Hochschule Augsburg
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Interaction Engineering

LET'S KNEAD

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0. Abstract

"Let's Knead" is an interactive application in which clay is used for interaction between humans and computers. For this purpose, the computer suggests various shapes to be kneaded by the user. The kneaded figures are recognized and evaluated via a webcam and a neural network. The neural network is based on the data records of Google Quickdraw and acts as a neutral referee. The game can be played alone or against another player. The goal of the research project is to find out to what degree clay, as a haptic input medium, influences the gaming experience and whether the fun of the game can be increased by a competitive component.

1. Motivation

The gaming sector is growing. In Germany alone, there are currently 34.3 million computer gamers[1], and the trend is rising. Interaction here usually takes place using classic input devices such as mouse/keyboard or gamepad. With the appearance of new technologies such as virtual reality headsets or Microsoft Kinect, new forms of human-computer interaction are constantly being introduced.

In our project, we want to go one step further and provide users with a new, more unusual interaction medium, clay. By means of modeling, it should be possible to create a haptic and extraordinary game experience, which gives the user even more freedom and encourages creativity. „Let's Knead" can be played alone or with a second player. The gameplay is very simple. The computer suggests an object, and the user must try to knead it. Using a webcam and a neural network, the computer tries to recognize the suggested object. If the object is guessed, the computer suggests a new object. The game starts again. The data sets for the neural network are provided by Google Quickdraw . A browser game in which players have the task of drawing one of a random object within 19 seconds.

In our game, we want to find out whether the haptic feeling of the clay influences the fun of the game and if so, in a positive or negative sense. Since most people are already familiar with Play-Doh since their childhood, we want to find out how intuitive the game is. The user should only be given an instruction such as "Knead a <object>" as a task. We also want to find out if the gameplay can be improved by a competitive two-player mode.

Our project aims to answer the following research questions:

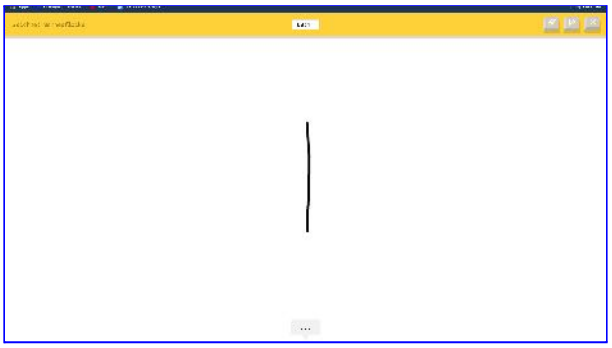
1. Does the haptic of Clay improve the gaming experience?
2. Is the two or one-player game more enjoyable?

[1] https://de.statista.com/statistik/daten/studie/712928/umfrage/anzahl-der-computerspieler-in-deutschland/

2. Related Work

As inspiration for the present work, we used two games. The first game is the "Google Quick Draw" game and the second is the "Play-Doh Touch" app. In the following, these games will be presented more in detail.

2.1 Google Quick Draw[2]



The present project is mainly based on the already existing "Google Quick Draw" game. This is a free to play computer game. The game was created with the help of machine learning. It works as follows:
The computer suggests a word that the user should draw within 19 seconds. While the user is drawing, a neural network tries to guess the word. The drawings of the game are all stored in a database. The network is trained with these drawings. The drawings are publicly available. They were used in the present project to guess words.

2.2 Play-Doh Touch App[3]

Another inspiration for the "Let's Knead" game is the "Play-Doh Touch" app. This is because clay is also used here in addition to the digital medium. In the "Play-Doh Touch" app, clay is used to form objects. These objects can be scanned into the app. The scanned objects will then become game characters in the virtual world.

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[2] https://quickdraw.withgoogle.com/

[3] https://play.google.com/store/apps/details?id=com.hasbro.playdohtouch&hl=de&gl=US

3. Concept

This chapter describes the concept of the game in more detail. The game consists of the following three game modes: Let's Draw - singleplayer, Let's Knead - singleplayer and Let's Knead - twoplayer. In the beginning, it is described why the different modes are necessary. Then it will be explained how they work. In a further point, the design of the game is explained and at the end, the individual interaction techniques are discussed in more detail.

3.1 Let's Draw - singleplayer

Relevance: To answer the first research question (Does the haptic of clay improve the gaming experience?) a Let's Draw game is needed to investigate how a conventional computer game operated with the mouse is played by the user.
Function: The "Let's Draw - singleplayer" game works similarly to the "Google Quick Draw" game. The computer suggests a word. After that, the user has to draw the word. While the user is drawing, the time is measured until the computer recognizes the word.

3.2 Let's Knead - singleplayer

Relevance: To answer the two research questions, a "Let's Knead - singleplayer" game is needed to investigate how a game with the haptic medium clay is liked by the user. In addition, it will be compared to a two-player game.
Function: In the "Let's Knead - singleplayer" game, the computer suggests a word. The user then has to knead the word. While the user kneads, the time is measured until the computer recognizes the word. The "Let's Knead - singleplayer" game, therefore, works in the same way as the "Let's Draw - singleplayer" game. The only difference is that instead of drawing, the user kneads.

3.3 Let's Knead - twoplayer

Relevance: To answer research question two (is the two or one player game more enjoyable?) a "Let's Knead - twoplayer" game is needed to compare it with a singleplayer mode.
Function: In the "Let's Knead - twopalyer" game, the computer suggests a word. Then two users have to knead against each other. while the users knead the given word, the time is measured. A round is finished as soon as the computer recognizes the kneaded image of one user. This user then also wins the round.

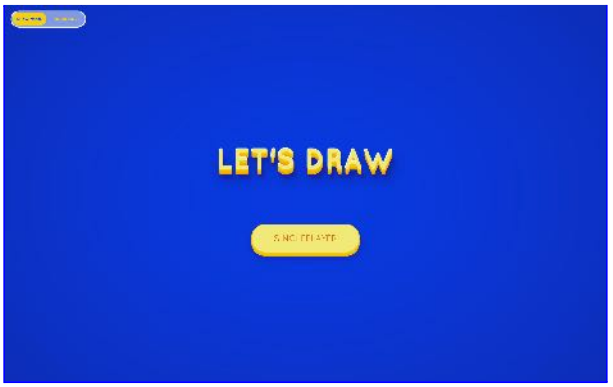
3.4 Design and Interaction Techniques

The design and interaction techniques are described below. The interaction techniques are marked **bold and yellow** so that they can be seen immediately.

3.4.1 Design

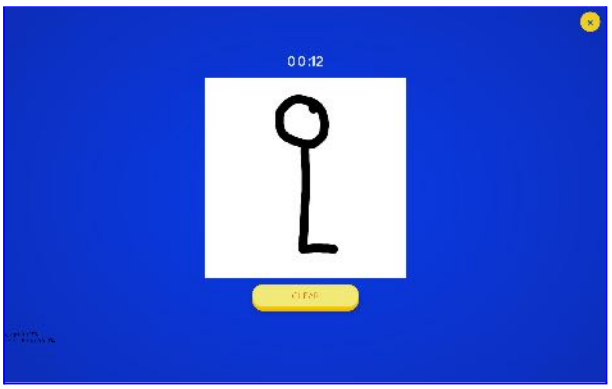
The two images of the chapter “3.4.2 Start screen” show the start screens of the "Let's Knead" and "Let's Draw" games. Throughout the games, the colours blue and yellow were used. The yellow colour is a reference to the "Google Quick Draw" game. The blue colour is used because it is on the opposite side of the colour wheel. This creates a high contrast to the yellow colour. In this way, good readability is achieved.
The background colour of the "Let's Knead" mode is yellow and the font is blue. In "Let's Draw" mode it is the other way around. This creates a difference between the "Let's Draw" and "Let's Knead" mode and it is clear for the user in which mode he is playing. The buttons and the headlines are three-dimensional. This is supposed to create a reference to the haptic, three-dimensional dough.

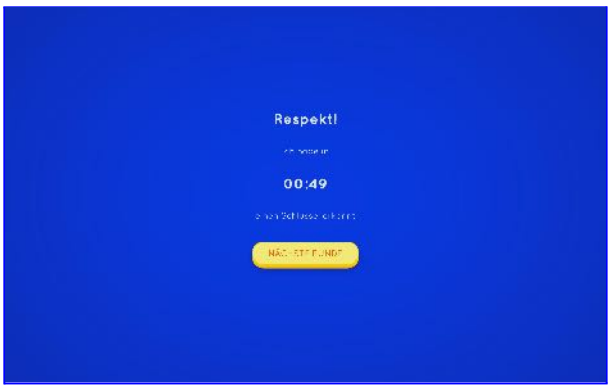
3.4.2 Start screen



Description and interaction: When the user opens the game, he gets to the start screen. The start screen is an overview of the game modes. In the beginning, the user is in the "Let's Knead" mode. Since this is the focus of the work. The user can decide here by **two buttons** between the "Let's Knead - twoplayer" and the "Let's Knead -singleplayer". **A tab** in the upper right corner of the game **allows the user to switch from "Let's Knead" to "Let's Draw" mode**. **The buttons are operated with the mouse.**

3.4.3 Let’s Draw - singleplayer



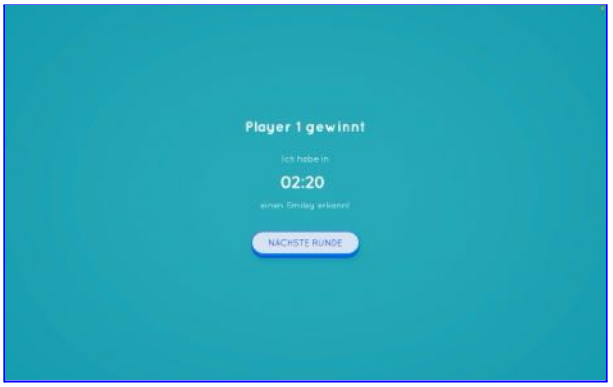


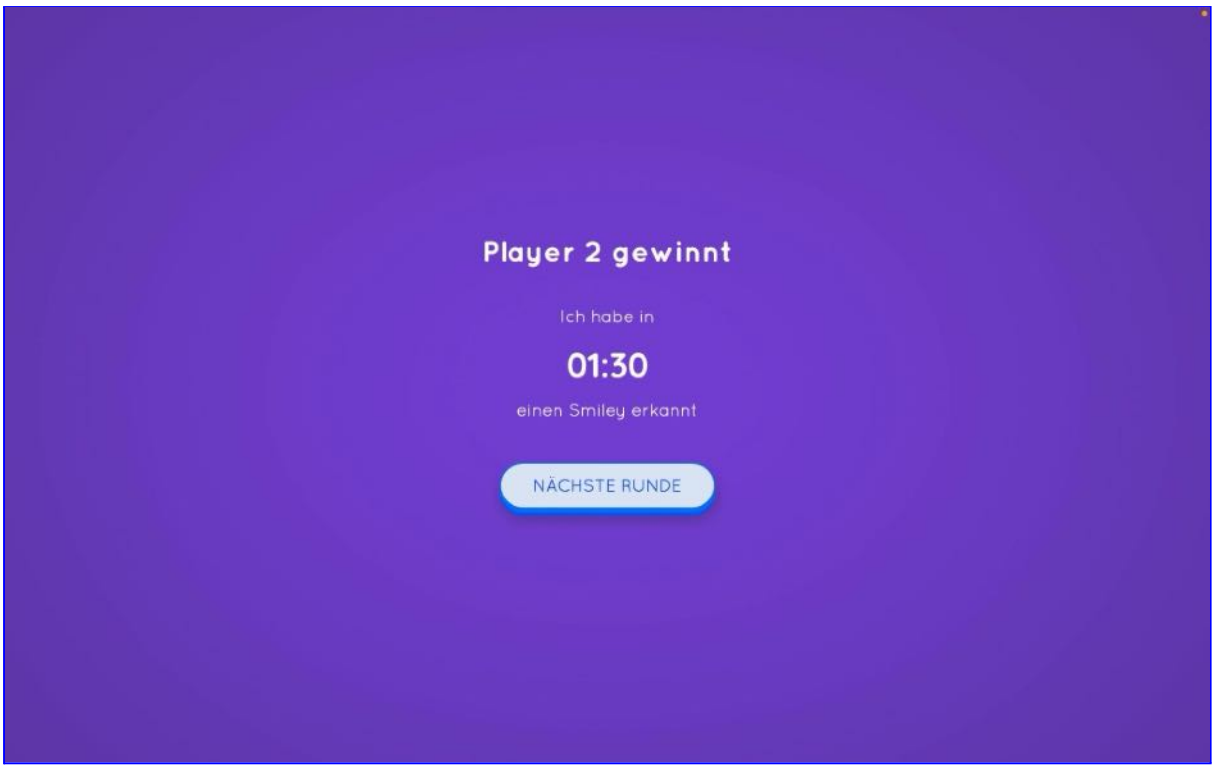
Description and interaction: The user is suggested what to draw at the beginning of the "Let's Draw - singleplayer" game. He can then **start the game by clicking a button.** Now a page opens with an area to draw on. **On this area can be drawn with the mouse**. If the user does not like the **drawing, it can be deleted with a "Clear button"**. During the drawing, the time is measured which can be seen by a timer. In the upper right corner of the game, there is an **"x-button". By clicking on it, two buttons appear** ("Exit Button" and "Continue Button"). With the **"Exit Button", the game can be stopped** at any time and the user will return to the start page. With the **"Continue button" the user moves on with the game.**
When the object that the user is painting is recognized, a page opens. This page tells the user that the object has been detected. There is also the time the user needed until the object was recognized. In addition, there is a **button that leads to the next task.**

3.4.4 Let's Knead - singleplayer

Description and interaction: The "Let's Knead - singleplayer" game is similar to the "Let's Draw - singelplayer" game. The difference is that the drawing surface is replaced by a kneading surface. A camera records what the user is kneading. **Instead of the mouse, the knead is used as an interaction medium.** Furthermore, there is no need for a clear button, because the clay can be easily removed.
If the object is recognized the same thing as in the "Let's Draw - singleplayer" will happen.

3.4.5 Let's Knead - twoplayer





Description and interaction: The "Let's Knead - twoplayer" also has an "x-button" in the right corner, as well as a timer. The difference in this mode is that there are two kneading areas, in which two people can knead against each other at the same time. **Instead of the mouse, the knead is also here used as an interaction medium.**
As soon as a player wins, a new window appears with the winning player in the title. The window is coloured in the clay colour of the winner. In this way, it is immediately clear which player has won. Apart from that, the window is structured in the same way as in "Let's Draw - singleplayer" and "Let's Knead - singleplayer" mode.

4. Implementation

4.1 Technical setup

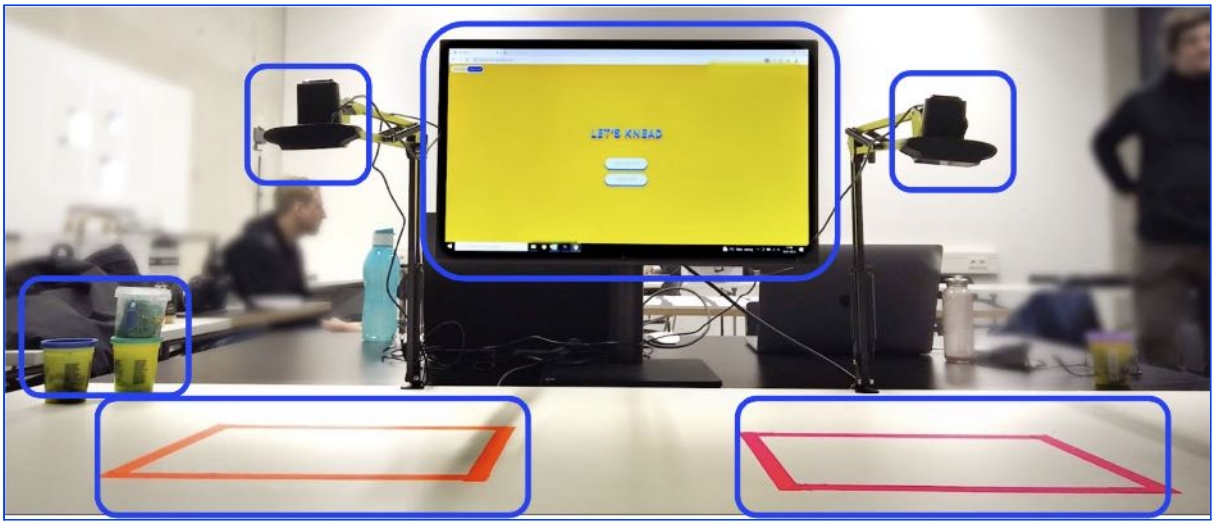
Display: On this screen, the user interface of "Lets Knead" is shown. Here, the user can see the appearance of his kneaded shape during the game. The various probabilities of the recognized objects are also displayed in the lower-left corner. This is done every 500ms.

In the main menu, the user can choose between single-player and two-player modes. A small icon in the upper left corner of the start screen can be used to switch from kneading mode to drawing mode. This mode was especially important for the evaluation and is adapted from the original application, Google Quickdraw.

Webcam: A webcam is required to recognize the clay figures in single-player. In the competitive two-player mode, two webcams are required.

Kneading Areas: To make the area where the clay will be placed more visible, it is also recommended to mark the clay area and calibrate the webcams to this area.

An example setup can be seen in the following picture.

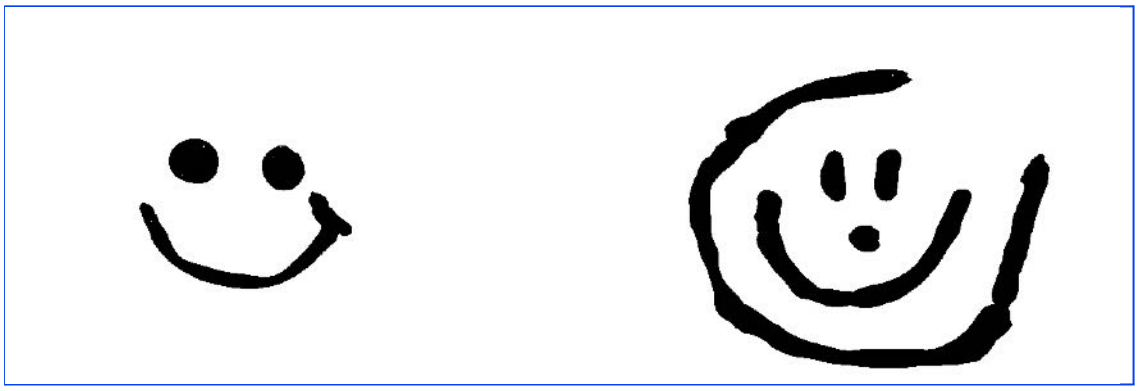


4.2 Coding

For the implementation of our prototype, we used the open-source HTML editor Brackets. This allowed us to switch smoothly between HTML, CSS and JavaScript when editing the code without using additional program instances. With the help of the live preview function, we were able to test and adjust our code on a local server. The design of the website was done using HTML and CSS. In addition to Javascript, the two libraries p5.js and ml5.js were used for the prototype.
The idea behind the open-source Javascript library p5.js[4] is based on open-source programming language Processing and enables fast canvas-based prototyping. For this purpose, graphical and interactive applications for the web can be created directly in the browser.
ml5.js[5] is a library built on top of Tensorflow.js that provides access to various machine learning and deep learning algorithms in the browser. Similar to p5.js, the focus is on particularly easy accessibility.

4.2.1 Identification of the clay

To identify the clay by using a webcam, the colour of the clay is first defined in the form of red, green and blue values (0-255). For this purpose, the colour values are determined using an image processing program (e.g. Photoshop). We have found out that colour detection works even better if a lower and upper colour (e.g. Rmin & Rmax) limit exists. Afterwards, two for-loops (for width and height) run through every single image of the video. Each pixel is checked if the value of the detected colours is within the previously defined limits of the kneading colours. If this is the case, it will be coloured black, otherwise white. Each pixel is represented by R, G, B and A values. Therefore, the first four values (indices 0-3) in the array will be the R, G, B, A values of the pixel at the position (0, 0).



```
function recogColor(){
//x = Image width and y = Image height
       for (var y=0; y<400;y++){
       for (var x=0; x<640;x++){
var index = (x + y * 640) * 4;
```

[4] https://p5js.org/
[5] https://ml5js.org/

```
if(p1_rotMin < player1.pixels [index] && player1.pixels [index] < p1_rotMax && p1_gruenMin
< player1.pixels [index+1] && player1.pixels [index+1] < p1_gruenMax && p1_blauMin <
player1.pixels [index+2] && player1.pixels [index+2] < p1_blauMax){

       player1.pixels [index]=0;
       player1.pixels [index+1]=0;
       player1.pixels [index+2]=0;
}
else{
       player1.pixels [index]=255;
       player1.pixels [index+1]=255;
       player1.pixels [index+2]=255;
                     }
              }
       }
}
```

4.2.2 Implementation of object recognition

As already mentioned, we used the ml5.js library to identify the kneaded objects. At first, the method ml5.imageClassifier() is used to create an object that classifies an image using a neural network. The model with the name "DoodleNet", which has already been pre-trained with the Google Quickdraw data, is passed here as a parameter. As soon as this model is loaded, the classification process is started via a callback method. For this, the canvas of each player is passed. The result is an array, which contains the recognized objects (label) and their probabilities (confidence) in descending order as return parameters.

```
const setup = function() {
//Initiate the recognition object using the DoodleNet
doodleClassifier = ml5.imageClassifier('DoodleNet', modelReady);
};

function modelReady() {
// Running the recognition method every 500ms
setInterval(classify,500);}

function classify() {
// Canvas with kneading image is transmitted. An array with the detected
// object and probability is returned.
doodleClassifier.classify(player1.canvas, gotResultsPl1);
    doodleClassifier.classify(player2.canvas, gotResultsPl2);
}
```

5. Evaluation

To test the prototype, a user test was conducted. First of all, the research questions were examined in detail. These were then used to formulate hypotheses which were then tested. The hypotheses are listed below:

1st hypothesis: Users prefer the "Let's Knead" game instead of the "Let's Draw" game because clay improves the gaming experience.
2nd hypothesis: The twoplayer "Let's Knead" game is more enjoyable than one player "Let´s Knead" game.

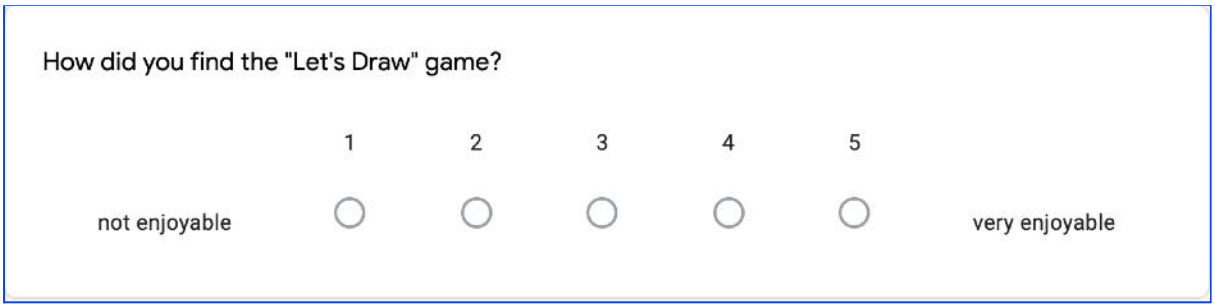
To test whether the hypotheses were true, the subjects of the user test had to complete three tasks. The tasks of the user test are listed below.

1st task: The subject has to play three rounds of the "Let's Draw - singleplayer" game. He has to draw a key, eyeglasses and a bicycle.
2nd task: The subject has to play three rounds of the "Let's Knead - singleplayer" game. He has to knead a key, eyeglasses and a bicycle.
3rd task: Tow subjects have to play three rounds of the "Let's Knead - twoplayer" game. They have to knead a smiley, a cat and an alarm clock.

The three tasks were performed using the ABA test procedure. This meant that each subject completed the tasks in a different order. After the test, subjects had to complete a questionnaire and select Reaction Cards. A total of 10 subjects participated in the user test. Six of them were male and four were female. The age of the subjects ranged from 23-29 years old.

5.1 Questionnaire

To find out how the individual games perform against each other, a questionnaire was created. The questionnaire measures on a "likert scale" how intuitive and enjoyable the individual games were. This helped to find out if the mentioned hypotheses could be fulfilled. In the following, single questions of the questionnaire are presented to get a better imagination of them.



How did you find the "Let's Knead" game (single player)?

	1	2	3	4	5	
not enjoyable	○	○	○	○	○	very enjoyable

How did you find the "Let's Knead" game (two player)?

	1	2	3	4	5	
not enjoyable	○	○	○	○	○	very enjoyable

How did you find the "Let's Draw" game?

	1	2	3	4	5	
not intuitive	○	○	○	○	○	very intuitive

How did you find the "Let's Knead" game (single player)?

	1	2	3	4	5	
not intuitive	○	○	○	○	○	very intuitive

How did you find the "Let's Knead" game (two player)?

	1	2	3	4	5	
not intuitive	○	○	○	○	○	very intuitive

5.2 Microsoft Product Reaction Cards

As a second method of evaluation, we used Microsoft Product Reaction Cards, which provide information about the emotional reaction regarding our game. After testing our game, the participants could choose 5 words from a list of 48 words that they thought best described our project. Some words were positive and some negative. The following table gives an overview of the reaction cards used.

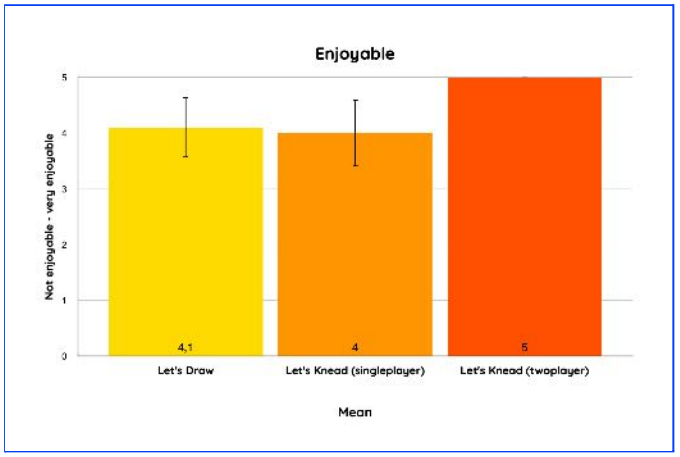
Appealing	Controllable	Expected	Impressive	Predictable	Stable
Annoying	Convenient	Fast	Innovative	Reliable	Stressful
Boring	Creative	Flexible	Intuitive	Responsive	Time-Consuming
Collaborative	Customizable	Frustrating	Motivating	Satisfying	Time-Saving
Comfortable	Difficult	Fun	Old	Simplistic	Uncontroll-able
Complex	Easy to use	Hard to use	Ordinary	Slow	Unconvent-ional
Confusing	Entertaining	Helpful	Over-whelming	Sophisti-cated	Under-standable
Confusing	Exciting	High Quality	Poor Quality	Stable	Unpredict-able

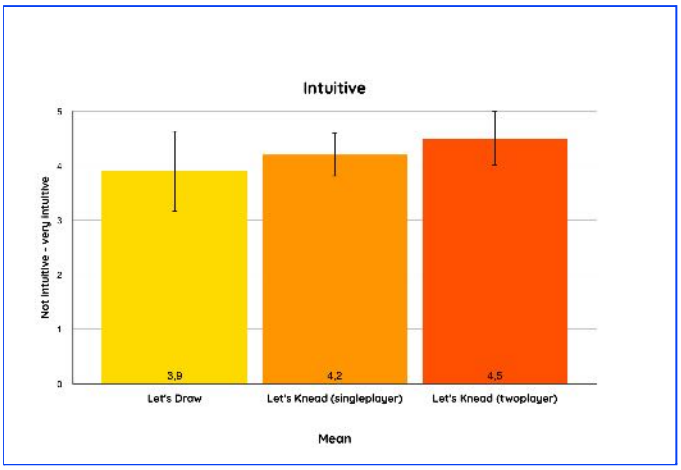
5.3 Outcome

In the following, the results of the Questionnaire and the Reaction Cards are explained in more detail.

5.3.1 Outcome Questionaire

The following two graphs show the results of the questionnaire. The first statistic shows enjoyment and the second statistic shows intuitiveness. But what do these statistics mean? This will now be explained in closer detail.





In terms of enjoyment of the game, it turns out that all the games were well rated by the user. Because the mean for each game mode is more than half (2.5). Furthermore, it can be seen that the "Let's Knead - twoplayer" game was the most fun to play, with a mean score of 5. Apart from that, the gaming enjoyment of the "Let's Draw - singleplayer" game with a mean value of 4.1 and the "Let's Knead - singleplayer" game with a mean value of 4 is almost the same. The gaming experience can therefore not be influenced regardless of whether the user has to draw or knead.

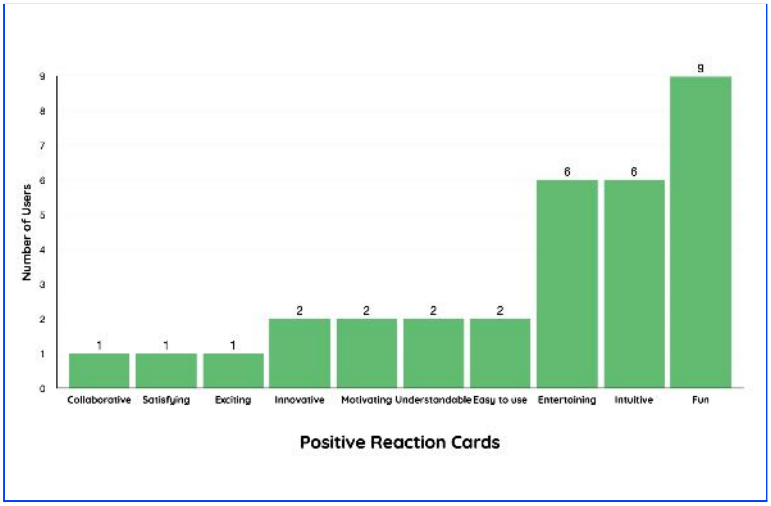
Next, the intuitiveness diagram will be explained. Like the game enjoyment, all three game modes were rated positively as well, as the average is always above half. Similarly to enjoyment, for intuitiveness, the "Let's Knead - twoplayer" game, is the best rated, with an average score of 4,5. Comparing the "Let's Draw - singleplayer" game and the "Let's Knead - singleplayer" game it becomes clear that the clay game is rated more intuitive with a mean value of 4,2 than the drawing game (average: 3,9). But what do the results of the diagrams mean in the context of the above mentioned hypotheses?

The first hypothesis (Users prefer the "Let's Knead" game instead of the "Let's Draw" game because clay improves the gaming experience.) is proved. This has two reasons. First, the "Let's Knead - twoplayer" game is rated best for intuitiveness as well as enjoyment. On the other hand, the "Let's Knead - singleplayer" game is also better rated. If only the enjoyment diagram is observed, the "Let's Draw - singleplayer" and "Let's Knead - singleplayer" games are rated almost the same. However, if the rating of intuitiveness is added, the "Let's Knead - singleplayer" dominates against the "Let's Knead - drawing game".

For these two reasons, it can be assumed that clay improves the gaming experience.
The second hypothesis is also true. The "Let's Knead - twoplayer" game was rated best for enjoyment as well as intuitiveness. This indicates that the twoplayer "Let's Knead" game is more enjoyable than the singleplayer "Let's Knead" game.

5.3.2 Reaction Cards Outcome and Improvement

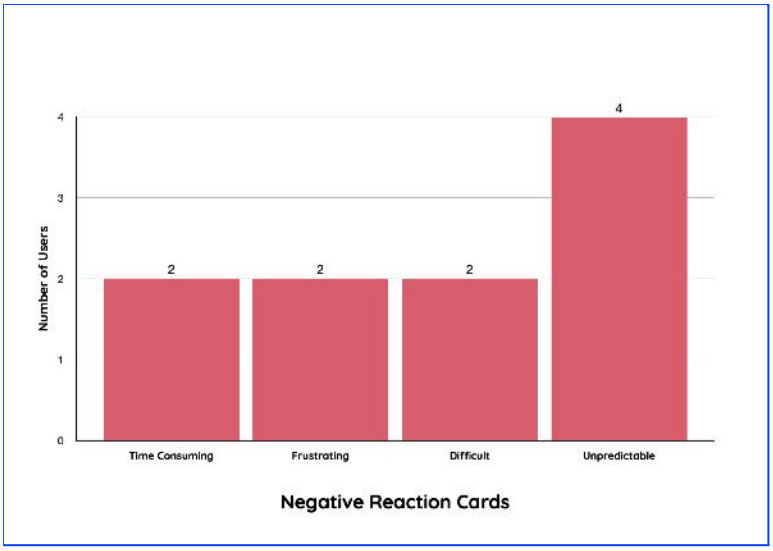
In general, the evaluation of our application using Reaction Cards was very good.



Here, most of the words that can be assigned to the game were positive. The three most frequently selected words were entertaining, intuitive, and fun.

However, there were also some negative cards such as time-consuming, frustrating, difficult and unpredictable.

Especially the negative ones gave us an overview of what should be improved further.



The aspects like time-consuming, frustrating and difficulty are related to the fact that the kneaded objects are recognized too slowly. This can be remedied by further adjusting the probability limits of the recognized objects.

However, since this also depends on the skill of the individual participants, some kind of difficulty selection at the beginning would be a possibility to counteract the problem. Also, the limit could decrease more and more as time goes on, accommodating to the players.
The most frequently chosen negative card was unpredictability. This has its origin in the nature of neural networks as well as in the choice of training data. One of the reasons could be that the neural network was trained with data from a drawing database. Also, it could be that we would knead things differently than we draw them.
In the conversation after the user test, it was mentioned that the user kneaded something, which was correct in the eyes of the user, but the neural network did not recognize it as a correct result. A solution for this problem could be clearer feedback of the neural network or training of the network with pictures of kneaded shapes.

6. Conclusion

6.1 summary

The idea of this project was to create a simple computer game in which clay is used to create a haptic and exciting gaming experience. This was implemented using image recognition and a neural network trained with data from Google Quickdraw.

In the procedure of the user test, clay was perceived by the majority of the test subjects as much more intuitive than drawing with the mouse. Since the tasks were the same in both scenarios, we can assume that clay is responsible for an improvement of the gaming experience, which confirms our first research question, whether the haptic of clay is responsible for the gaming experience.

For the second research question, which scenario was preferred by the test subjects, the results of the questionnaire clearly showed that the participants favored the two-player mode. In the subsequent interview, this was emphasized once again, also confirming our second research question.

In conclusion, we can say that we have benefited greatly from each other's knowledge and therefore were able to learn a lot of new things, especially in the areas of html, css and js. The work with the neural network has turned out to be extremely exciting and has given us interesting insights into how such a network works.

6.2 future work

Several things could be improved for the future.

In order to increase the long-term motivation, more shapes could be added to the already existing six. Adding a high score could also increase the motivation in the long run with regard to the single-player mode.

Another improvement to further challenge the player could be an automatic adjustment of the difficulty depending on the user's skills. In this way, the NN could automatically increase the percentage limits for successfully solving the task, depending on the time needed. Also, the percentage limit could decrease as soon as the time increases too much.

As a third improvement, the recognized figures could be used to train the neural network and therefore improve the recognition further, just like Google Quickdraw. Training the network with kneaded images would also improve the recognition mechanism and make the game less unpredictable.