Sketch Master -
A Sketch Game for Collecting Exploratory Data

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ABSTRACT
We present the concept and implementation of a sketching game called Sketch Master. Sketch Master is a game designed to help players learn and practice drawing from memory. The architecture of the tool and its various game modes are presented. Additionally, we describe how functions in Sketch Master serve as a research instrument to collect exploratory data about the relation between perception, memory, and sketching.

Author Keywords
Sketch, Game Design, Human Cognition, Computer Supported/Mediated Creativity

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces.

INTRODUCTION
Sketch Master is a sketch-based game designed to strengthen drawing and memory skills in a fun and engaging manner. Additionally, Sketch Master serves as a research instrument to study the relation between perception, memory, and sketching. It is an example of a "game with a purpose", such as ESP, the online guessing game that motivates users to tag photos for search optimization [2].

The gameplay is as follows. The Sketch Master system presents a source image for a limited amount of time (e.g., 20 seconds or 3 minutes). After the source image disappears, the player is asked to sketch that image from memory. The drawn image is scored based on the accuracy from the source image. The user has the ability to "spy" on the source image and also the drawings of other players (if any) who participated or competed simultaneously during the sketch session. There are multiple game modes that vary gameplay, which include single player, multiplayer, and cooperative.

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Research shows that learning how to properly perceive a source image is one of the most difficult skills for novices. Non-artists do not know what visual information to select for visual processing. Humans can only attend to a subset of information in the visual field [7]. Non-artists are not as skilled at selecting the most critical information and therefore make errors in the way they perceive the source image [5, 9].

Sketch Master can help us collect data about how users perceive and remember source images. This data will serve to tweak the interaction of Sketch Master to help novices improve their perceptual skills in drawing. To achieve this, the sketching behavior and in-game decisions of the user are recorded. The order of the drawn strokes has the potential to provide insight into the clarity of the user's memory of the source image. For example, the initial strokes represent the most recent or salient features of the source image perceived by the user. The airtimes between the strokes may provide insight about which parts of the source image are easier or harder to remember.

In the remainder of this paper, we will describe the Sketch Master prototype and the related works that justified implementation decisions. We will then describe the implementation, including how we record the data, the system architecture, and the scoring algorithms. Finally, we will conclude the article by describing future directions for this research.

Figure 1. The introductory interface of Sketch Master.

SKETCH MASTER GAME PLAY AND MODES
Figure 1 shows the home screen interface that prompts a user to enter the game. On this screen, players are asked to choose the game mode or review their previous works. The game has three different playing modes, single player,

multiplayer, and cooperative mode (co-sketch). Single and multiplayer sessions are meant to strengthen an individual's drawing skills, while co-sketch session provides novel drawing experiences that introduce a social and collaborative element to drawing.

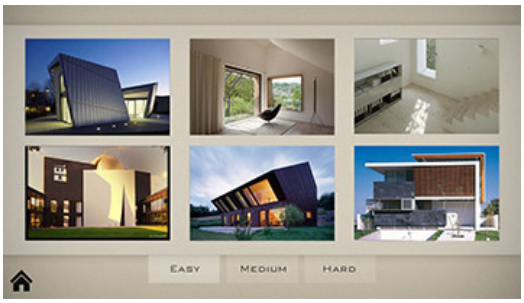

Figure 2. The interface used to select the source photo and difficulty.

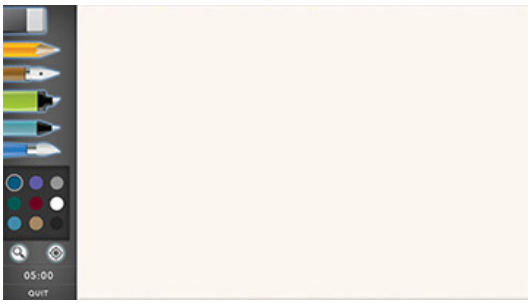

Figure 3. The sketch tool panel on the left of the sketch canvas; users can select colors, brushes and use the spy mode.

Single Player

Single player mode can be considered a practice mode meant to strengthen the drawing from memory skills. While the drawing is scored, this mode is not as competitive as the multiplayer mode. The users can select from 3 levels of difficulty (easy, medium, hard), as well as which photo they would like to draw (see Figure 2). The difficulty levels dictate the complexity of the image and the amount of time provided for memorizing the image. The default amount of time the image is presented for the user in the current working prototype is 30 seconds. This time will be calibrated for each of the difficulty levels based on user feedback.

Five seconds before the time is up, the player is provided with a text prompt warning that the photo will soon disappear. After the photo disappears, the drawing interface is activated, as shown in Figure 3. The drawing interface is a fully featured drawing program with multiple tools, such as a pencil, pen, and marker to achieve different textures. The player then has a limited amount of time to sketch the picture from her memory. In the current prototype, the sketching time limit is set at 3 minutes (subject to future calibration).

When the sketch is finished, the system calculates and records a score. The score is determined by how similar the user's sketch is compared to the source image. The details of the scoring algorithm are described in the implementation section. Users also have the option to review a playback of their sketching process and compare how other players draw the same photo in the feedback phase.

Multiplayer

In multiplayer mode, players compete sketches with each other. The server pairs 2, 3, or 4 players randomly. In this mode, the system selects a photo randomly for all players according to the average difficulty levels selected by users. The playing process is similar to single player mode with a limited viewing time of the source image followed by a 3 minute sketching session. However, during the game, players have the option of spying on the original photo as well as other players' rendition of the image. After the competition is over, players can review all players' drawing processes and the final work in the system. The system will also score each of the drawings. The user with the highest score wins.

Cooperation

Cooperation mode features two players cooperating with each other to finish one shared sketch. While the gameplay is similar to single and multiple mode, the source image is selected by the system automatically in this mode. The critical difference is that two players sketch onto one canvas in synchrony. During the sketching session, each player uses a separate input device, but they are able to see each other's sketch actions in real-time on the same canvas. Similar to other modes, each player has two chances to spy the original photo. Different color codes will be given for each player's cursor for current active stroke. The cursor color code will display in cooperators' screen for 3 seconds and then turn to the colors that are drawn by the player.

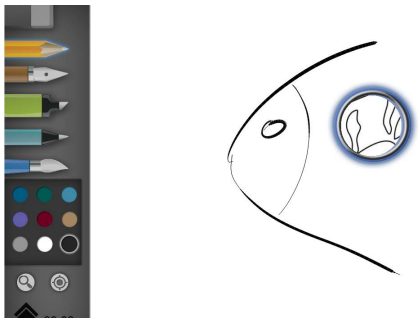

Figure 4. When users enter spy mode, they can either watch the original image or what other players are drawing.

Spy Window

During the sketching session, players have two chances to use the spy function to inspect regions of the source image as well as the drawing of competing players in multiplayer mode. During spy sessions, players have 20 seconds to observe the regions their cursors are pointing at. We restricted the spy window to a circle region 200 pixels in diameter. Figure 4 shows an example of a player spying on a source image of a fish. Inside the spy window reveals the original details of the fish.

The spy window collects data about the perceptual process of the user. The system collects data about where and when users chose to take a peak at the original image. This information informs us about which visual features the user deems most notable as well as which features they forgot. We expect the exploratory data to help us understand how the spy window affects the user's memory. Do users develop a strategy for using the spy window that improves their accuracy? Does the spy window help focus attention and improve recall? What are the user's perceptual strategies at different stages of expertise?

RELATED WORK

Sketch Master resides at the intersection of serious games and creativity support tools. Serious games refer to games that are designed for a 'serious' purpose other than pure entertainment [1, 2]. In that sense, Sketch Master is designed as an educational game that helps users learn to draw from memory.

Since it is supporting the creative process of sketching, Sketch Master can also be considered an example of Creativity Support Tools (CST). Creativity support tools enhance and support the creative process of users. Nakakoji describes the range of creativity support tools using the analogies of *running shoes*, *dumbbells*, and *skis* [6]. Running shoes enhance existing creative skills (practice). Dumbbells help the user learn about a creative domain to strengthen their creative skills (muscle) that would be applicable even when they are not using the tool. Skis introduce completely new creative experiences that would not be possible without the tool.

Sketch Master is primarily a dumbbell CST because it helps users practice and learn successful strategies for sketching from memory. Athletes use dumbbells to train their muscle to gain strength that can be used for other physical exercises beyond the use of dumbbells. Similarly, users of Sketch Master would learn strategies to obtain better sketching scores. These strategies are still relevant after the user disengages the tool. For example, users may learn that it is crucial to remember the outside contour of a shape in order to increase the representational accuracy of drawing that image from memory. This type of drawing and memory heuristic is applicable to general freehand drawing skills and applications without the Sketch Master tool. Knowledge transfer to other creative media is a trademark of dumbbell CSTs. Additionally, the cooperative mode introduces a new type of sketching experience, which could be classified as a ski CST.

Other digital drawing games, such as 'Draw Something', are popular, but do not provide the same learning incentives as Sketch Master. Draw Something is a mobile app where users sketch out concepts that their partners try to guess. Players develop communication strategies to convey their meaning, such as arrows, and circles to direct attention to key areas. Crude, clear drawings are preferred over detailed, precise, and realistic representations. The game helps users select easy to draw items to represent more complex concepts. This skill helps visually communicate concepts, but it does not necessarily increase the drawing skills of the user.

The other aspect of Sketch Master is its potential to be an extremely valuable data collection tool about sketching and related cognitive abilities. Many researchers have used online crowd-sourcing platform to mediate the collection of sketch data. For example, Koblin developed the sheep market application to collect 10,000 sheep drawings through crowd sourcing [4]. Eitz et al. also used a similar method to collect thousands of human sketches for the database of recognizing sketched objects [3]. These approaches show the merit of collecting large databases of sketch data. Instead of using a crowd-sourcing platform such as Amazon's Mechanical Turk, we built Sketch Master to collect different drawing data and explore the relationship between sketching, memory, and perception. In the next section, we describe the details of the system architecture, and the scoring algorithms.

IMPLEMENTATION

We built the system based on Microsoft .Net framework 4.0 on Windows 7 and Windows 8. Instead of using InkPicture provided from Microsoft Tablet API, we utilize GDI+ for rendering inks more flexibly.

System Architecture

The system has two distinct components that work together in real time: (1) clients that interface with tablet input for collecting the drawing data; (2) a centralized service collecting the sketch data and facilitating communication between all the other pieces. The system uses a TCP/IP server with a publish/subscribe model to provide a framework for routing messages between the different clients in the prototype.

Active clients provide the server with a description of their gaming modes, which are then used to determine what kinds of messages, if any, to deliver to that client. For instance, the server will pair the clients together when the players choose the cooperation mode. The server also receives the stroke messages and then sends it to the client that is accepting them when the player chooses to spy on other client's sketch. When collecting a stroke, the client is responsible for passing information in three segments to the server: the starting point, the packet points, and the ending point of a stroke. The starting point includes the information of the brush type, thickness, and the stroke colors. A packet point contains the color information, the pressure values, the timestamps, and the coordinate. The client that received the data will push notifications (incoming, unsolicited TCP/IP messages) for raising events and regenerating the strokes programmatically when applied.

Sketch Scoring

The player's goal of the game is to create a sketch that matches the source image as closely as possible. We

implement an automated scoring algorithm at the end of the sketching session to determine how closely a user's hand drawn image matches the source image. Higher scores are better—they signify the drawings are more similar to the source image. The scoring algorithm can also be used to analyze what regions of the image were most difficult for the user.

We employ the template matching algorithm available in an open source software library called OpenCV [8]. OpenCV provides six template-matching methods; we selected the "Correlation Coefficient Matching" as the main method for calculating similarity scores. Before using the method to compare the source image to the user drawn picture, our algorithm runs some preprocessing to optimize the scores. First, we employ Canny edge detection to extract the contours of the source image since the player typically draws the edges of the objects in the picture. Next, the system scales the player's drawing to the same size of the source image in pixel space. After the system scales the player's sketch, it creates a bounding rectangle around the player's drawing and feeds it into the template-matching algorithm provided by OpenCV. Finally, the algorithm scales the values returned from the template-matching algorithm to 100.

There are some advantages of using this method. The most significant one is that the final scores are based on the proximate contours of the original drawing. In other words, if players draw the approximate shapes from the original picture, the score will be higher than those who draw only the details. However, in order to get scores close to 100, the user needs to complete all the features and details of the original drawing. Figure 5 shows the results of using this algorithm for a complex figure (often used for cognitive impairment screening – ref Rey-O) [10]. The drawback of this approach is the line contours generated by the Canny edge detection does not necessarily correspond to the real contours in the source photograph.

FUTURE DIRECTIONS

Sketch Master is the first version of an interactive sketching game developed on windows platform. The prototype was demonstrated for two days during a graduate-level class and initial user reactions were promising. Users enjoyed the competitive element of sketching, and cooperative sketching introduced a new experience that seemed to creatively engage users. The next step for game design and development is a full-scale deployment and formal evaluation.

Sketch Master is also a crowd sourced data collection tool. As we deploy the system on a large scale, we will begin exploratory data mining and analysis. This research will investigate the relationship between sketching, memory, and perception. This effort will help us add features to increase the effectiveness of Sketch Master as a creativity support tool to help novices improve their ability to sketch from memory.

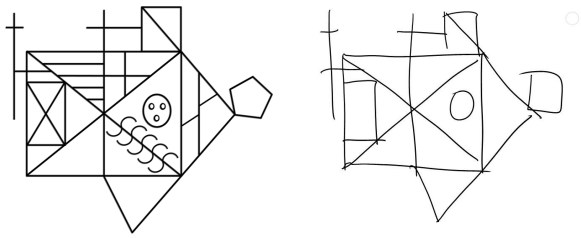

Figure 5. Left: The original image [10]. Right: The user omitted some details, so system gave a score of 76 points for this sketch.

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