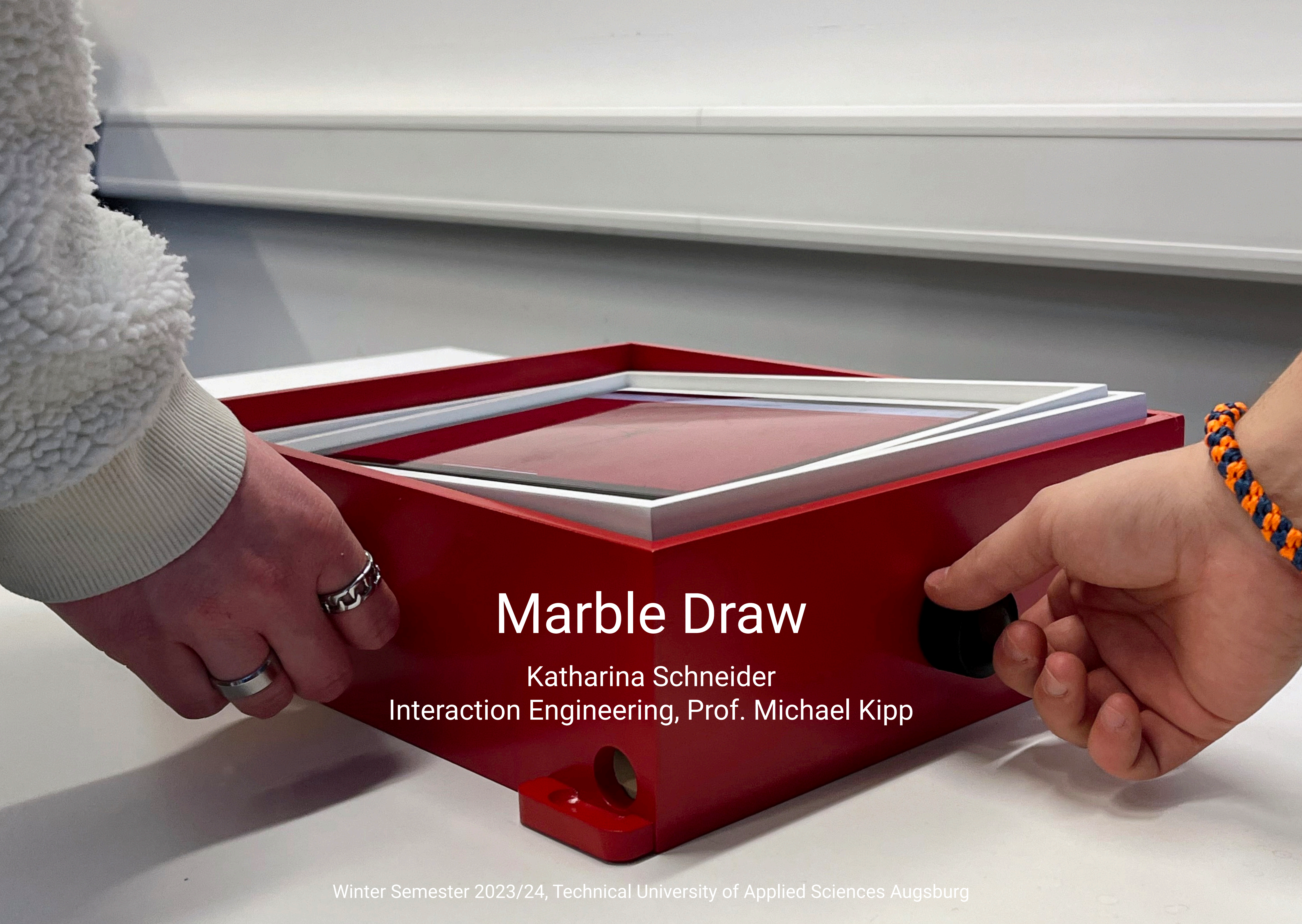

Marble Draw

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Abstract

The Marble Draw Interface and Game are an experimental implementation that seeks to provide a collaborative challenge to a team of two users. Inspired by a ball-in-the-maze puzzle, the interface provides two knobs to control an on-screen cursor by the tilt of a plane. The cursor movement is then translated to a line drawing in the game, which challenges users to trace a simple shape as precisely as possible. The game offers two different drawing methods, namely Cursor Placement Method and Continuous Method. The Cursor Placement Method lets users draw in line segments by allowing them to place the cursor before their existing line is connected to its position. On the other hand, the Continuous method draws a line wherever the cursor passes by. The two drawing methods, as well as the interface's general impression, were assessed in a user study (N=4). The participants found the Cursor Placement Method to have been easier and to have allowed for more confident use while they chose the Continuous Method to have been more fun, more complex, and more challenging. The latter was also their preferred drawing method. Finally, they described the overall interface as being creative, engaging and collaborative.

1 Marble Draw Interface & Game.

1 Motivation

The idea of the Marble Draw Interface originated in an interest of creating an interface that is challenging to operate. To achieve this, the control of an on-screen cursor, which is usually happening through the interface of the mouse, was instead projected onto a rectangular ball-in-a-maze puzzle.

2 Wooden ball-in-a-maze puzzle, taken from https://www.dusyma.com/de/kugellabyrinth/556700.

This approach brought two changes to the control of a cursor: Firstly, while a mouse combines the two degrees of freedom it offers (movement in x and y direction) in a narrow space so that they are easily controlled by one hand, the Marble Draw Interface projects the two dimensions onto the tilt of a plane around the x- and y-axes controlled by two single and spatially divided rotary knobs. That way, two hands are needed to control both dimensions. This further fostered the idea to have two people each control one of the dimensions to make cursor control more challenging by having it be a collaborative effort. Secondly, as the movement along the dimensions is translated from the tilt of the marble maze's plane, a more unusual way of cursor control is created.

These unusual and collaborative cursor controls were then utilized in the Marble Draw Game, a drawing game that features two different drawing methods. The drawing methods were compared with each other regarding their appeal to users. Further, the general impression of the interface was assessed.

2 Related Work

A similar approach to a collaborative interface was implemented by Microsoft for their Xbox console and Windows OS in 2017 (Bill, 2020). The Copilot feature allows two users to link their game controllers as if they were using one and the same (Xbox Support, n.d.). The feature lets users control the same game character for instance, analogous to the users controlling the same cursor using the Marble Draw Interface. However, it does not assign exclusive responsibility of certain dimensions to each user like the proposed interface does. The apparent lack of public research on the Copilot feature fueled a greater interest in exploring the Marble Draw Interface. It is only being briefly mentioned regarding its existence referenced from the Xbox Support source in three CHI-affiliated research articles by Gonçalves et al. (2021), Wentzel et al. (2022) and Gonçalves et al. (2023).

3 Concept

3.1 Interface

The Marble Draw Interface lets two users draw collaboratively in the Marble Draw Game by controlling a cursor on an integrated screen. Users move the cursor by tilting the plane that the screen sits on. The plane can be tilted using two rotary knobs which are located on the interface's front and right panel. The front-facing knob controls the plane's tilt around the y-axis, while the right-hand knob controls its tilt around the x-axis. Each user takes control of one of the knobs. The tilt is then translated to the cursor, moving it on the screen just like if it were a ball placed on the plane.

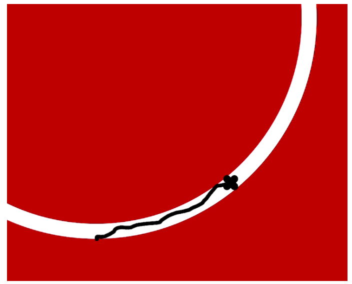
3.2 Game

3 Left: Four tracable shapes / Right: Reference shape & user-drawn line.

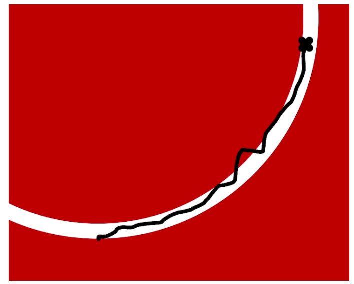
The Marble Draw Game consists of tracing a white reference outline of a square, a triangle, a circle, or a heart as precisely as possible (Fig. 3). These shapes were chosen as they seemed to represent different difficulties. By moving the cursor, the users can draw a line which cannot be corrected. There are two proposed drawing methods that were compared to each other in a user study (see evaluation):

Continuous Method Using the Continuous Drawing Method, a continuous line is drawn wherever the users pass by with their cursor (Fig. 4 & 5).

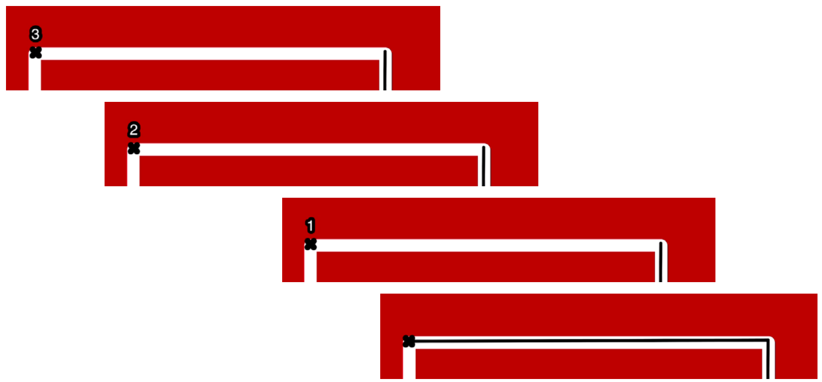
Cursor Placement Method Using the Cursor Placement Method, the users can place their cursor before adding onto their existing line. Once there is no more user movement registered, a countdown is activated and upon it ending, a line is drawn, connecting from the existing end of the line to the cursor's position (Fig. 6).



4 Continuous Drawing Method (a).

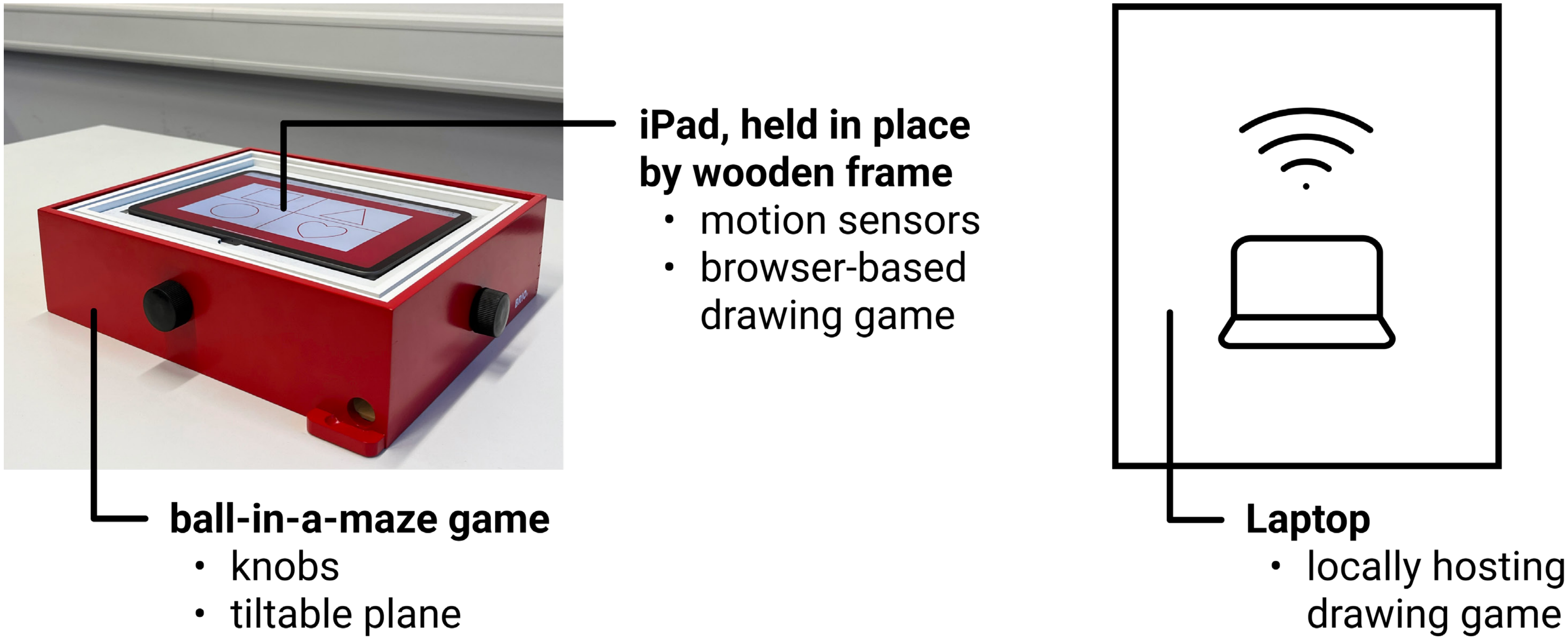


5 Continuous Drawing Method (b).



6 Cursor Placement Drawing Method.

4 Implementation



7 Marble Draw Interface & Game implementation.

- **Wooden ball-in-a-maze game:** Makes up tangible interface, consists of the knobs and plane that the users control.
- **iPad, held in place by a wooden frame:** Provides the game screen and motion sensors registering the plane’s tilt.
- **Laptop:** Locally hosting the browser-based drawing game (Accessing iPad sensor data, translating it into an on-screen drawing).

5 User Study

5.1 Setup

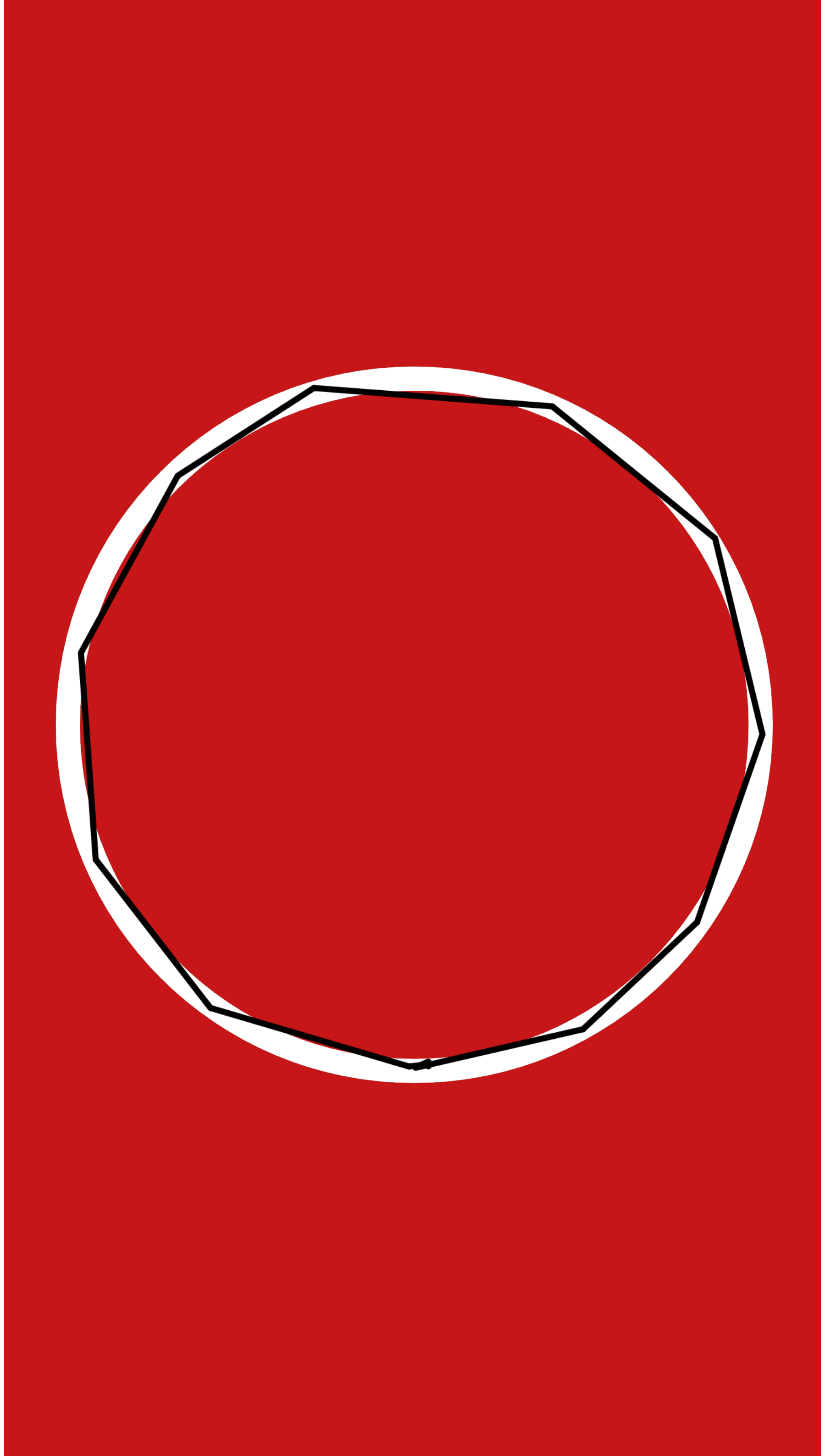
The two proposed drawing methods were tested and compared in a user study by two teams A and B, consisting of two participants each (N=4). The four participants were aged 25-31 (2 female, 2 male).

The starting method alternated across the teams. Team A started with the Cursor Placement Method and Team B with the Continuous Method. For each drawing method, the teams were tasked with tracing the four shapes, having three attempts per shape. A single task consisted of completing the attempt for a shape. An attempt begun with the participants hitting a start button after placing their cursor where they wanted their line to originate from and ended with them closing the shape (connecting the line to its origin). Afterwards they were shown a score out of 5 that communicated how precisely they traced the shape to keep them engaged. Between tasks, the participants were given up to two minutes to deliberate their approach for their next attempt. Before starting the set of tasks for a tested method, the participants had up to two minutes to try out the method on an empty canvas without a reference shape.

The participants' main objective was precision in the tracing, but they were allowed to focus on speed if high precision were to be achieved easily. For each attempt, precision, time taken, and line drawing were recorded.

In the evaluation, precision is defined as the percentage of the user-drawn line that is within the reference shape. This definition differs from the one used for the score the participants were shown. Their score was based on the proximity of their drawing's pixels to the pre-defined waypoints of a shape. Unfortunately, the automated process to record these proximity measurements was flawed and rendered the data useless. Consequently, the precision measurements were recalculated post-study using the previously described method.

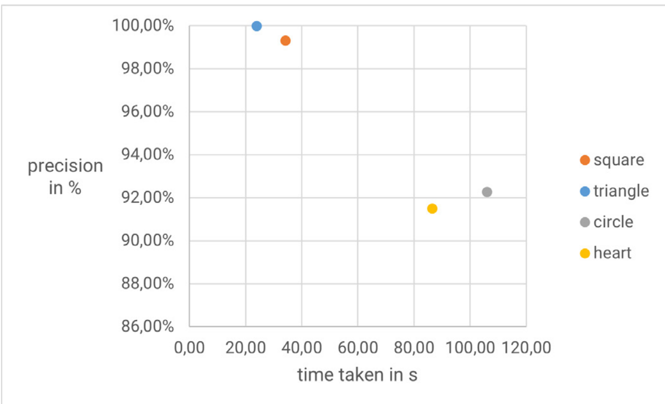
Team A's first tracing attempt of the circle could not be considered in the evaluation due to data loss from the malfunction in the automated recording process.



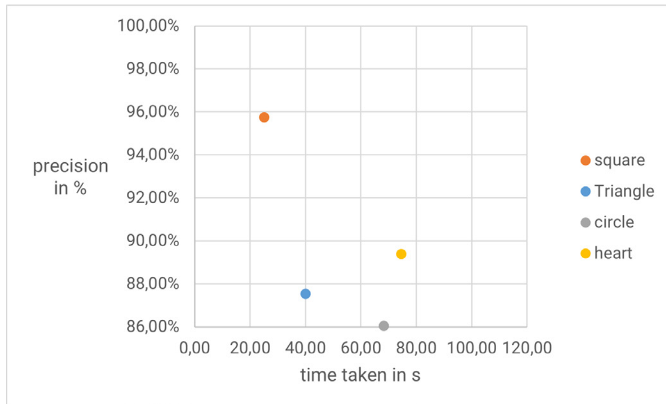
8 Right: Example of a circle traced using the Cursor Placement Method.

5.2 Task Measurements Evaluation

The teams on average achieved higher tracing precision using the Cursor Placement Method than the Continuous Method (Fig. 9 & 10). Also, the time taken to trace was shorter with the Continuous Method, except for the triangle.
Judging by the observations made during the user study, the strong difference in time taken to trace the square and triangle versus the circle and heart using the Cursor Placement Method might stem from the workings of the drawing method. This method, by design, does not allow to draw smooth curves which must instead be approximated by drawing multiple corners. In addition, the participants had to wait for the countdown that led to adding onto the existing line to finish. At times, the participants struggled to hold still enough for it to be triggered. This made tracing the triangle and square, which require fewer corners, quicker in comparison. Conversely, the Continuous Method allowed faster drawing because participants did not have to wait for a countdown and could draw curves. But they could not rely on the Cursor Placement Method's straight lines and possibility to adjust the cursor position which probably caused the average precision to decrease compared to the Cursor Placement Method. The square's precision average achieved using the Continuous Method is much higher than those of the remaining shapes (95,76% versus below 90%). This can be attributed to the shape only requiring lines to be drawn along one axis at a time.



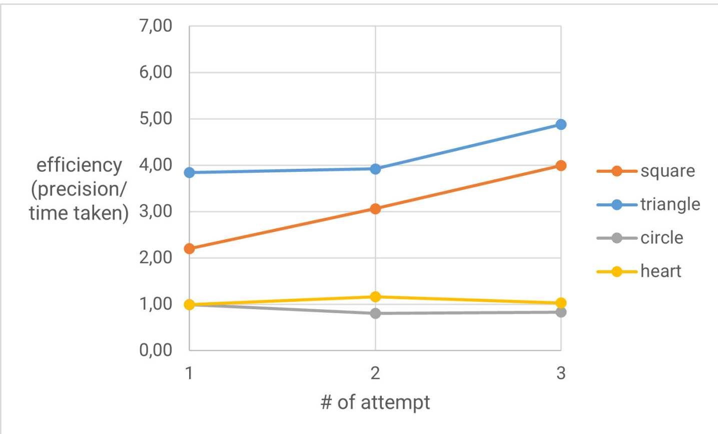
9 Cursor Placement Method: Average precision and time take to trace a shape.



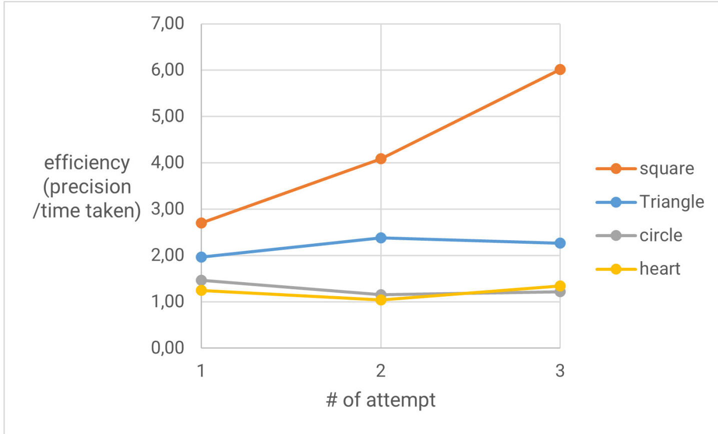
10 Continuous Method: Average precision and time take to trace a shape.

Looking at the learnability (Fig. 11 & 12), derived from the tracing efficiency equaling precision per second (time taken), a learning effect, meaning the efficiency improving with every attempt, could be identified for the tracing of two shapes.
Specifically, with the Cursor Placement Method, a learning effect is apparent for the tracing of the square and triangle. The highest efficiency using this method was achieved for the triangle, climbing from 3,85 in the first attempt to 4,88 in the last attempt. It was followed by the square, going up from 2,20 to 4,00. The efficiency values for the circle and heart were the lowest and fluctuated relatively constant around the value of 1,00 across all attempts.

For the Continuous Method, a learning effect is visible only in the tracing of the square, with efficiency improving from 2,70 to 6,02. Efficiency for the other shapes remained relatively constant across the attempts. For the triangle shape, the values ranged from 1,96 to 2,38. The values stayed within the limits of 1,00 and 1,25 for the circle and heart shape.



11 Cursor Placement Method: Efficiency per shape and attempt.



12 Continuous Method: Efficiency per shape and attempt.

To put it in a nutshell, the Cursor Placement Method allowed the participants to pick up the skill of quite precisely and quickly tracing the square and triangle all within three attempts. The Continuous Method only allowed this for the square. Combined with the higher average tracing precision using the Cursor Placement Method it may be suggested that the method is easier to master. Reciprocally, the Continuous Method may be harder to master. The results not showing a learning effect for the tracing of the circle and heart could be an indication that an interaction with the interface and game might be engaging and interesting beyond three attempts per shape because it seemingly takes more attempts to master the shapes that appear harder to trace.

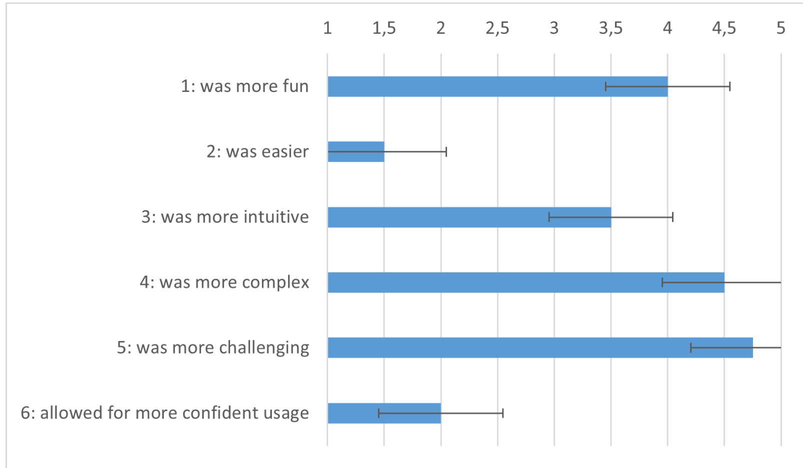
5.3 Questionnaire Evaluation

After finishing the shape tracing tasks, the participants were given a questionnaire letting them compare their experience with the two drawing methods.

The first part of the questionnaire let participants choose whether a statement applied more to the Cursor Placement Method (1) or the Continuous Method (5) on a 5-point Likert Scale. The statements were partially inspired by the SUS (Brooke, 1995) and Perlman's (n.d.) version of the USE questionnaire (Fig. 13).
It showed that on average, the participants inclined towards the Continuous Method having been more fun (M=4, SD=1.41), and at the same time more complex (M=4.5, SD=0,58) and more challenging (M=4.75, SD=0.5).
On the other hand, they predominantly reported that the Cursor Placement Method was easier (M=1.5, SD=1) as well as that it allowed for more confident usage (M=2, SD=2). It should be noted that three of the four participants strongly preferred the Cursor Placement Method regarding the more confident usage, while the single remaining participant expressed a strong preference for the Continuous Method.
The participants were divided regarding which method they deemed more intuitive (M=3.5, SD=1,29). Half of them were inclined towards the Continuous Method, the other half towards the Cursor Placement Method.

In the next part, the questionnaire explicitly asked to state which of the methods was preferred and to include an explanation. Three out of four participants said they overall preferred the Continuous Method, their main reasoning being the method being more challenging. Some participants also positively mentioned more excitement, higher satisfaction upon succeeding as well as having to communicate more with their partner. The remaining participant based their preference for the Cursor Placement Method on it allowing them to see what they were doing and having "more logic behind it".

The third part let participants choose whether a collaboration-related statement applied more to the Cursor Placement Method (1) or the Continuous Method (5) on a 5-point Likert Scale (Fig. 14).
All participants explicitly chose that the Continuous Method required more coordination in the collaboration (M=5, SD=0). Further, neither method proved to have predominantly yielded more satisfying results over the other (M=3, SD=1.83). 50% leaned towards the one method, while the other 50% favored the other method. The almost same applied to the statement asking which method allowed for more equal participation (M=3.5, SD=1.91). Half the participants fully preferred the Continuous Method in this regard, while one participant fully preferred the Cursor Placement Method. The remaining participant rated the methods to be allowing for equal participation likewise.

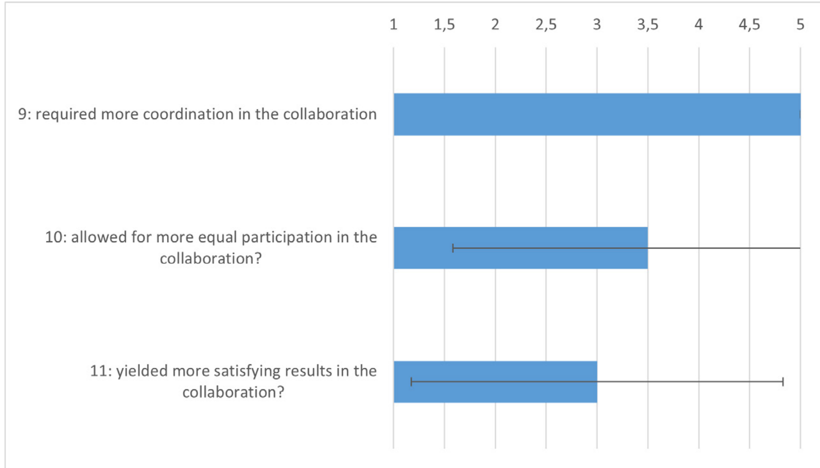


13 Questionnaire: Average responses with standard deviation to questions 1–6.

The following part asked the participants about how they coordinated with their partner during the drawing process.
All participants mentioned verbal communication generally. Verbal communication during the tasks was addressed by three participants. One tester mentioned the communication happening through explicit orders and another one through noises. Two mentioned talking their tactics through in advance. There were further mentions of practicing before starting an attempt and moving intuitively by observing how the partner moved.

The second to last part listed 22 adjectives taken from the Microsoft Product Reaction Cards (Hawley, 2010) and asked participants to choose up to three adjectives to describe the interface in order to assess their impression of it. The participants were also asked to explain their choice.
The three most mentioned adjectives were creative (3), engaging (3) and collaborative (2). The choice of the adjective creative was explained with the interface's Continuous Drawing Method allowing freestyle drawing and the participants not having seen a similar interface before. The participants saw the interface as being engaging in its demand to focus and making one want to interact with it. Finally, collaborative was chosen due to having to depend on one's team member in the interaction and the collaborative nature of the interface.

The last part of the questionnaire asked for further comments.



14 Questionnaire: Average responses with standard deviation to questions 9–11.

6 Conclusion

In summary, it can be stated that the participants found the Continuous Method to have been more fun, more complex, and more challenging. The Cursor Placement Method was chosen to have been easier and to have allowed for more confident usage. The participants' assignment of easiness and hardness aligns with the established average precision values and learnability. The participants did not render a clear image of which method was more intuitive.

Looking at the aspect of collaboration, the participants were divided regarding which method allowed for more equal participation and which method yielded more satisfying results. But they unanimously agreed that the Continuous Method required more coordination in the collaboration. The participants verbally communicated before and during tasks to coordinate their collaboration.

Regarding the overall interface, participants said it was creative, engaging and collaborative.

During the user study, an alternative version for the Cursor Placement Method came to mind. Instead of letting the users have essentially infinite time to place their cursor by waiting for their immobility to start the countdown, there could be a countdown limiting the time they have to place the cursor before the line will be extended. That way the method could become more challenging and engaging over a longer period of time. This approach could be implemented and compared with the current rendition of the method in the future.

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