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Developing App Features for Figure Drawing Practice

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Developing App Features for Figure Drawing Practice

A Major Qualifying Project

submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the
Degree of Bachelor of Science In Computer Science

By

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Abstract

DrawSession is a website where people can practice figure drawing. The goal of this project was to develop new features for DrawSession, so that the website can become a viable tool to practice figure drawing. These features were derived from research on deliberate practice, figure drawing, progressive web apps, and prior related work. Two observational studies were conducted in order to evaluate DrawSession with the inclusion of those features. Ultimately, the new features were well received, but further research about visual art teachers can be performed in order to revise DrawSession for a wider audience.

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1. Introduction

1.1. DrawSession's Origin

Figure drawing is a common discipline for artists, and some attend life drawing sessions to practice this speciality. At a life drawing session, artists gather around a model and draw them from different perspectives. Occasionally, the model will change their pose.

A drawback that I initially perceived with life drawing sessions is that one had to travel to them, wherever and whenever they are held. Previously, I went to life drawing sessions offered by the Worcester Art Museum and found that it was often hard to attend on a regular basis; they often conflicted with my university course schedule. Eventually, the museum suspended the life drawing sessions, and I could only find alternative sessions offered by C.C. Lowell, located farther than I was willing to travel and with a more expensive admission price.

With that in mind, I created a website that emulates a life drawing session, called DrawSession. DrawSession accomplishes this by generating an image slideshow of poses. I developed DrawSession with the hope that it would be a more accessible alternative to life drawing sessions; with it being a website, one could practice figure drawing from wherever they browse the web. In addition to being more convenient, DrawSession is customizable; the pose slideshow can be customized using tags to include only certain sexes or body positions. Therefore, a user could draw, for example, male models that are standing one day, then draw female models that are sitting the next day or whenever they believe they are satisfied with their ability to draw standing male models.

1.2. Incorporating Deliberate Practice

DrawSession emulates the "present a pose every interval" aspect of a life drawing session, but as I continued to use DrawSession, I was dissatisfied with how slowly I was improving my drawing ability. While pondering how I could improve faster, I remembered some particular benefits of life drawing sessions that I have not incorporated into

DrawSession. During the life drawing sessions at Worcester Art Museum, a faculty member would ask the model to pose such that attendees could practice drawing them in different conditions (e.g. under chiaroscuro lighting). The faculty member would also set the duration for how long each pose should be held; typically the first poses of a session would be held for seconds, so that the attendees could warm up before moving on to poses that are held for minutes.

Recommending poses for attendees to draw, presumably for more effective practice, is an exemplar of a principle of deliberate practice. Deliberate practice involves practicing tasks meant to push one out of their comfort zone, and the learning approach has gained popularity for more than a decade. Theoretically, deliberate practice for figure drawing can be done with DrawSession by customizing the pose slideshow. Users aren't required to use that feature, but I do think there is some merit to revising DrawSession such that users are encouraged to incorporate deliberate practice in their figure drawing routine.

1.3. Project Goal

The goal of this project was to develop new features for DrawSession so that it can better serve its function to emulate a life drawing session and become a viable tool to practice figure drawing. In order to identify these features, I produced a literature review on deliberate practice and figure drawing curricula, as well as other applicable domains. Next, I implemented features within DrawSession's existing technology stack as specified in Appendix B. Finally, I conducted observational studies with a small, yet diverse demographic; study participants were instructed to perform tasks using DrawSession. By implementing these new features and observing how people interacted with said features, I hoped to learn more about how technology available for individual use can contribute to visual arts education.

2. Literature Review

The design of DrawSession, and future iterations of it, is inspired by prior research on deliberate practice and figure drawing curricula. In this section, I will give an overview of those domains, as well as the inception of progressive web apps and prior work that is comparable to DrawSession.

2.1. Deliberate Practice

Deliberate practice is a particular approach to practicing a skill, in order to improve towards achieving expertise. This approach was derived from professor Anders Ericsson's research on experts in their respective domains, after Ericsson found that the experts he observed shared certain principles in their approaches to improve their performances. After journalist Malcolm Gladwell's published his 2008 book *Outliers: The Story of Success* with a more compelling interpretation of deliberate practice, the learning approach quickly permeated popular culture, from numerous self-help books based on Ericsson's research being published within a year of *Outliers* publication¹ to song lyrics being written with the concept of deliberate practice in mind².

Ericsson and his colleagues initially defined deliberate practice in their 1993 paper "The Role of Deliberate Practice in the Acquisition of Expert Performance" through the following conditions (p. 367):

- The task(s) to be practiced should take into account the preexisting knowledge of a practitioner so that the task can be correctly understood after a brief period of instruction.

¹ Daniel Pink's *Drive* (2009), Daniel Coyle's *The Talent Code* (2009), and Geoff Colvin's *Talent Is Overrated* (2010) are examples of such books.

² Dan + Shay and Justin Bieber's song "10,000 Hours" debuted at No. 4 on the Billboard Hot 100 (Trust, 2019).

- The practitioner must have enough motivation “to attend to the task and exert effort to improve their performance”.
- The practitioner should receive immediate informative feedback and knowledge of results of their performance.

Further publications by Ericsson, including his 2016 book *Peak: Secrets from the New Science of Expertise* describe additional observations of experts partaking in deliberate practice, including that (p. 98–100):

- The experts’ respective domains had criteria for determining which of their performers were excelling.
- The experts typically had teachers (who were familiar with effective training techniques for their respective domains) design tasks for practice.
- The experts practiced tasks that pushed them out of their comfort zone.
- The experts practiced tasks in order to reach well-defined, specific goals (often set by teachers) that led them to expertise.
- The experts responded to feedback on their performance by developing efficient mnemonics for their current knowledge.

Despite studying experts that were among the top performers in their respective domains, Ericsson did not find talent, whether it be genetics or otherwise intangible, to be a contributor to their expertise beyond skill introduction (Ericsson & Pool, 2016, p. 233). Because deliberate practice typically pushes practitioners out of their comfort zone, their bodies will adapt, whether it be by training muscles or developing more efficient mnemonics. And if those practitioners will eventually become experts, they will have practiced to the point that any effect talent may have on their performances will be overtaken by their expertise acquired through practice.

Ericsson does acknowledge that not everyone will have an opportunity to follow all of the principles of deliberate practice as observed from experts, access to an informed teacher being a notable concern (Ericsson & Pool, 2016, p. 157). However, Ericsson believes that

following at least some of those principles when practicing a skill will be more effective than practicing without alteration to their regimen (Ericsson & Pool, 2016, p. 11–14).

In summary, if one wants to learn a skill that has established training techniques, it can be done with deliberate practice, which consists of performing tasks with sufficient motivation to focus on those tasks. Those tasks are designed with the practitioner's prior knowledge, ideally by a teacher, and are meant to push them out of their comfort zone so that they can reach specific goals to lead them towards expertise. As a result of performing those tasks, the practitioner will develop mnemonics to retain their newfound knowledge. Finally, in order to ensure that the practitioner's goals are being met, the practitioner must receive timely feedback on their performance and modify their attempts in response. Ideally, a teacher will identify problems with the practitioner's performance and suggest ways to address those problems, but eventually as they develop more efficient mnemonics, the practitioner will be able to identify and address those problems on their own.

2.2. Figure Drawing Curricula

This literature review will frequently refer to Brown and McLean's *Drawing From Life* (2004) in order to provide a background in figure drawing. This publication has been advertised as "The leading textbook for figure-drawing classes" (Brown, Publications) and has been used in liberal arts colleges such as the College of the Holy Cross and Wheaton College in Massachusetts. However, it should be stated that curricula can vary by instructor and environment, and that this section is meant to give an overview of commonly taught figure drawing fundamentals in western culture.

Figure drawing is the act of producing a representation of the human figure through mark-making tools such as pen and paint. Figure drawing has been formally taught since the founding of the Accademia del Disegno in 1563 (Brown & McLean, 2004, p. 4). This tradition continues today in part because the knowledge acquired from figure drawing can be applied towards other visual arts; Brown and McLean (2004) state that "The human figure, perhaps

more than any other image, presents the artist with the greatest opportunity to explore all elements of visual arts with a single subject” (p. 6).

Some of those elements are described by Brown and McLean (1992) as “conceptual drawing tools”, named for how they can convey impressions of the figure that vary as much as those from “physical drawing tools” (e.g. pen, paint) (p. 9). They are as follows (Brown & McLean, 1992, p. 9–19):

- Line: a mark made by a physical drawing tool
- Value: the range of tones from light to dark
- Form: the three-dimensional volume and structure of a subject
- Space: the three-dimensional volume around and between forms
- Texture: a representation of tactile appearance
- Pattern: the sequential arrangement of shapes, values, and textures over a broad area
- Color: the visual perception of light reflected from the surface of objects

Practitioners in figure drawing will also have learned visual art elements that are more fundamental to figure drawing, such as gesture, structure, and anatomy.

2.2.1. Gesture

Gesture is an expression of a figure’s pose (Brown & McLean, 2004, p. 257). Artists practice their ability to visualize gesture by performing gesture drawing.

Gesture drawing is the act of creating sketches that transcribes a figure’s kinetic energy (Brown & McLean, 2004, p. 20–23). These sketches are often observed to possess a lot of movement and energy and conveys a major idea from the figure’s body language. When gesture drawing, an artist typically draws lines that follow the figure’s movement. They will attempt to see the figure as a whole, so that they can recognize how the figure’s movement is made possible by the arrangement of the figure’s body parts in space.

Experts in figure drawing are able to visualize gesture immediately; when they perform gesture drawing, they are able to make lines as if through intuition, without any lengthy analysis of the figure.

2.2.2. Structure



Figure 1 "Capture of Jesus Christ" by Luca Cambiaso, dated between 1550 and 1575

Structure can be defined within the context of visual art as a simplification of a figure's form into basic three-dimensional shapes, such as cubes and cylinders. Structure applied to figure drawing can be used to more easily convey a figure's form and space, as the orientations and positions of cubes and cylinders in space are easy to perceive by

their edges receding towards vanishing points.

Structure can also be drawn with perspective devices in order to better represent "three-dimensional objects and depth relationships on a two-dimensional surface" (Brown & McLean, 2004, p. 47). These devices include overlapping, when one object is drawn on top of another in order to suggest that the former is in front of the latter in space, and size differentiation, where one object is drawn smaller than another in order to suggest that the former is farther away in space than the latter.

Experts in figure drawing often have "go-to" shapes to convey a figure's body parts (e.g. cuboids for the rib cage and the pelvis, cylinders for the limbs).

2.2.3. Anatomy

While (human) anatomy within the context of visual art is still concerned with the structure of the human body, artists typically use their knowledge of anatomy to capture the surface of the figure accurately and denote landmarks from the human skeleton when figure drawing.

We perceive the human body by any light that reflects off of its surfaces. Artists that are fluent in their knowledge of anatomy can also interpret the figure's form even when the figure is illuminated in a manner that is unusual. Experts in figure drawing are not limited to recording the pattern of light and shadows as they fall across the figure and are instead free to use value to depict anatomical features in what they imagine is ideal.

This dichotomy of applying value toward depicting anatomy can be rephrased as two drawing processes: rendering and modeling (Brown & McLean, 2004, p. 82–84). Rendering refers to the “recording” approach to applying value, where the artist is as objective and like a camera in that they are only aware of reflected light when drawing the figure. Modeling refers to the “imaginative” approach to applying value, where the artist is like a sculptor, using darker tones to express surface indentations, even reinventing anatomical features if it makes for a better composition.

Every figure has a unique form; artists use skin protrusions made by the skeleton to orient themselves when visualizing the figure. These landmarks are present even if the figure has a bulky physique³. In his 1994 book *The Vilppu Drawing Manual*, artist Glenn Vilppu diagrams common landmarks such as corners of the rib cage and the edges of the iliac crests. These landmarks can give a sense of where a line of symmetry goes through the figure, starting from the head into the torso. They also hint at spatial relationships between larger anatomical features.

³ Whether it is the result of building muscle or fat.

2.3. Deliberate Practice Applied to Figure Drawing

The premise that deliberate practice can be applied to figure drawing assumes that figure drawing has criteria for excellence and established training techniques. This assumption corresponds with prerequisites for deliberate practice.

Such criteria for evaluating figure drawing may not qualify for deliberate practice, if the act of evaluating art cannot be proven to be objective. In her 2018 book *How Art Works: A Psychological Exploration*, professor Ellen Winner recounts several studies⁴ in which researchers investigated whether judgements of art are objective (p. 106–113). The studies she recounted could not conclude that judgements of art are objective or even believed to be, regardless of participants' cultural backgrounds or general education. And yet, occupations such as an art critic and museum curator exist to shape artistic canon.

Is it worrisome that no consensus on criteria for evaluating art can be reached without resorting to cultural teachings? Within the context of deliberate practice and figure drawing, it should not be a concern.

Anders Ericsson remarked that individual sports, “such as gymnastics, figure skating, or diving”, are domains that are eligible for deliberate practice (Ericsson & Pool, 2016, p. 98). But in spite of its presence in the Winter Olympics since 1908, figure skating has a history of modifying its criteria for excellence; in particular, the International Skating Union implemented a then new scoring system for Olympic figure skating competitions in 2002 in response to judging collusion taking place that year. Even with the ISU Judging System in place to this day, it has received criticism for rewarding “risk and difficulty over artistry” (Vuelta, 2018).

It can be inferred from Ericsson's approval of figure skating that criteria for excellent figure drawing does not have to be objective or final. That doesn't suggest that there isn't any criterion that can be relied upon when figure drawing practitioners require feedback on their

⁴ Including a 1964 study by professor Irving Child, in which he showed and asked participants to judge pairs of paintings with similar subject matter. The pairs had already been judged by 12 specialists.

work. Figure drawing has been an institution for centuries, and to this day instructors include art from the Renaissance in their curriculums. It has been debated whether the inclusion of certain Renaissance artwork in artistic canon is based on frequent exposure to said artwork by art connoisseurs and their predecessors, but perhaps this exposure is warranted because they are exemplars of fundamentals taught in figure drawing classes, such as gesture, structure, and anatomy.

After reviewing studies and opinions on evaluating art, Winner (2018) favored philosopher David Hume's opinion that "works considered great and that stand the test of time are objectively higher in quality than works failing the test of time" (p. 105, 124). Brown and McLean (2004) remark that in the context of figure drawing, "Quality is something we experience in a comparative sense", although they do define some "general traits" that contribute to the quality of a drawing: authenticity, presence, enhancement, economy, and creative insight (p. 248–249). Even if none of these traits indicate a drawing's quality⁵, practitioners of figure drawing can refer to artistic canon and their previous work in order to solicit feedback. A number of figure drawing instructors also exist to help, as figure drawing has existed long enough to establish training techniques, such as the tradition of life drawing sessions and memorizing anatomical landmarks as visual aids.

Before concluding this overview on deliberate practice and figure drawing, it is worth directing some skepticism towards deliberate practice. Deliberate practice has been demonstrated to be effective as it is derived from experts' routines, and with its prominence in popular culture, deliberate practice seems to be sufficient for any practitioner aiming to become an expert, even in figure drawing. Winner (2018) disputes this claim, believing talent to be a larger factor than previously thought in determining who becomes an artist (p. 226–232). She cites "precocious achievement in drawing" by children with biological characteristics

⁵ Winner (2018) discussed philosopher Dennis Dutton's list of features that characterize typical works of art as published in his 2009 book *The Art Instinct: Beauty, Pleasure, and Human Evolution* (p. 9–14). She concluded that Dutton's list cannot define art because not all features are necessary to a particular work of art, the features can describe entities outside of art, and the list only applies to art included in artistic canon.

shared by adult artists as evidence of talent contributing to artistic development, as well as the children's innate motivation to draw without provocation.

Journalist David Epstein is also a critic of deliberate practice; in his 2019 book *Range: Why Generalists Triumph in a Specialized World*, Epstein deconstructs the notion of following deliberate practice as closely as possible. Epstein (2019) argues that there are very few domains eligible for deliberate practice⁶ as most domains provide feedback that is “delayed, inaccurate, or both” (p. 21). In lieu of deliberate practice, Epstein (2019) advocates for practitioners to rotate between domains, as “Modern work demands knowledge transfer: the ability to apply knowledge to new situations and different domains” (p. 45).

2.4. Progressive Web Apps

User engagement is said to be characteristic of progressive web apps. Pinterest, self-described as a "visual discovery engine" company, reported that after their engineers rewrote their mobile website as a progressive web app, their weekly active users of their mobile website increased by 103 percent after a year (Argyle, 2018). As one of the principles of deliberate practice requires a practitioner to be motivated, there could be features common to progressive web apps that may be beneficial for DrawSession to adapt for its purposes.

What defines a progressive web app can vary among advocates of progressive web apps. Frances Berriman and Alex Russell, who coined the term "progressive web app", came to the conclusion that progressive web apps have these attributes (Russell, 2015):

- Responsive: to fit any form factor
- Connectivity independent: progressively-enhanced with Service Workers to let them work offline

⁶ Performers in domains typically brought up in testimonials of deliberate practice, such as musical performance, ballet, and chess (Ericsson & Pool, 2016, p. 98), are susceptible to narrow specialization; although the rigidity of each domain's rules allows performers to develop efficient mnemonics, those mnemonics only help performers solve issues they had already encountered (Epstein, 2019).

- App-like-interactions: adopt a Shell + Content application model to create appy navigations & interactions
- Fresh: transparently always up-to-date thanks to the Service Worker update process
- Safe: served via TLS to prevent snooping
- Discoverable: are identifiable as “applications” thanks to W3C Manifests and Service Worker registration scope allowing search engines to find them
- Re-engageable: can access the re-engagement UIs of the OS; e.g. Push Notifications
- Installable: to the home screen through browser-provided prompts, allowing users to “keep” apps they find most useful without the hassle of an app store
- Linkable: meaning they’re zero-friction, zero-install, and easy to share

In his own article written in response to Berriman's subsequent article about where the term "progressive web app" came from, Jeremy Keith wrote that he believes a website that (a) is served over HTTPS; (b) has a manifest file; (c) uses a service worker, is a progressive web app (2017).

What constitutes a progressive web app will shift as more web developers continue to adopt the concept. However, I believe Berriman put it best in her retrospective of the term’s origin. To summarize her position, while some developers claim that progressive web apps should still be considered websites rather than apps, she argues that it is more important that other people perceive the websites as app-like, being as valid as native apps (Berriman, 2017).

2.5. Competitors

There are several websites that share DrawSession's purpose to enable figure drawing practice. Their design informs DrawSession’s design, including features implemented during this project.

Line of Action⁷ is perhaps the most popular competitor to DrawSession. Like DrawSession, it generates an image slideshow of poses from a wide array of criteria (Kim,

⁷ Accessible at <https://line-of-action.com/practice-tools/figure-drawing>

2018). Users can also specify how long they will be practicing for, thereby leaving Line of Action to determine how long each pose should be shown for. However, Line of Action's implementation of this feature is basic; each of the five durations users can choose to denote practice length is mapped to a predetermined set of pose durations. While these sets of pose durations are based on typical life drawing sessions, it is assumed that these pose durations are applicable for all users. Line of Action also allows users to register for a forum account for drawing critiques.

Quickposes⁸ also generates a pose slideshow from criteria. Quickposes also promotes a desktop version of itself for users who want to practice figure drawing offline. Quickposes also incentivises users to practice on the site frequently by offering certificates based on how long they practice for.

Pinterest is a website for sharing and creating collections of images, not necessarily for practicing figure drawing. Many artists find Pinterest to be a great resource in finding poses and other image references to draw from. Although Pinterest does not directly compete with DrawSession and other websites for figure drawing, some of Pinterest's features may prove to be worthwhile for DrawSession to take inspiration from.

For example, when a user views an image on Pinterest, the website also shows related images. Therefore, a user can use this feature as a roundabout method to search for images, with the advantage of using an image for their query. Pinterest has since allowed users to search from within images and whatever images they take with their phone (Zhai, 2015, 2017). It may be beneficial to allow DrawSession users to perform "visual searches" as well to specify pose criteria.

⁸ Accessible at <https://www.quickposes.com/en>

3. Methodology

The methodology for this project consists of implementing new features for DrawSession and evaluating their inclusion through user testing. Overall, this took place over the course of approximately three months.

3.1. Implementation of New Features

During the process of reviewing deliberate practice, figure drawing, and other relevant domains, I planned to implement the following features described below:

- Provide recommendations for poses based on previous site visits
- Cache extra poses so that DrawSession can be used offline
- Prevent DrawSession from showing a pose twice by storing past poses as hashes
- Create a Web App Manifest for DrawSession
- Superimpose landmarks on a figure using pose estimation
- Provide a plumb line

These features were identified for their relation to the reputation of progressive web apps or established training techniques for figure drawing. The sequence in which these features were implemented over the course of two months were based on amount of labor, which included allotted time to learn prerequisite web development concepts. I describe each feature in more detail in the following subsections, as well as explain my reasoning for implementing them and how I attempted to implement them.

3.1.1. Web App Manifest

A web app manifest is a JSON file that identifies a website as a progressive web app. Valid attributes in which a developer can assign values for include the app's name and branding icons (MDN Contributors). A developer can also declare attribute-value pairs that specifies how a web browser should alter its appearance, when a website installed on a device

is launched. As native apps do not have web browser widgets such as an address bar, I thought it was important to include a web app manifest with DrawSession in order to minimize the presence of widgets and have DrawSession be perceived as app-like.

The web app manifest included with DrawSession can be found in Appendix C. Attributes to take notice of are “display”, “background_color”, and “theme_color”. The “display” attribute determines which of four “display modes” should a web browser’s user interface chrome adhere to. The “background_color” attribute defines a placeholder background to display as a web browser waits for assets necessary to render the DOM tree. The “theme_color” attribute sets a color that may be reflected in a web browser’s user interface chrome or a device’s application switcher.

3.1.2. No Duplicate Poses

Preventing DrawSession from showing a pose twice, while being a relatively minor feature in scope, is important if the app is to emulate life drawing sessions. Obviously in a life drawing session, the model doesn’t make the same pose twice. Not that attendees would want to draw the same pose twice; what with the limited time allotted per session.

Perhaps more important than the feature itself, is how the implementation of this feature can coincide with the implementation of features with wider scopes like having offline poses and pose recommendations. Keeping track of poses previously shown to a user may require client-side storage if the hashes identifying the poses must persist after the user closes their browser. Client-side storage could also hold images of poses, and the hashes could also be used to create pose recommendations.

Traditionally, client-side storage in the context of web browsing was done with cookies. To create a cookie, a developer assigns an attribute-value pair to the “Set-Cookie” HTTP header in an HTTP response sent by the related website’s server. A cookie can persist after a visitor closes their browser if a “Expires” or “Max-Age” directive is set.

A criterion that I had while searching for a client-side storage solution was that it would be able to handle hundreds of kilobytes per item stored. A cookie is only specified to store at

least 4 kilobytes of data, and at least 50 cookies are to exist per domain (Barth, 2011).

Nowadays, browsers have access to JavaScript APIs dedicated to persistent client-side storage, Web Storage and IndexedDB, which have fewer security vulnerabilities and can store more data.

A mechanism within WebStorage called `localStorage` also stores items as attribute-value pairs, being capable of storing at least 5 megabytes of data across all major web browsers (Kitamura, 2014). However, as the final client-side storage solution would need to store different types of items, `localStorage` would not be a suitable client-side storage solution since it only supports character strings for values.

That would leave IndexedDB as the remaining client-side storage solution. IndexedDB allows for the creation of object stores, which gives the impression that using IndexedDB is akin to creating nested JavaScript objects. Unfortunately, IndexedDB's API has a reputation for being inaccessible to developers due to its low-level design; developers are encouraged to utilize a library that abstracts IndexedDB's API such that it requires fewer extraneous function calls or even resembles the APIs of other storage solutions such as Web Storage or SQLite.

Examples of IndexedDB wrapper libraries include `localForage`, which abstracts IndexedDB into "a simple, `localStorage`-like API" (`localForage` Contributors, n.d.), `Dexie`, which has a more concise API than native IndexedDB and supports more advanced queries (`Dexie` Contributors, n.d.), and `idb`, which makes minor improvements to IndexedDB such as adding JavaScript promise support (`idb` Contributors, n.d.). Ultimately, I chose to use `idb` in my implementation of this "no duplicate poses" feature because of the three libraries, it had the most thorough documentation, with Google developing videos on the library as part of its developer advocacy efforts (Google Chrome Developers, 2019).

The code I wrote to initialize and modify the object store for tracking hashes of previously shown poses can be found in Appendix D. When `DrawSession` is launched for the first time on a device, an IndexedDB object store, called "session", is initialized in the "componentDidMount" method in `DrawSession.jsx`. This object store represents individual visits to `DrawSession`, akin to acts of attending a life drawing session. Afterwards, and on

subsequent launches, an object with an empty array property is added to the store. This array, called “series”, represents series of poses that are shown during a site visit; poses in a series are shown sequentially until the user elects to stop for a break or to leave⁹.

The “series” array is populated with “series” objects in the “handleSessionStart”, “handlePoseTimerExpire”, and “handleSessionStop” methods¹⁰. A “series” object has the following properties:

- `startTime`: a Date instance that indicates when the first pose in the series was shown
- `endTime`: a Date instance that indicates when the user elected to stop the series of poses from being shown
- `selectedTags`: an array of tag names selected by the user as pose criteria for the series
- `selectedDuration`: the number of milliseconds each pose in the series should be shown for
- `poses`: an array of “pose” objects, each with a pose’s hash and attributed tags

Unfortunately, idb does not make the process of populating object stores easy; for each modification to the “session” object store, I had to write code to (a) await for the connection to the database containing “session” to be ready; (b) prepare a database transaction; (c) retrieve the current “session” with the transaction, before making any assignments. Despite having prepared an IndexedDB object store for storing hashes of poses, I decided that it would be easier to use an array that is initialized inside the scope of `DrawSession.jsx` instead, since I judged that having duplicate poses between sessions (rather than during a session) would be acceptable.

So I initialize the “hashes” array in the “componentDidMount” method of `DrawSession.jsx`. The server which hosts `DrawSession` sends images of poses as HTTP responses attached (through HTTP headers) with a SHA-256 hash of the image and JSON of the

⁹ It may be helpful to think of the relationship between a series and a pose as analogous to a set and repetition from fitness terminology.

¹⁰ In hindsight, the method names “handleSessionStart” and “handleSessionStop” are misnomers; perhaps they should be “handleSeriesStart” and “handleSeriesStop” instead.

pose's attributed tags. Whenever a new pose is about to be shown, its hash is pushed into the "hashes" array in the "setNewModel" method of DrawSession.jsx. On subsequent requests for poses (done through the "fetchNewModel" method of DrawSession.jsx), the "hashes" array is appended as part of a URL query string, to tell the server what poses to exclude when querying for a new pose.

3.1.3. Offline Poses

A website that is available and works when there is low connectivity or offline is an attribute commonly ascribed to progressive web apps. If offline functionality does portray progressive web apps as being app-like, then access to poses offline would legitimize DrawSession as a viable tool to practice figure drawing.

Unfortunately, I didn't complete the implementation of this feature within the project's timeline. Implementing this feature would've required creating a service worker, a background script that intercepts requests to the server. This service worker could then be used to cache DrawSession assets while the internet is available, including poses, and serve said assets when a user tries to access the website while offline.

While learning about service workers, I came across a collection of libraries intended to streamline service worker initialization, called Workbox. Workbox can generate a service worker that performs tasks developers typically write service workers for such as caching assets on worker initialization and re-routing requests (Workbox Contributors, n.d.). I was able to use Workbox to implement a service worker that would allow offline users to access DrawSession's user interface. However, I wasn't able to determine how to make background requests for extra poses without blocking the single JavaScript thread DrawSession operates on.

3.1.4. Pose Recommendations

As mentioned before, a faculty member from the Worcester Art Museum life drawing sessions would ask for a pose based on what attendees had drawn so far. I believed that a

feature similar to that training technique could be implemented for DrawSession, by taking user feedback in the form of their regular interactions with the website and recommending poses based on that feedback.

The code I wrote to capture user interactions and make recommendations of poses to draw can be found in Appendix D. As I mentioned before, DrawSession is currently using IndexedDB and idb for client-side storage. A user can interact with DrawSession by selecting tags, setting the duration for poses to be shown, and starting and stopping a series of poses from being shown. These interactions are captured as “series” objects stored in an IndexedDB object store.

Whenever a user elects to stop a series of poses from being shown, in the “onSessionStop” method of DrawSession.jsx, DrawSession checks whether the user had been drawing poses that were (a) shown during this session; (b) of the pose criteria they specified immediately before this particular series; (c) shown for more than twenty minutes. If so, DrawSession adds to an array a notification that recommends the user to specify different pose criteria for their next series of poses. This array is passed to a “Dashboard” React component, which renders the contained notification above the “tag selection” control.

3.1.5. Plumb Line

In a virtual environment, images of poses can be manipulated to help users analyze figures. I had a conversation with professor Cristi Rinklin from the College of the Holy Cross about how DrawSession could best serve users in their figure drawing routines; Rinklin commented that with poses held for longer durations, users would have more time to draw poses that typically were not held for those durations in real life and use features that did image manipulation (personal communication, September 26, 2019).

One example of a “pose manipulation” feature that was brought up in our conversation was to allow users to playback poses in motion, frame-by-frame, as if they were looking through Eadweard Muybridge’s photographs from his studies in locomotion. Such a feature could require knowledge in high-speed photography, but a more achievable feature that was

also mentioned was a line that users could drag over the image of a pose. The feature is analogous to a plumb line, and it should share the same purpose in the context of figure drawing to help users perceive spatial relationships between anatomical features of the figure.

The code I wrote to implement the “plumb line” React component can be found in Appendix E. `Plumb.jsx` is imported by `PoseViewport.jsx`, which renders an image of a pose and any manipulations made to it. `PoseViewport.jsx`, in turn, is imported by `DrawSession.jsx`, the React component encompassing all of the client segment of `DrawSession`.

The “plumb line” component imports Framer Motion in lieu of `react-spring` in order to animate itself as it is dragged. Although Framer Motion has better support for SVG attributes, `react-spring` and Framer Motion still perform UI animation similarly, both libraries even animating “outside of React's render lifecycle” (`react-spring` Contributors, n.d.; Framer Motion Contributors, n.d.). Unfortunately, any animation bugs caused by Framer Motion, such as the plumb line moving too fast in relation to a user’s cursor or finger, cannot be fixed easily without direct manipulation of the DOM, which would interfere with how React works.

3.1.6. Superimposed Figure Landmarks

This feature was inspired by the TensorFlow team’s release announcement of a machine learning model that would allow human pose estimation to run on a web browser. TensorFlow is an ecosystem of tools, libraries and community resources that helps developers build and deploy machine learning models (TensorFlow Contributors, n.d.). Among its ecosystem, TensorFlow has a JavaScript library with pre-trained models for body segmentation, pose estimation, and more.

Superimposing landmarks of a figure onto an image of a pose was implemented by deploying a machine learning library for pose estimation using `TensorFlow.js`. Human pose estimation refers to techniques used to estimate the position and orientation of human figures in images or videos by detecting their body joints or landmarks. Taking an image of a human figure as input, `TensorFlow.js` will output a `Pose` object with an array of two-dimensional body

joint/landmark coordinates and a confidence score as its members. These coordinates can then be used to draw a makeshift “skeleton” of the figure using SVG¹¹.

The code I wrote to deploy pose estimation on an image of a pose and to superimpose a makeshift “skeleton” on that image can be found in Appendices D and F respectively. When a new image of a pose is ready to be shown, I get the body joint/landmark coordinates in the “setNewModel” method of DrawSession.jsx and pass them to PoseViewport.jsx within a React component property. In PoseViewport.jsx, I normalize the coordinates such that they align with the coordinate system of a SVG element, assign to each pair of coordinates one of three categories (head, upper body, and lower body), and render the makeshift “skeleton” as the SVG element with colors that correspond to the specified categories.

3.2. Study Protocols

In order to evaluate DrawSession after the implementation of features specified for this project, I conducted two similar but distinct observational studies. Both studies instruct study participants to perform tasks using DrawSession and are preceded or proceeded by different surveys with questions on participants’ backgrounds and study performances. Both studies’ participants were members of the Worcester Polytechnic Institute community, including students, faculty, and staff, and were over the age of 18. All participants were informed before participating in how the studies would generally proceed and what risks the studies could present (exposure to nudity from images of nude models, in particular).

The first observational study took place on October 28, 29, and 31, from 6:00pm to 9:00pm EST. Members of the Worcester Polytechnic Institute community could register for a 20 minute appointment with me at the George C. Gordon Library in order to participate. I provided a laptop capable of running DrawSession, sheets of 14" by 17" drawing paper, 2 Conté pencils, a 0.5mm fineliner, a 1mm marker, and a plastic eraser as study equipment.

¹¹ In the release announcement I mentioned, there are images of such “skeletons” being implemented using TensorFlow.js (Oved, 2018).

The survey questions I asked participants of the first observational study before starting the study can be found in Appendix G. These questions assess a study participant's background in deliberate practice and figure drawing. They also provide a rough indication of what consumer technologies are used by this "study participant" demographic and whether impairment may have affected the study results.

After a study participant completed that survey, I gave an overview on gesture drawing and a demonstration on how to use DrawSession before instructing them to draw 4 poses from DrawSession, that last for 1 minute. The study participant was free to select any tags to determine whatever poses were shown. After their attempt to draw the 4 poses, I offered the study participant a break before instructing them to draw 2 additional poses from DrawSession, that last for 2 minutes.

The survey questions I asked participants of the first observational study at the end of the study can be found in Appendix G. These questions provoke a study participant to reflect on their performance during the study.

The second observational study took place on November 2, from 12:00pm to 3:00pm EST, about 2 days from the first study. Participants of the first observational study could register for a 20 minute appointment with me at the George C. Gordon Library in order to participate. The equipment for this observational study is the same as that of the first study.

Once again, I instructed study participants (of this second observational study) to draw 4 poses from DrawSession, that last for 1 minute, then 2 additional poses, that last for 2 minutes. The survey questions I asked participants at the end of this second observational study, again for performance evaluation, can be found in Appendix G.

Once again, the study conductor will ask the research subject to navigate through DrawSession and draw from a series of poses. Study conclusion will be within 20 minutes. Upon conclusion, the research subject will complete another survey that asks them to evaluate their experience with using DrawSession, including whether they had used it between studies and whether they would continue to use it.

4. Study Results

12 members of the Worcester Polytechnic Institute community participated in the first observational study. User advocate Jakob Nielsen once claimed that product evaluations should be performed with no more than 5 users at a time; the amount of insight gained from an evaluation diminishes as more users are involved, especially after 5 users (2000). I view Nielsen's claim as assurance that I recruited enough study participants to qualitatively evaluate DrawSession with the inclusion of features implemented for this project.

I am also confident that I've recruited a diverse group of study participants. Although I did not ask any study participant to give their race or gender when registering for the observational studies, I can state that the group of study participants cannot be characterized by a single race and that its gender ratio is about the same as that of Worcester Polytechnic Institute's student body during the 2018–2019 academic year¹² (WPI Institutional Research, 2019).

As a study participant used DrawSession, I made observations on how the participant interacted with various user interface controls and drew poses. To start, all study participants understood and completed their tasks of drawing four 1-minute poses and two 2-minute poses; this provides additional support to the notion that DrawSession successfully emulates a life drawing session if members of a university known for science and technology could quickly grasp onto DrawSession's concept.

8 of the 12 study participants had expressed interest in figure drawing as a skill according to my surveys. 4 of the 12 actively participated in a hobby related to visual art. I also asked study participants what figure drawing concepts they knew, but ultimately what their initial drawing abilities were before their participation would be revealed by observing how they draw their first poses from DrawSession.

Although I assumed that the study participants would most likely not have formal training in figure drawing, I was impressed that some participants were able to draw what they

¹² About 1.8 males for every female.

perceived in a pose without relying on their knowledge of the stereotypical human and its appearance¹³. But regardless of drawing ability, each study participant used a unique combination of conceptual drawing tools when drawing their poses. What follows are accounts of participants' drawing efforts:

- One participant focused on capturing a figure's form; the resulting silhouette was appealing.
- Another participant used long, unbroken lines to outline what I describe as blob-like stick figures.
- Yet another participant used lines that were clustered together as a pattern to indicate the motion of a figure.
- One more participant's drawings had a texture similar to a cartoon one might see in *The New Yorker*.

My final observation in regards to the study participants' drawing abilities is that although I gave them an overview on gesture drawing and limited time to draw, I don't believe the study participants could finish what they intended to draw of their poses often, nor were their drawings somewhat as energetic as a typical gesture drawing. This is likely due to inexperience with gesture drawing, but I will say that I did not notice any substantial improvement in drawing ability from participants of the second observational study.

As for how study participants interacted with various user interface controls, my overall observations are that demonstrations of DrawSession were necessary in order to encourage study participants to interact with all of the controls, including the "plumb line", and participants of the second observational study remembered how to use DrawSession without asking for help. Those demonstrations were not scripted, so if I neglected to mention how tags work, a study participant would not attempt to select tags. If a study participant did interact

¹³ Brown and McLean bring up preperception, "the storing of visual concepts", in their figure drawing textbook (2004, p. 46). Preperception helps people recognize objects, but can cause them to perceive the appearances of those objects inaccurately. Preperception is what encourages people to draw faces as smileys rather than portraits typical of artistic canon.

with a specific feature and attended the second observational study, they would most likely perform that feature during the second study.

What follows are additional observations on participants' interactions:

- Some participants did not use the “plumb line” feature on purpose because (a) it was too sensitive to the participants' touch; (b) manipulating it takes too much time; (c) they were concentrating on drawing; (d) it did not fit with their approach to drawing.
- Pose estimation was done accurately on images of models that were standing.
- Pose estimation was inaccurate too often for the superimposed figure landmarks to be of much use.
- It wasn't easy to determine whether selecting one tag as well as another corresponds to a logical conjunction or a logical disjunction between the two tags.

To conclude this section, I present the results of the surveys the 12 study participants completed, as tables and figures and presented in order of when the related question was asked.

Theater, Drawing, Video Games, Improvisational Comedy
Traveling, baking, spending time with family & friends
Reading, writing
hiking, biking, reading, CAD
Binge Watching
Basketball, Greenhouse and Horticulture Club, various programming projects, working out, video games
Drawing, Rugby
Painting, Travelling, Listening to Music
Fencing, weightlifting, church, videogames
Language learning
Tinkering, Tutoring, Career Development Coach
art

Table 1 Responses to "What hobbies do you actively participate in?"

If you wanted to learn a new skill, which of the following choices would you solicit feedback from? (Rank by priority.)

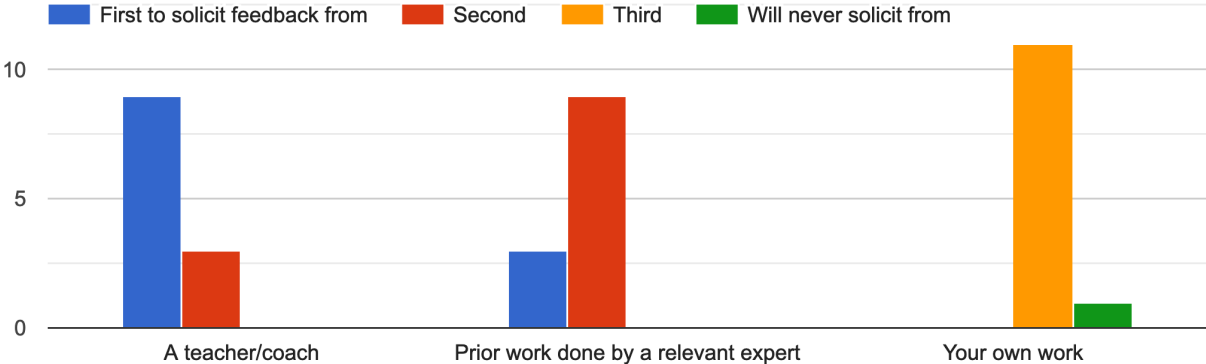


Figure 2 Responses to "If you wanted to learn a new skill, which of the following choices would you solicit feedback from? (Rank by priority.)"

Are you interested in figure drawing as a skill?

12 responses

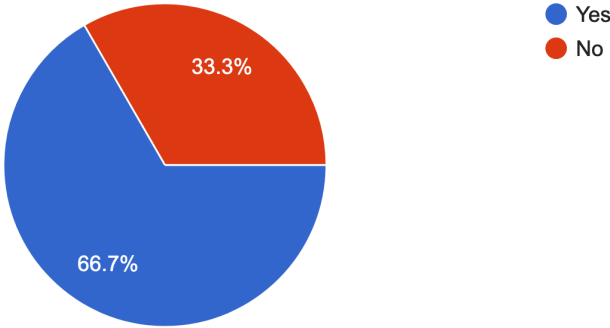


Figure 3 Responses to "Are you interested in figure drawing as a skill?"

Please indicate whether you are familiar with the following concepts as they relate to figure drawing.

12 responses

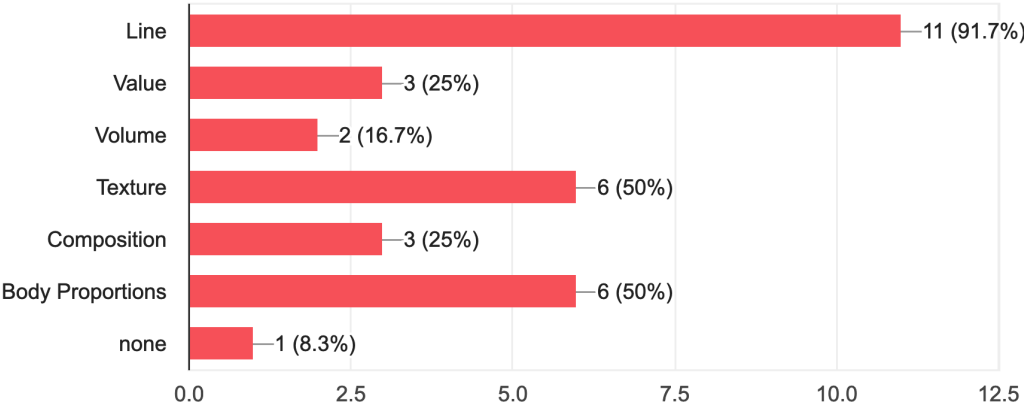


Figure 4 Responses to "Please indicate whether you are familiar with the following concepts as they relate to figure drawing."

What personal computing devices do you regularly use?

12 responses

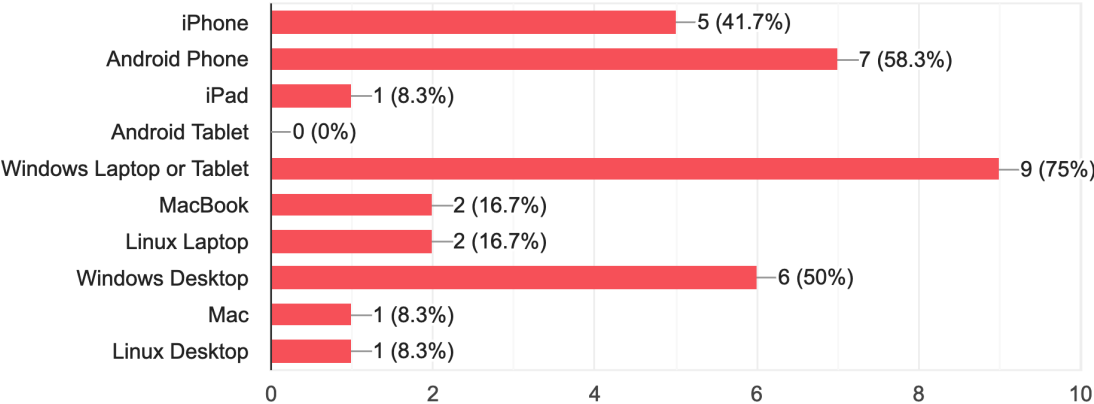


Figure 5 Responses to "What personal computing devices do you regularly use?"

What web browsers do you regularly use?

12 responses

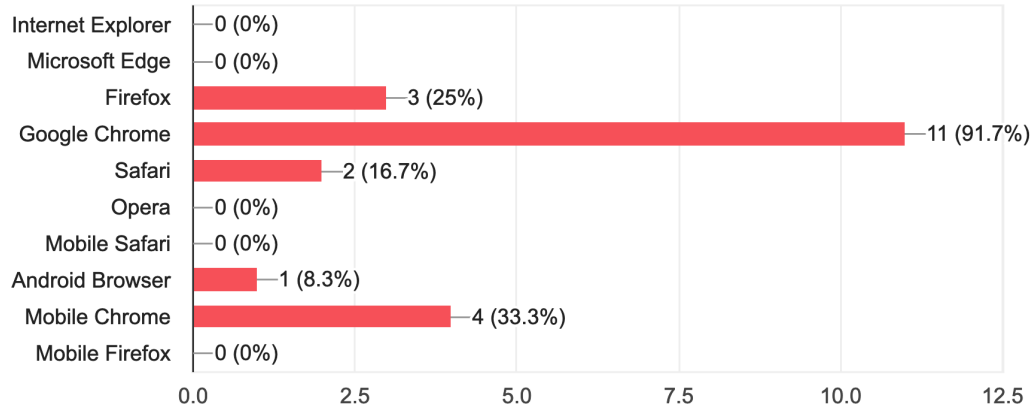


Figure 6 Responses to "What web browsers do you regularly use?"

Do you have an impairment that you believe affects your ability to visually perceive?

10 responses

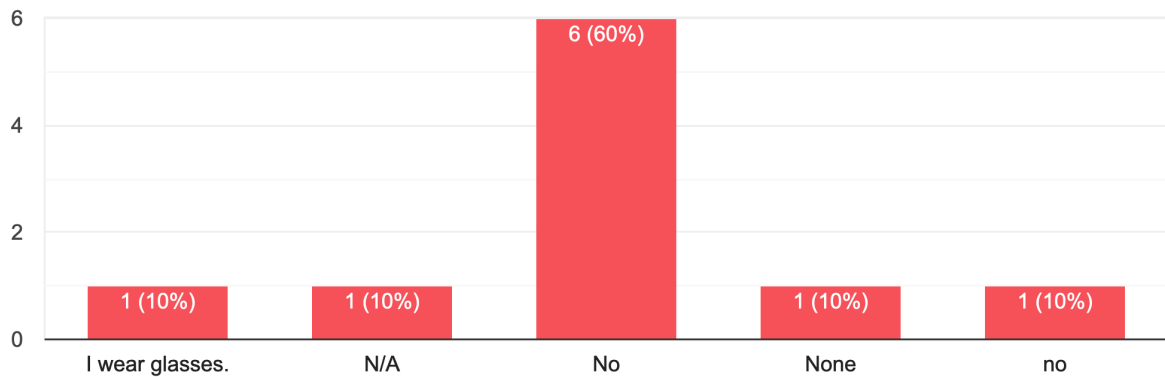


Figure 7 Responses to "Do you have an impairment that you believe affects your ability to visually perceive?"

Do you have an impairment that you believe affects your motor skills in using a drawing tool?

10 responses

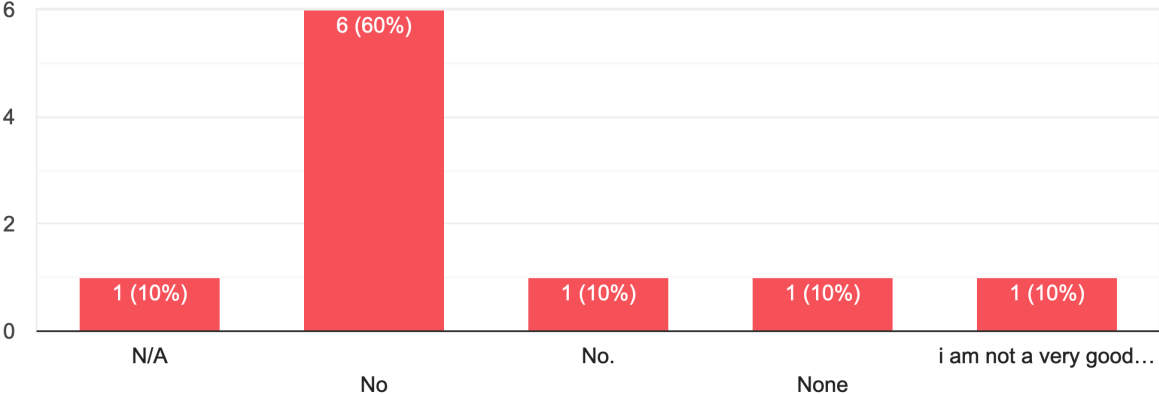


Figure 8 Responses to "Do you have an impairment that you believe affects your motor skills in using a drawing tool?"

Do you prefer websites that present themselves as a browser page or as an app with its own window?

12 responses

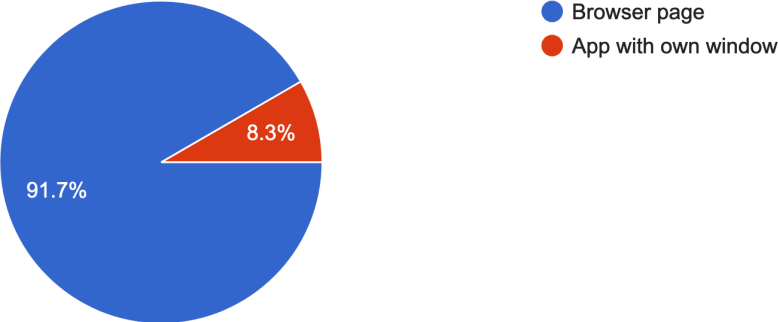


Figure 9 Responses to "Do you prefer websites that present themselves as a browser page or as an app with its own window?"

Line and general form of the figure, greater emphasis on making sure the lines follow their direction of motion
Body proportions and lines
i was trying to get the general shape of the head, torso and limbs, typically without much detail into each unless time permitted, giving a general idea of body shape
I tried to focus on getting the outlines and the flow of the poses in the drawings I made.
Line and Body Proportions and Composition
I tried to capture the general outline of the poses with an emphasis on what the person was doing
Standing and Crawling
Lines and body proportions, Basically tried to get the skeleton of the human and add muscles to it based on proportions.
I was trying to get the general outline of the people I was drawing first
Outline, body proportions
Mostly focusing on getting the body of the figures and the volume and for the later drawings I also thought more about the lines.
I wanted to focus on the lines, composition, and body proportions. These I think are essential to capture the movement of the body on the poses drawn with the time constraints.

Table 2 Responses to "In general, what aspect of the poses were you trying to capture with your figure drawings?"

Not really, I mostly went by looking for the line of motion for each limb
Yes, I tried to see where the hand and leg positions were and tried to imagine them proportionate to the actual body while drawing the figure.
i had a general idea of the typical z-axis positions that the poses would have. I also thought the general shape of the arms was helpful to quickly draw the arm shape (though not details like muscle etc) after drawing the head shape.
Not really- I used the stick guides in some poses.
I as aware of the 3-dimensional space that was being drawn in two-dimensions
I used the line available in the application to figure out where things were in vertical relation to each other
I would pay attention for when legs overlapped, or how arms were placed in relation to chests.
Yes I did see that for 2 mins drawings, I could not use that mnemonics for 1 min drawings.
The shadows would help out figuring out which non-overlapping parts of the body were closer/ farther away
No
I used size to depict the distance of objects and the direction of the stroke in the places they were overlapping to help indicate what was the objects direction and position
I used mnemoics in how the different body postures would overlap in the images. This allowed me to correctly proportion the body parts even if it seemed odd at first when drawing them shorter, longer, etc.

Table 3 Responses to "Did you use mnemonics while figure drawing?"

Do you believe that your gesture drawings improved as the study progressed?

12 responses

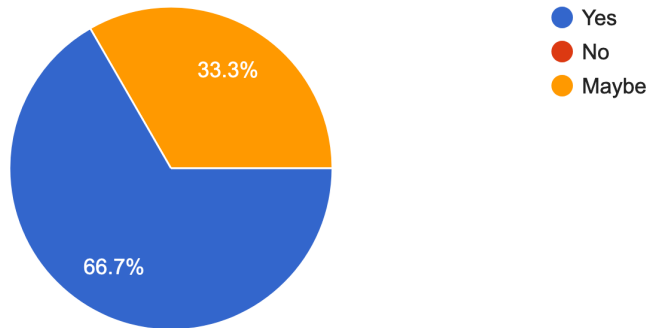


Figure 10 Responses to "Do you believe that your gesture drawings improved as the study progressed?"

With shorter times the vertical line can be a bit distracting, perhaps a thinner line or an easy toggle would help with that
I think it's a great app and has potential to improve in the future. Maybe include in app guidance such as tool tips to tell the user what each feature is for.
This is a good application for the intended target audience, although i would appreciate something which could also offer something to newcomers to this field like myself.
Interface was good overall and simple to use- would recommend that center line be moved more slowly/ with more stability.
Maybe work on the alignment of the lines that appear onto the photo.
Make it easier to click the line/make it clear that the "tags" at the beginning are "and" not "or"
None. Very great
May be give one more detailed skeletal diagram for drawing detail, present skeletal diagrams are more than enough for gesture drawings.
There are a couple things I would recommend adding to this app for quality of life. For one an "infinite" time duration where the user clicked to the next picture would be nice. Having a pausing function if there was a particularly interesting pose that someone would have liked a little more time with to draw. Lastly, some way to switch between poses/sex while the roulette is going could make things more convenient for someone using the app.
Maybe include a section that allows you to convert the model to a different type of drawing to like an outline or black and white version?
N/A

Table 4 Responses to "Any feedback that you would like to give to improve this app?"

Between playtesting sessions, did you use the app again?

5 responses

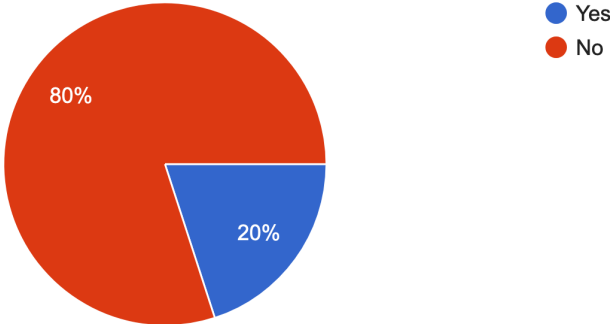


Figure 11 Responses to "Between playtesting sessions, did you use the app again?"

Do you believe that your gesture drawings improved as this study progressed?

5 responses

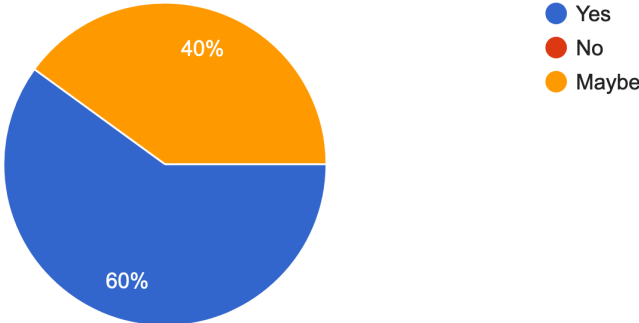


Figure 12 Responses to "Do you believe that your gesture drawings improved as this study progressed?"

Do you believe that your gesture drawings improved between playtesting sessions?

5 responses

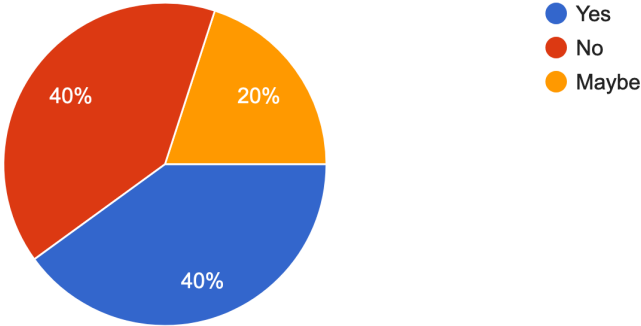


Figure 13 Responses to "Do you believe that your gesture drawings improved between playtesting sessions?"

Do you believe that you exerted more or less mental energy when drawing compared to the last session?

5 responses

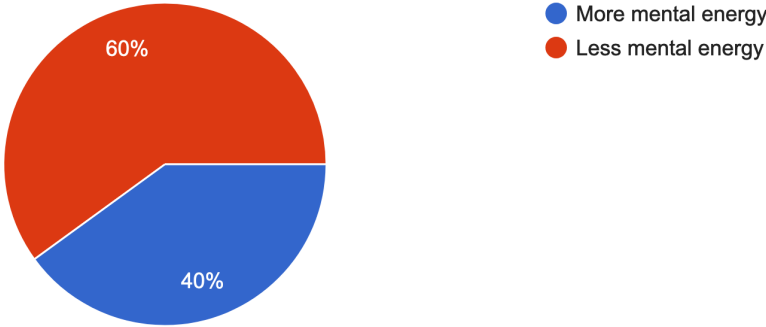


Figure 14 Responses to "Do you believe that you exerted more or less mental energy when drawing compared to the last session?"

5. Discussion

To reiterate, the goal of this project was to develop new features for DrawSession so that it can better serve its function to emulate a life drawing session and become a viable tool to practice figure drawing. I proposed and attempted to implement the following features, which were derived from my literature review on deliberate practice, figure drawing, and other applicable domains:

- Provide recommendations for poses based on previous site visits
- Cache extra poses so that DrawSession can be used offline
- Prevent DrawSession from showing a pose twice by storing past poses as hashes
- Create a Web App Manifest for DrawSession
- Superimpose landmarks on a figure using pose estimation
- Provide a plumb line

After evaluating DrawSession and these features by conducting observational studies, was any meaningful insight gathered regarding DrawSession or how technology can contribute to visual arts education? I should say that there was limited time to conduct this project; thus there were features that I wish I had more time to implement properly or evaluate more thoroughly. Notably, I didn't have the chance to gather study participants' responses to features that use persistent storage such as pose recommendations and preventing duplicate poses; I only had twenty minutes with each study participant, and only 1 of the 5 participants of the second observational study had used DrawSession outside of the first observational study. Nevertheless, some broad insight can be gleaned from all aspects of this project.

Was it constructive to look into deliberate practice for inspiration on how to modify DrawSession into a viable tool for figure drawing practice? I would concur that researching deliberate practice was worthwhile. In particular, I found that the "mnemonic" component of deliberate practice was applicable to how students in figure drawing are taught to visualize the figure in their minds by abstracting the complex anatomy they see into visual elements they

can remember. Study participants had also mentioned in surveys how they had used mnemonics while drawing poses from DrawSession.

Researching deliberate practice also showed me the importance of having a teacher when learning a new skill. In a conversation with professor Laura Schomp from the College of the Holy Cross, we discussed whether DrawSession could be an effective tool to practice figure drawing because people inherently have visual literacy; since most people can tell if a drawing is somehow off-putting, with some prodding artists could identify and correct their mistakes (personal communication, September 19, 2019). But providing an automated recommendation to self-reflect may not be a substitute for a teacher.

This became clear when I did not see substantial improvement in drawing ability from participants of the second observational study and tried to hypothesize what issues their drawings had. Even though I had researched figure drawing curricula for this project, I had trouble articulating what I thought were issues with their drawings beyond a feeling of uneasiness. If I couldn't identify what went wrong, I could only imagine how study participants, who were unlikely to have much drawing experience, were struggling to fix their drawing mistakes.

Deliberate practice depends on a teacher's participation. Ideally, it is a teacher that will design tasks that help a practitioner reach expertise. Finally, it is a teacher that will identify the first few problems a practitioner may encounter and suggest ways to address those problems.

DrawSession was initially designed for and inspired by artists who regularly attend life drawing sessions. But after conducting observational studies on individuals who probably haven't attended a life drawing session, it may be worth reconsidering DrawSession for a more general audience. While implementing features related to progressive web apps or techniques for figure drawing may be in the pursuit of following aspects of deliberate practice such as "having the practitioner be motivated" and "designing practice tasks with established training techniques", future iterations of DrawSession may require further research on how teachers contribute to visual arts education.

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WPI Institutional Research. (2019). *Common data set* [Data file]. Retrieved from <https://public.tableau.com/profile/wpi.institutional.research#!/vizhome/WPICommonDataSet/CommonDataSet>

Introduction to Web Components. (2012, May 22). Retrieved from World Wide Web Consortium (W3C): <https://www.w3.org/TR/2012/WD-components-intro-20120522/>

Stack Overflow. (2019). *Developer survey results* [Data file]. Retrieved from https://insights.stackoverflow.com/survey/2019#technology-_web-frameworks

Appendix A: Screenshots of DrawSession

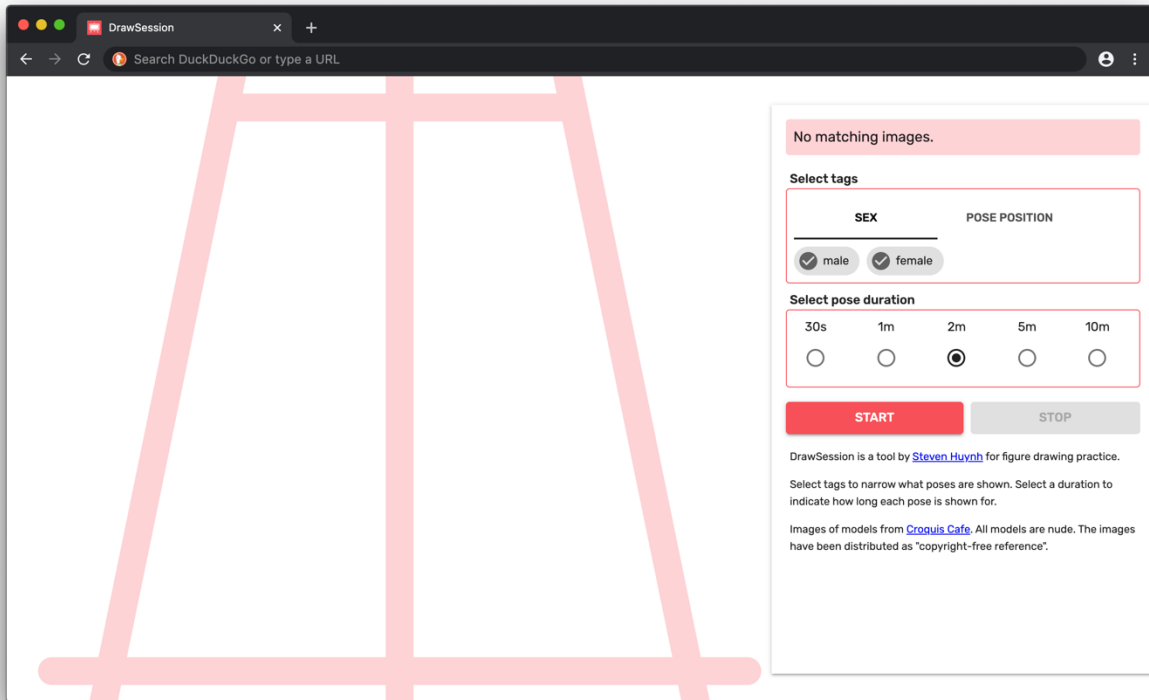


Figure 15 Screenshot of DrawSession, while no pose is being shown. There is an error notification near the top-right corner.

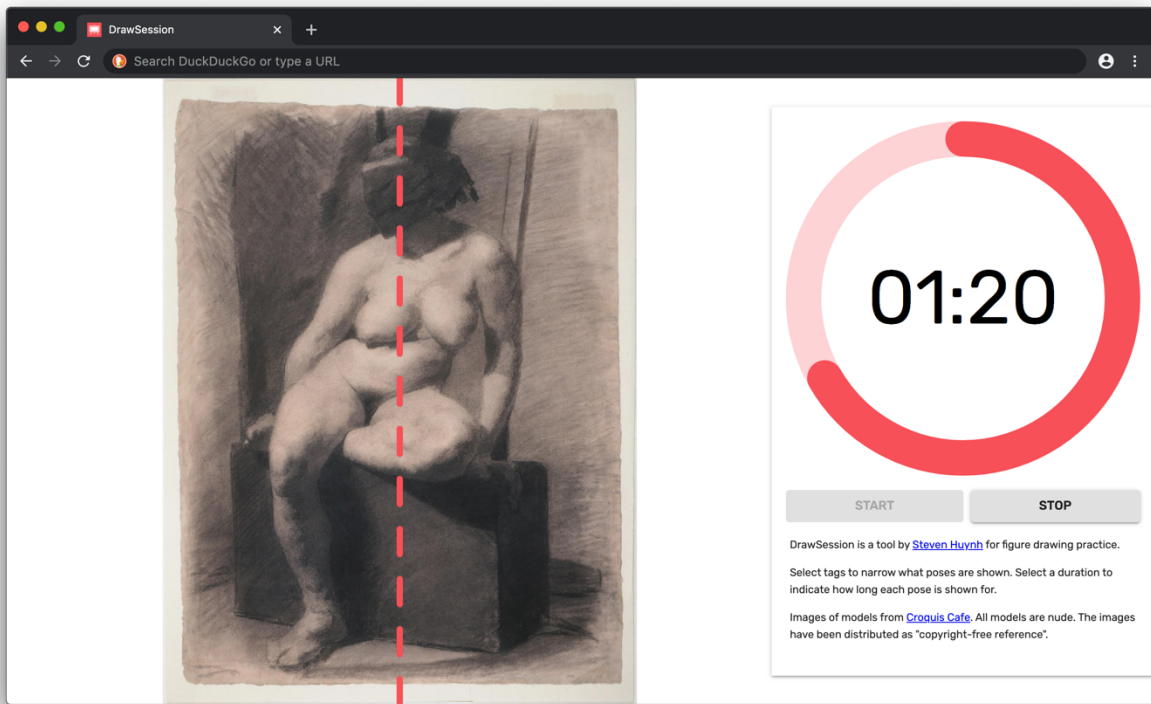


Figure 16 Screenshot of DrawSession, while a pose is being shown. The pose has been artificially replaced by Thomas Eakins' "Study of a Seated Nude Woman Wearing a Mask", dated between 1863 and 1866.

Appendix B: Major Technologies Used in

DrawSession

DrawSession's front-end client was made with React¹⁴ in mind. React is a JavaScript library used to create components, which are akin to custom HTML elements that can be reused. The World Wide Web Consortium actually introduced a set of browser standards for developers to create components without importing a library in 2012, one year before React was open-sourced ("Introduction to Web Components", 2012). However, React's advocacy of Javascript over a domain-specific language to create components as well as its introduction of a virtual DOM for more performant DOM manipulation won over developers; according to a survey conducted by Stack Overflow in 2019, React is the second most used "web framework" technology among 63,585 participants. React's popularity was taken into consideration when deciding what "web framework" to use to implement DrawSession. However, what ultimately led React to be DrawSession's "web framework" of choice was that it has a relatively small API as a result of not having a domain-specific language.

Additional front-end libraries used to implement DrawSession include Material-UI¹⁵, emotion¹⁶, and react-spring¹⁷. Material-UI is a framework built on top of React; it provides a set of components built with React that are designed to follow Google's "Material Design" design language¹⁸. Among other React frameworks with their own design language, Material-UI was chosen for adhering to Material Design's paper aesthetic, which is tangentially related to DrawSession's concept, while providing a custom styling solution if developers want to move away from Material Design and integrate their own brand identity.

¹⁴ Project page is at <https://reactjs.org/>

¹⁵ Project page is at <https://material-ui.com/>

¹⁶ Project page is at <https://emotion.sh/>

¹⁷ Project page is at <https://www.react-spring.io/>

¹⁸ Specification is at <https://material.io/design/introduction/>

However, DrawSession uses emotion over Material-UI's styling solution, as emotion is a CSS-in-JS library that is independent from Material-UI. The term CSS-in-JS generally refers to the practice of composing CSS with JavaScript in lieu of writing external stylesheet files (whether it be through a preprocessor or by hand). There are many libraries with their own approach to CSS-in-JS, but they share the motivation to scope CSS to components without worrying about CSS selectors clashing in the global namespace. Among those libraries, emotion was chosen because it gives developers access to the underlying class names that are derived from a stylesheet generation function. With those class names, developers can pass them as the "className" property of a React component; no need to wrap the component in a higher-order component or manually trigger the creation of a stylesheet. And with React, emotion enables styling that can automatically update based on what state DrawSession is in.

react-spring is DrawSession's UI animation library of choice. While Material-UI and emotion have some support for UI animation, such as React components that implement basic transitions and a @keyframes helper function, react-spring's support for UI animation is more complete considering it can perform interpolation on many CSS properties or SVG attributes, whether they use keyword or length data types. What separates react-spring from traditional UI animation approaches is that instead of describing animation in terms of duration and acceleration curves, react-spring describes animation in terms of the mass and tension of springs. Thus it allows developers to create animations declaratively with confidence that their animations will always look natural; no need to specify keyframes while worrying about the different states DrawSession could be in. react-spring also supports animations for mounting and unmounting React components.

DrawSession utilizes SQLite¹⁹ to implement its database for images and tags. This database is what provides content for the pose slideshow and populates the front-end client with criteria users can specify to customize the pose slideshow. While deployed, DrawSession will only make queries to the database, without writing to it. Given that SQLite can perform

¹⁹ Project page is at <https://sqlite.org/>

read operations concurrently but is limited to performing write operations sequentially, it seemed like a natural fit for DrawSession.

Queries to the database are triggered by an HTTP request to `"/pose"`, with a valid query string. How DrawSession responds to the request is handled by Express²⁰, a web framework for the JavaScript runtime Node.js.

²⁰ Project page is at <https://expressjs.com/>

Appendix C: manifest.json

```
{
  "short_name": "DrawSession",
  "name": "DrawSession",
  "icons": [
    {
      "src": "favicon.svg",
      "sizes": "64x64 32x32 24x24 16x16",
      "type": "image/x-icon"
    }
  ],
  "start_url": "/",
  "display": "standalone",
  "background_color": "#fdd3d5",
  "theme_color": "#f65058"
}
```

Appendix D: Excerpts from DrawSession.jsx

```
componentDidMount() {
  this.cachedModel = null;
  this.abortController = null;

  this.sessionTimestamp = new Date();
  const timestamp = this.sessionTimestamp;
  this.db = openDB('client', 1, {
    upgrade(db) {
      db.createObjectStore('session', {
        keyPath: 'timestamp'
      });
    }
  });
  this.addSessionPromise = this.db.then(db =>
    db.add('session', {
      timestamp: timestamp,
      series: []
    })
  );

  this.hashes = [];

  this.minWidthMediaQuery.addListener(this.handleMinWidthChange);
}
```

```
async setNewModel() {
  try {
    let [model] = await Promise.all([this.cachedModel, this.setModel(null)]);

    async function estimatePoseOnImage(imageElement) {
      const net = await posenet.load();

      const pose = await net.estimateSinglePose(imageElement, {
        flipHorizontal: false
      });
      return pose;
    }

    const url = URL.createObjectURL(model.blob);
```

```

const imageElement = new Image();
imageElement.src = url;
const dimensions = await new Promise(resolve => {
  imageElement.onload = () =>
    resolve({
      width: imageElement.naturalWidth,
      height: imageElement.naturalHeight
    });
});
model.landmarks = await estimatePoseOnImage(imageElement);
model.landmarks.dimensions = dimensions;
URL.revokeObjectURL(url);

this.setModel(model);
this.hashes.push(model.hash);
this.cachedModel = this.fetchNewModel();
} catch (error) {
  throw error;
}
}

```

```

fetchNewModel() {
  return new Promise((resolve, reject) => {
    const searchParams = new URLSearchParams();
    this.state.queryParameters.forEach(parameter => {
      searchParams.append('tag', parameter);
    });
    this.hashes.forEach(hash => {
      searchParams.append('exclude', hash);
    });

    fetch(`/pose?${searchParams.toString()}`, {
      signal: this.abortController.signal
    })
    .then(response => {
      switch (response.status) {
        case 200: {
          resolve(
            response.blob().then(blob => ({
              blob: blob,
              hash: response.headers.get('X-Hash'),
              tags: JSON.parse(response.headers.get('X-Tags'))
            }));
        }
      }
    });
  });
}

```

```

        )))
    );
    break;
}
case 204: {
    const error = new Error('No matching images.');
```

error.name = 'MatchError';

```

    throw error;
    break;
}
default: {
    throw new Error(response.statusText);
}
}
})
.catch(error => {
    if (error.name === 'TypeError') {
        const networkError = new Error('Could not connect.');
```

networkError.name = 'NetworkError';

```

        reject(networkError);
    } else {
        reject(error);
    }
});
});
}

```

```

async handleSessionStart() {
    try {
        this.abortController = new AbortController();
        await new Promise((resolve, reject) => {
            this.setState(
                {
                    isSessionInProgress: true,
                    notifications: []
                },
                resolve
            );
        });
        const [db] = await Promise.all([
            this.db,
            this.addSessionPromise,

```

```

    (() => {
      this.cachedModel = this.fetchNewModel();
      return this.setNewModel();
    })()
  ]);

  const tx = db.transaction('session', 'readwrite');
  const session = await tx.store.get(this.sessionTimestamp);
  session.series.push({
    startTime: new Date(),
    endTime: null,
    selectedTags: [],
    selectedDuration: null,
    poses: []
  });
  tx.store.put(session);
  await tx.done;
} catch (error) {
  this.handleSessionStop();
  this.setState({
    notifications: [{ message: error.message, isError: true }]
  });
  throw error;
}
}

```

```

async handlePoseTimerExpire() {
  const db = await this.db;
  const tx = db.transaction('session', 'readwrite');
  const session = await tx.store.get(this.sessionTimestamp);
  const index = session.series.length - 1;
  session.series[index].poses.push({
    hash: this.state.activeModel.hash,
    tags: this.state.activeModel.tags
  });
  tx.store.put(session);
  await tx.done;

  await this.setNewModel().catch(error => {
    this.handleSessionStop();
    this.setState({
      notifications: [{ message: error.message, isError: true }]
    });
  });
}

```

```

    });
  });
}

```

```

async handleSessionStop() {
  this.abortController.abort();

  const db = await this.db;
  const tx = db.transaction('session', 'readwrite');
  const session = await tx.store.get(this.sessionTimestamp);
  const index = session.series.length - 1;
  session.series[index].endTime = new Date();
  session.series[index].selectedTags = this.state.queryParameters;
  session.series[index].selectedDuration = this.state.poseDuration;
  session.series[index].poses.push({
    hash: this.state.activeModel.hash,
    tags: this.state.activeModel.tags
  });
  tx.store.put(session);
  await tx.done;

  if (session.series[index].selectedTags.length) {
    let allottedTime = 0;
    for (let i = 0; i < session.series.length; i++) {
      if (
        session.series[index].selectedTags.every(tag =>
          session.series[i].selectedTags.includes(tag)
        ) &&
        (allottedTime +=
          session.series[i].endTime - session.series[i].startTime) > 1200000
      ) {
        const allTags = this.props.tags.map(tag => tag.name);
        const otherTags = allTags.filter(
          tag => !session.series[index].selectedTags.includes(tag)
        );
        this.setState({
          notifications: [
            {
              message: `You've been drawing poses tagged with
${session.series[index].selectedTags} for at least 20 minutes this session.
                You may want to select some other tags instead, such as
${otherTags}.`,
            }
          ]
        });
      }
    }
  }
}

```

```
        isError: false
      }
    ]
  });
  break;
}
}
}

await this.setModel(null);
await new Promise((resolve, reject) => {
  this.setState(
    { isSessionInProgress: false, description: this.props.description },
    resolve
  );
});

this.cachedModel = null;
await new Promise((resolve, reject) => {
  setTimeout(resolve, 1000);
});
}
```


Appendix E: Plumb.jsx

```
import React from 'react';
import { motion } from "framer-motion";
import { withTheme } from '@material-ui/core/styles';

const Plumb = function PlumbComponent(props) {
  return (
    <svg viewBox="0 0 100 100">
      <motion.line
        x1="50%"
        y1="0%"
        x2="50%"
        y2="100%"
        stroke={props.theme.palette.primary.main}
        strokeWidth="1"
        strokeLinecap="round"
        strokeDasharray="4"
        drag="x"
        dragMomentum={false}
      />
    </svg>
  );
}

export default withTheme() (Plumb);
```

Appendix F: Excerpt from PoseViewport.jsx

```
const convertPosition =
  item.poseLandmarks.dimensions.width <
  item.poseLandmarks.dimensions.height
  ? position => {
    let xIntercept =
      (item.poseLandmarks.dimensions.height -
       item.poseLandmarks.dimensions.width) /
      2;

    return {
      x:
        (position.x + xIntercept) *
        (100 / item.poseLandmarks.dimensions.width) *
        (item.poseLandmarks.dimensions.width /
         item.poseLandmarks.dimensions.height),
      y:
        position.y *
        (100 / item.poseLandmarks.dimensions.height)
    };
  }
  : position => {
    let yIntercept =
      (item.poseLandmarks.dimensions.width -
       item.poseLandmarks.dimensions.height) /
      2;

    return {
      x:
        position.x *
        (100 / item.poseLandmarks.dimensions.width),
      y:
        (position.y + yIntercept) *
        (100 / item.poseLandmarks.dimensions.height) *
        (item.poseLandmarks.dimensions.height /
         item.poseLandmarks.dimensions.width)
    };
  };

const headLandmarks = [];
```

```

const upperBodyLandmarks = [];
const lowerBodyLandmarks = [];
item.poseLandmarks.keypoints.forEach(keypoint => {
  const position = convertPosition(keypoint.position);
  position.part = keypoint.part;
  switch (keypoint.part) {
    case 'nose':
    case 'leftEye':
    case 'rightEye':
    case 'leftEar':
    case 'rightEar':
      headLandmarks.push(position);
      break;
    case 'leftShoulder':
    case 'rightShoulder':
    case 'leftElbow':
    case 'rightElbow':
    case 'leftWrist':
    case 'rightWrist':
      upperBodyLandmarks.push(position);
      break;
    case 'leftHip':
    case 'rightHip':
    case 'leftKnee':
    case 'rightKnee':
    case 'leftAnkle':
    case 'rightAnkle':
      lowerBodyLandmarks.push(position);
      break;
  }
});

function sortLandmarks(landmarks, partOrder) {
  landmarks.sort(
    (a, b) =>
      partOrder.indexOf(a.part) - partOrder.indexOf(b.part)
  );
}
sortLandmarks(headLandmarks, [
  'rightEar',
  'rightEye',
  'nose',

```

```

    'leftEye',
    'leftEar'
  ]);
  sortLandmarks(upperBodyLandmarks, [
    'rightWrist',
    'rightElbow',
    'rightShoulder',
    'leftShoulder',
    'leftElbow',
    'leftWrist'
  ]);
  sortLandmarks(lowerBodyLandmarks, [
    'rightAnkle',
    'rightKnee',
    'rightHip',
    'leftHip',
    'leftKnee',
    'leftAnkle'
  ]);

  function toPoints(landmarks) {
    let points = '';
    landmarks.forEach(landmark => {
      points = `${points} ${landmark.x} ${landmark.y}`;
    });
    return points;
  }

  const headPoints = toPoints(headLandmarks);
  const upperBodyPoints = toPoints(upperBodyLandmarks);
  const lowerBodyPoints = toPoints(lowerBodyLandmarks);

  return (
    <animated.svg
      viewBox="0 0 100 100"
      className={classNames(
        this.imageContainerStyles,
        this.itemStyles
      )}
      style={{
        transform: props.scale.interpolate(
          number => `scale(${number})`
        ),
      }}
    />
  );

```

```

    opacity: props.opacity,
    zIndex: z
  }}
>
<image href={item.poseURL} height="100%" width="100%" />
<polyline
  points={headPoints}
  stroke="blue"
  fill="transparent"
  strokeWidth="0.5"
  onClick={item.onHeadSelect}
/>
<polyline
  points={upperBodyPoints}
  stroke="green"
  fill="transparent"
  strokeWidth="0.5"
  onClick={item.onUpperBodySelect}
/>
<polyline
  points={lowerBodyPoints}
  stroke="orange"
  fill="transparent"
  strokeWidth="0.5"
  onClick={item.onLowerBodySelect}
/>
<Plumb />
</animated.svg>
);

```

Appendix G: List of Questions Asked in Surveys

As I conducted observational studies for this project, I asked study participants to complete three surveys: one preceding the first study, another proceeding the first study, and the last proceeding the second study. Additional context is provided beneath each question if necessary.

Questions Asked Before First Observational Study

1. What hobbies do you actively participate in?
 - a. Deliberate practice may be more effective for certain hobbies. Playing an instrument may be such a hobby, because a practitioner's current ability can be determined (are they playing a chord wrong?) and catered to immediately (have them practice that measure). It may be inferred from a study participant's responses to this question whether they are familiar with deliberate practice and whether they may apply the learning approach to their performance in the study.
2. If you wanted to learn a new skill, which of the following choices would you solicit feedback from? (Rank by priority.) (*A teacher/coach, Prior work done by a related expert, Your own work*)
 - a. In deliberate practice, feedback from a practitioner's performance in their activities determines how they should adjust their performance.
3. Are you interested in figure drawing as a skill? (*Yes, No*)
 - a. Their interest will determine how a study participant will perform at figure drawing over time.
4. Please indicate whether you are familiar with the following concepts as they relate to figure drawing. Also mention concepts not listed here. (*Line, Value, Volume, Texture, Composition, Body Proportions*)

- a. General assessment of the study participant's expertise in figure drawing. Refers to Brown and McLean's "conceptual drawing tools" (1992, p. 9)
5. What personal computing devices do you regularly use? (*iPhone, Android Phone, iPad, Android Tablet, Windows Laptop or Tablet, MacBook, Linux Laptop, Windows Desktop, Mac, Linux Desktop*)
 - a. DrawSession can be used on different devices; therefore how a user will interact with the website will be affected by how they interact with their personal computing devices.
6. What web browsers do you regularly use? (*Internet Explorer, Microsoft Edge, Firefox, Google Chrome, Safari, Opera, Mobile Safari, Android Browser, Mobile Chrome, Mobile Firefox*)
 - a. Browsers expose different APIs used to implement app features to various extents. Therefore, some browsers may prevent some app features from being deployed correctly.
7. Do you have an impairment that you believe affects your ability to visually perceive?
8. Do you have an impairment that you believe affects your motor skills in using a drawing tool?
9. Do you prefer the app as within a browser window or with its own window? (*In-browser, As own window*)
 - a. This question refers to an attribute of progressive web apps. Unlike typical websites, progressive web apps can ask a web browser to omit its user interface chrome, thereby giving itself the appearance of a full-screen app.

Questions Asked After First Observational Study

1. In general, what aspect of the poses were you trying to capture with your figure drawings?
2. Did you use mnemonics while figure drawing?

- a. As an example, if you saw someone from the front about to pick something up from the ground, you would see that their arms are in front of their legs. This overlapping of limbs indicates that the limbs are in different positions in space along the z-axis.
3. Do you believe that your gesture drawings improved as the study progressed? (*Yes, No, Maybe*)
4. Any feedback that you would like to give to improve this app?

Questions Asked After Second Observational Study

1. Between playtesting sessions, did you use the app again? (*Yes, No*)
 - a. The observational studies were advertised as “playtesting sessions”.
 - b. General indication of whether DrawSession gave study participants motivation to revisit the website of their own will.
2. Do you believe that your gesture drawings improved as this study progressed? (*Yes, No, Maybe*)
3. Do you believe that your gesture drawings improved between playtesting sessions? (*Yes, No, Maybe*)
4. Do you believe that you exerted more or less mental energy when drawing compared to the last session? (*More mental energy, less mental energy*)
 - a. Were study participants accustomed to gesture drawing by the time they revisited the skill a couple days later? Was it easier this time?