 7, note that #3 has a “stable hand”, which makes the pressure differences hardly noticeable.)

Figure 7: Average pressure applied in each direction by Participant #3, #4 and #5







This is similar to what we had in Insight 2: people apply different strategies while drawing, and the amount of art training they received, as well as their natural hand structures, can affect the pressure they applied to their pen tip. However, this "pressure trait" is not as obvious when it comes to speed and accuracy metrics.

Insight 4: Speed-precision tradeoff

The two drawing tasks, Line-Tracing and Dot-Connecting, differ from each other in that people attack the two drawing tasks differently (Table 3 and Figure 8).

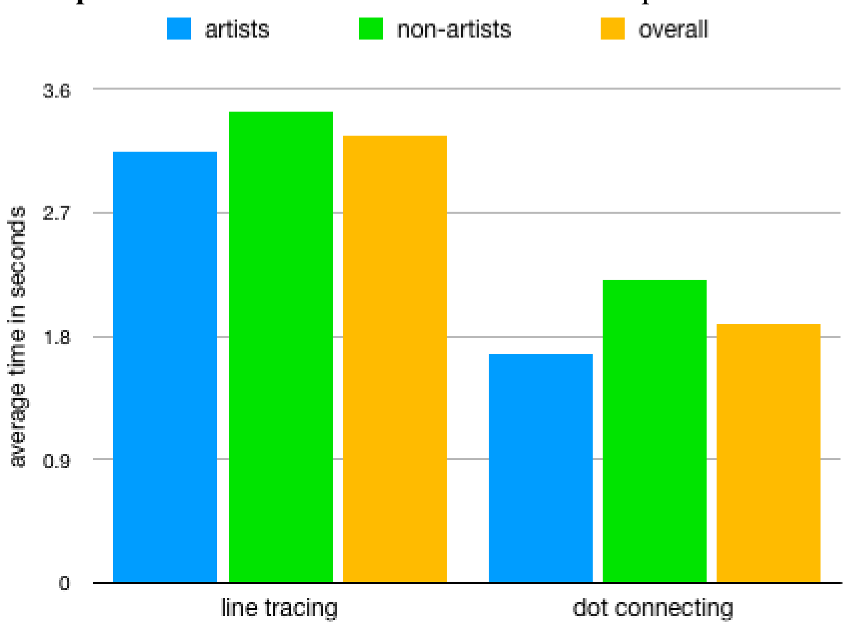
In general, artists draw both faster and more accurate than non-artists. However, when they are doing the line-tracing task, both artists and non-artists tend to focus on their accuracy; when they are doing the dot-connecting task, both tend to focus on the speed.

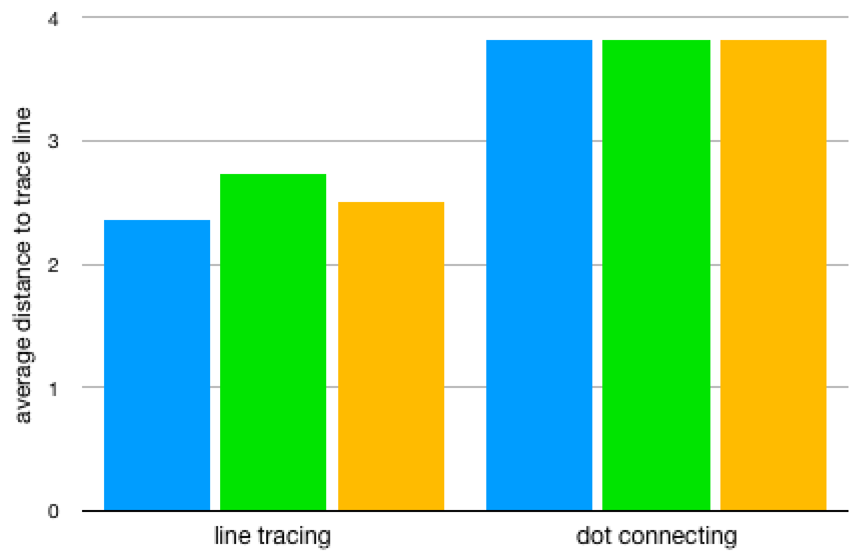
This results in the well-known speed-accuracy tradeoff, which has been found in other literature too: in Gowen and Miall's 2006 study, it was found that people have small saccades in front of the moving pen during tracing tasks; when it came to drawing, however, the gap between saccades grew larger. It is thus suggested that tracing "demands continual comparison between the line to be traced and pen tip, which in turn requires the continual transfer of this visual information to the hand movement system." Drawing, on the other hand, has less emphasis on visual feedbacks and memory-guidance would play a more critical role. (Gowen & Miall, 2006)

Table 3: Average time per stroke and distance to trace line of each participant.

Task	Line Tracing		Dot Connecting	
Metric	**Time (s)**	**Distance (pixel)**	**Time (s)**	**Distance (pixel)**
Participant 1	3.04891043749638	2.5041015032225	2.23752175000037	3.48875717535702
Participant 2	2.98686500000087	2.21657648113079	1.48595556961899	3.49609547618539
Participant 3	3.4112268125055	2.38285579809214	1.31513125000285	4.49106793040588
Participant 4	2.821190499997	3.60224482312125	2.13829151898481	4.49509499058076
Participant 5	4.06709874999812	1.86059421042974	2.2766368125	3.15281622019709
average of each metric				
artists	3.14900075000092	2.36784459414847	1.67953618987407	3.82530686064943
non-artists	3.44414462499756	2.73141951677549	2.20746416574241	3.82395560538892
overall	3.26705829999957	2.51327456319928	1.8907073802214	3.82476635854523

Figure 8: Bar chart of the average time per stroke and distance to trace line of each participant. This is a data visualization of Table 3 presented above.





Future Work

This case study points us several potential interesting directions for future studies.

Extensive Study

This experiment is a case-study, with some conclusions that may or may not be generalizable to a larger scale. We would like to see the experiment performed on a larger scale and reach statistically significant conclusions.

Potential In Using Hand Drawings As A Form Of Biometrics

The insight #3 points us to a potential direction: if people have certain "patterns" in their drawings, is it possible to identify a person from the way they apply pressures to the pen tip while drawing? Hook, Kempf & Scharfenberg developed a biometric smartpen prototype that logs both pen pressure and inclinations for people's handwriting tasks, which indicates some potentials in using the stylus for biometrics in online signature tasks (Hook, Kempf & Scharfenberg, 2004). Would their prototype be applicable when it comes to hand drawings?

Left-Handedness

In this experiment, all our participants happened to be right-handed. Are the conclusions applicable to left-handed people? Are insight #2 and insight #3 going to be simply mirrored when it comes to left-handed people?

Compare Direct Interactions to Indirect Interactions

Due to technical limitations, we only tested participants on the Wacom Tablet, an indirect technique. Because so many of the interviewees in the research interviews noted anecdotally that there is a large learning curve for the indirect devices whereas direct devices are more natural, it would be interesting to see how users (both artists and non-artists) perform on both devices for comparison.

References

1. Sutherland, Ivan Edward. “Sketchpad : a Man-Machine Graphical Communication System .” *Dept. of Electrical Engineering, Massachusetts Institute of Technology*, 1963. Print.
2. The 5 Best Digital Pens for Artists in 2019 (For Ergonomics and Quality). *SecretAsianMan*. 02-19-2019 [04-10-2019] https://www.secretasianman.com/best-digital-pen-for-artists/
3. Armstrong, Rebecca. Best Smart Pens 2019 - Digital Pens for Sketching, Note-Taking. *TopTenReviews*. 01-31-2019. [04-10-2019] https://www.toptenreviews.com/electronics/family/best-digital-pens/
4. COLEMAN, C. “Digital inking”: how to make perfect line drawings on computers. *Organisms Diversity & Evolution*. 2003, 3 (4): 303–304. doi:10.1078/1439-6092-00081
5. Coyne, Richard; Park, Hoon; Wiszniewski, Dorian. Design devices: digital drawing and the pursuit of difference. *Design Studies*. 2002-05, 23 (3): 263–286. 10.1016/S0142-694X(01)00038-2
6. Hinckley, Ken; Cao, Xiang; Izadi, Shahram; Guimbretiere, Francois; Benko, Hrvoje; Song, Hyunyoung. Grips and Gestures on a Multi-Touch Pen (CHI '11 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems). ACM: 1323–1332. 2011-05-09.
7. Lee, David & Son, Sophie & Hyub Lee, Joon & Bae, Seok-Hyung. (2012). PhantomPen: Virtualization of pen head for digital drawing free from pen occlusion & visual parallax. *UIST'12 - Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology*. 10.1145/2380116.2380159.
8. Gowen, Emma; Miall, R. Chris. Eye–hand interactions in tracing and drawing tasks. *Human Movement Science*. 2006-10, 25 (4-5): 568–585. 10.1016/j.humov.2006.06.005
9. Hook, Christian; Kempf, Juergen; Scharfenberg, Georg. A Novel Digitizing Pen for the Analysis of Pen Pressure and Inclination in Handwriting Biometrics. *Biometric Authentication (Springer Berlin Heidelberg)*. 2004: 283–294. 10.1007/978-3-540-25976-3_26

Some thoughts come from the Interaction Technique lecture notes.

Appendix: Research Interview Questions

Demographic Questions

1. What do you study? Which year are you in? (For Students)
2. What do you teach? How long have you been teaching? (For Professors)
3. What kinds of mediums do you use to do creative work? (if any)

Technology Specific Questions

4. What art technologies do you use? How frequently do you use each and when did you start?
5. Which one do you prefer and why?
6. Are there any pain points in specific technologies?
7. Other technologies you would want to try out but not having a chance yet?
8. Tell us about your learning curve with creative technologies?

Interaction Technique Specific Questions

9. What interaction techniques are involved in digital art?
10. What drawing techniques are involved?
11. Are there any pain points in specific interaction techniques?
12. At what point of deviation far from a trace line, do you become frustrated?

Appendix: Experiment Questionnaire

Participant's Bio (Student / Major or Professional)

Participant's Age

Years of Formal Art Education

Field of Creative Study

Participant’s most frequent creative medium(s) (pen on paper, pencil on paper, watercolor, Illustrator, etc.). Include the length of use and tasks involved.

Participant's dominant hand? Have there been any major hand injuries in the dominant hand?

Experiences with the interaction techniques tested during the experiment:

- Have you used this technique?
- How many years?
- What kind of tasks would you use this for?
- Thoughts on this input device for the tasks in this experiment?
- While doing 2D drawings, what is your body positioning? Do you sit, stand, lying on the bed? How do you hold the pen in your hand?
- What do you like/dislike about the input method?

Appendix: Script for Testing

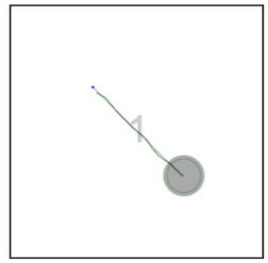
1. **Introduction**
   My name is __, and this is an experiment for my Interaction Technique class term project. We expect this experiment to last for 15 to 20 minutes. The purpose of the experiment is to test the speed, accuracy, and pressure of a stylus when 2D artists are working on digital drawings. During the experiment, we will be measuring the time, coordinates, and pressure of the pointing device. At the end of the entire experiment, we will issue a questionnaire to collect demographic information.
   Please note that this is a test on the input device, and we are not testing your ability to draw. We will not be logging any personal identification information.
   Before we begin do you have any questions?
2. **First Task: Trace Rank**
   On the paper, there are examples of tracing similar to what you will be doing in the digital test. The green line is the trace line that a user is supposed to draw, and the black line is what the user actually draws. How would you rank the accuracy of these tracings, from 1 to 10, with 1 being the worst, and 10 being the best?
3. **Second Task: Drawing Test - Computer**
   a. *Practice*
      First, you will do a quick practice stimulation of the recorded tests to get you familiar with the pointing device and test. You will go through both the line tracing and dot connecting tasks with 16 lines for each task. This practice test results will not be recorded and is a shortened version of real practice.
      You should draw in the same way that you usually draw.
      i. For the line-tracing task, you will be drawn starting from the blue dot and follow the green line until the end.
      ii. For the dot-connecting task, you will be drawing a straight line starting from the blue dot to the red dot without the assistance of a trace line.
   b. *Real Test*
      After the completion of the practice test, we will run the recorded test. Unlike the practice runs, during these tests, your data will be logged. You will go through both the line tracing and dot connecting tasks with 80 lines for each task.
4. **Questionnaire**
   Now that the tasks are complete, we will issue a questionnaire to collect demographic information. We are collecting background information of participants to help see the trends between participants with different level of artistic expertise.
5. Thank you very much for your participation!

Appendix: Trace Rating Task

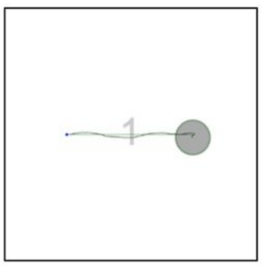
Trace Ranking Task given to Participants

Trace Ranking Task

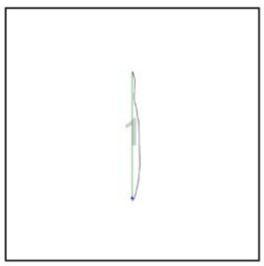
These are examples of line traces you will be preforming in the test. This will be used as a subjective measure of accuracy to compare to the qualitative results. How would you rank the accuracy of these tracings, from 1 to 10, with 1 being the worst, and 10 being the best?



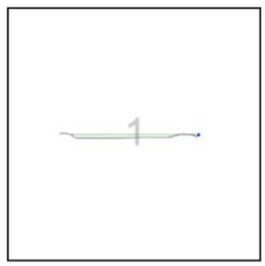
1. /10



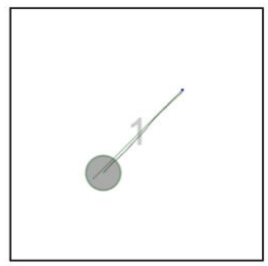
2. /10



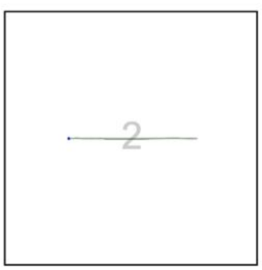
3. /10



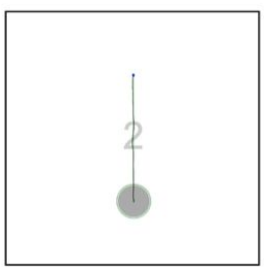
4. /10



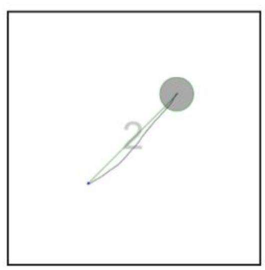
5. /10



6. /10

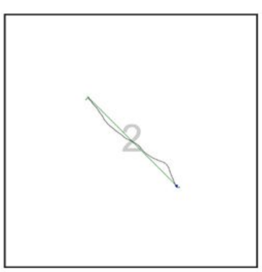


7. /10

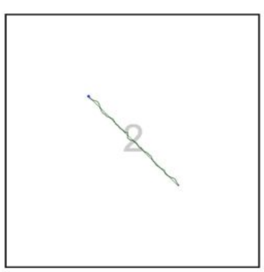


8. /10

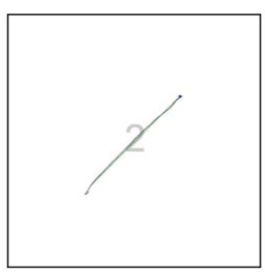
9. /10



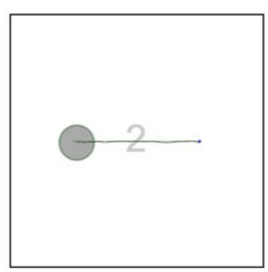
10. /10



11. /10



12. /10



13. /10

Appendix: Assets

Practice runs: https://huayunh.github.io/resources/IxT/test.html?runs=2
Real runs (Both Task 2 & Task 3): https://huayunh.github.io/resources/IxT/test.html
Github link to the source code:
https://github.com/huayunh/huayunh.github.io/tree/master/resources/IxT
The technology only works for the Google Chrome browser.

Link to final presentation Google Slides
https://docs.google.com/presentation/d/1cSGHvOrBTsAWlfjOavLutR-qAyPTSsyXOQ4tRSz2huY/edit?usp=sharing