M.Sc Interaction Technology Thesis

Exploring possibilities in interactive technology to create Cross-Domain Interactive Breathing Exercise Games

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Preface and acknowledgements

The final graduation project phase in my Master degree in Interaction technology at the University of Twente, has been full of ups and downs with the work progressing at several different paces. The social distancing that we are obligated to maintain didn't help either. However, with the help of my main thesis supervisor, dr. ir. Dennis Reidsma, this phase seems to have been pleasant and fruitful, despite the several adjustments and complications owing to the ongoing COVID-19 situation. This document is a summary of the accomplishments and findings to have occurred in my graduation project. With the help of this project, I learned and enhanced several skills, such as critical thinking, some programming, understanding users, drawing good, meaningful conclusions, game design, prototyping, hosting brainstorming sessions and much more, owing to the guidance of Dennis Reidsma, Deger Ozkaramanli and Laurien Hakvoort.

I would sincerely extend warm gratitude towards, of course, Dennis for all his help, understanding and guidance. Deger and Laurien have also been of much help with their specific and expert inputs. Robby's extensive feedback on the report is also much appreciated. Ben Bulsink provided the breath sensor and information on how to use it, which was helpful in this project. Further, I would like to thank my several interviewees, for their valuable time and information. Also, importantly, my housemates and friends have been great as always and helped keep one another's spirits high during this worldwide pandemic. I'm not sure if its weird, but I'd like to thank technology for existing and helping everybody so much, especially during these trying times. Last, but certainly not the least, as always, my family in India, despite being oceans away, have always been there for support and love.

Abstract

Breathing is an integral part of our existence, affecting several aspects of the human body, other than just getting oxygen into our systems. The right breathing technique can help singers, wind-instrumentalists, mindfulness seekers, breathing difficulty patients and several others to fulfil their goals optimally and comfortably. Initial explorations about several breathing techniques, their benefits, technological interventions in the form of sensors, media, music and games, to facilitate and motivate people to perform breathing exercises intuitively, regularly and correctly were done in the Research Topics phase of this project [12]. Information about this was gathered via existing literature, interviews of experts in various domains and analysis. Using the information gathered, further research was done in the Master thesis which includes statistical analysis of breathing data received from the breath sensors to enable using the sensor to be used as a game controller, understanding and formulating ways to create multipurpose, configurable breathing games, further understanding user requirements for one domain (singing) via co-design sessions, creating and evaluating a basic breathing exercise game prototype for singers and finally, a framework about the possibilities to translate breathing exercise games to other domains. This project could possibly lead to further research about several aspects of breathing exercise games, which are also discussed in this report.

1 Introduction

It is no secret, that everybody breathes. More often than not, we are not even conscious about the fact that we are breathing. However, understanding the importance of breathing can make one marvel at how many benefits it has, if done consciously and correctly. People from various fields of work find conscious breathing techniques as an essential part of their everyday life. These include people from singing, wind-instrument playing, mindfulness, pregnant women, therapy seekers and many more. These domains have specific breathing exercises so as to fulfil various goals, thereby contributing to their performance in that domain as well as general well-being. There has already been research conducted about these aspects of breathing and it is already a well-established practice. However, one can imagine that individuals may tend to lose interest and end up not performing their breathing exercises regularly and correctly, as also suggested in [36]. We believe this could be caused by general resistance to perform breathing exercises, possibly due to boredom, lack of interest and forgetfulness, in addition to the factors (lack of confidence in exercise effects, lack of knowledge about the way to do them, no clear routine) presented by Qin et. al in [36]. This was also suggested in interviews of experts in singing, wind-instrument playing, mindfulness, breath therapy for disorders & addictions and a midwife conducted during the Research Topics phase of this project [12]. Making breathing exercises a part of the every day life of such individuals can reap genuine and proven benefits, as discussed in the Research Topics phase [12]. Traditional strategies to provide these benefits to individuals who need/seek them, include verbal/written instructions and medication in case of therapeutic needs [43, 44]. However, could it be possible that these breathing exercises can benefit from technological aid? The answers to this question is 'yes, but it depends', as explained in chapter 2, where we talk about the related work and existing exercises, techniques and games used for breathing, in various domains.

Breath practitioners try to make these breathing exercises more interesting to their students/patients via games [12]. Games are a very useful tool to having fun experiences with the help of a technological interface. Also, many of us believe that music plays an important role in our lives and some research has also proven music to be relevant to breathing. Since I have been an avid gamer since childhood and also been a singer, my personal motivation for this project lies in my passion for games, music and interactive technology, given my educational background.

In the literature study conducted, to the best of our knowledge, we could not find studies that explore the use of technologically interactive games for breathing exercises in singing. Hence, building upon the Research Topics and taking my interests into account, this project explores how breathing exercise games, with music playing a role in it, can be built for several purposes, but 'singing' was chosen as the starting point for this as building prototypes for all domains, while also understanding potential users from these domains would be beyond the scope of this Master thesis project. So, we explore different possibilities of elements in the game and roles of game audio/music that can be tweaked so as to incorporate different breathing exercises within and across domains. These thoughts bring us to the following research questions:

1. Given a breath sensor, how can we use the obtained data to develop an efficient game controller, using breath as the game input?

2. Since we know that there are several breathing exercises used in different domains, what elements of gaming (controls, level design, visuals, in-game audio/music, etc.) could be altered such that these exercises can be performed with the help of games?

3. First considering one domain of work - singing, what do potential users of such a game want in it, such that the game is useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises? How can music play a role in such a game?

4. How can such a breathing exercise game be translated to other domains of work?

This report is an attempt to answer these questions in a detailed manner. In Chapter 2, we take a look at the related work for this project, in which we made initial explorations about the importance, goals and breathing exercises from the domains - singing, wind-instrument playing, pregnancy, mindfulness and breath therapy, much of which is summarized from the Research Topics phase of this project [12]. Chapter 3 explains how we plan to tackle each research question in this project. In chapter 4, we see how the incoming data from the *Breathline* breath sensor was statistically analyzed, pre-processed and made usable as game control input data. After that, we describe the different elements of the controllability of games, such as the real-world action to game action coupling, level designs (which affect how the game can be controlled), etc. in Chapter 5, in which we see an illustrative example of how these elements can be altered, so as to incorporate different breathing exercises. Then, in chapter 6, we take a look at the various possible roles that in-game audio/music can play in breathing exercise games. Chapters 7 and 8 show how participants from the singing domain were involved, via a co-design session and feedback, in the process of designing the game and interface prototypes built, which we see in chapter 10. Chapter 11 takes a look at how these prototypes relate to the requirements that resulted from the user involvement in the design process. Thereafter, another round of interviews with participants was conducted to get additional insights and feedback in greater detail about the different elements of the game, as seen in chapter 12. Chapter 13 brings together ideas of how various breathing exercise games can be created within and across domains, by tweaking game elements like the game controllability, audio and visuals. Finally, in chapter 14, we discuss the work done, limitations and future work that can be done, building upon this project.

We believe that this project could contribute as a starting point for further research in creating breathing exercise games that can be beneficial to singers, wind-instrument players, mindfulness-seekers, breathing difficulty and breath therapy patients, pregnant women among several other domains, while also possibly benefiting game designers to design and develop breathing exercise games for them. First, with the sensor analysis to enable the breath sensor to be used as game controller, we provide an introduction about what features of breath sensor data can be used to get game control and feedback, which can be useful to game developers and researchers, when using sensors like the *Breathline* sensor. Second, the explanation of the different elements of game design that can be altered so that they can embody various breathing exercises within and across several domains can provide a broad arsenal of possibilities to work with, in breathing exercise game research and for designers to design games. These game elements include the GACEs introduced in this project, in addition to level design, in-game audio/music and visual elements in the game, which altogether provide a broad palette of game elements to tweak according to the domain, goal and exercise. Third, by involving participants in the prototype design process via co-design and feedback sessions, we gained insight on how singing-related breathing exercises would be usable, acceptable and likeable to singing teachers and students. With this information, it could be possible to build detailed, full-fledged breathing exercise games for singers, after further prototyping and testing, thereby eventually benefiting singing teachers and students. Using such techniques of user involvement in the design process of domains other than singing, it is possible to get the in-depth insight required to build breathing exercise games for them.

2 Related Work

From literature studies and interviews taken during the Research Topics[1] [12] phase of this project, we saw that breathing is an important aspect in the domains explored, viz., singing, wind-instrument playing, pregnancy, therapy and mindfulness. For singing and wind-instrument playing, breathing is used to develop the correct technique, which also results in physical and mental conditioning in addition to skill development [2, 6, 18, 25, 34, 38, 40]. Pregnant women use breathing exercises to calm down and increase the chances of the labor stage of pregnancy to be a smooth process [26, 27]. In therapy, breathing exercises are used for recovery from various conditions that may/may not include breathing difficulties, such as ADHD, COPD, DMD (Duchenne Muscular Dystrophy), asthma, addictions, etc. as breathing helps one relax, focus and improve physical conditions like less breathing capacity and heart conditioning [4, 20, 36, 43]. Breathing is also a key part of mindfulness exercises, for reasons similar to that of therapy [3, 22, 29]. With the help of literature study, we found out several possible breathing exercises suggested in different domains and see several goals that they fulfil. We see this in Table 1[2].

Table 1: Exercises and goals found in literature

Domain	Exercise name	Exercise Explanation	Goal
Singing [6]	Verbal Instruction	Explain: a) which specific sound is to be produced; b) what is needed to do that; c) what they must carefully watch during the formation of voice.	Understanding
	Training inhalation	a) Visualize a bunch of flowers; b) calmly inhale through the nose, while thinking of pleasant aroma; c) a short hold; d) exhalation.	Understanding, noiseless breathing
	Push-ups	a) A push-up from a (school) desk: while doing this, pay attention to the character of inhalation and immediate holding of breath; b) repeat the inhalation in a standing position, fixing with hands the lower costal area and the front abdominal wall.	Developing stable sensation of lower costal breathing
	Training exhalation	"Let's blow the candle", i.e., try to keep the smoothness of exhalation and concentrate the flow of the exhaled air	control of air consumption
	Constant consonant	a) an active inhalation, b) a hold, c) a long active exhalation on sound "s"/"f"/"v", d) expelling of the residual air.	Developing right breathing technique for singing
	Visualize	a) Students are asked to visualize themselves as big colorful air-balls; b) after the game, the ball is put on the grass to rest for a while and the valve is taken out: the air gradually goes out (students let the air out very slowly)	Understanding

[1] Full Research Topics report and codes written for it can be found at: here

[2] The names of the goals and exercises in Table 1 are either taken directly from literature or are interpreted from statements made therein.

Mindfulness [29]	Three part breath	1. Sit comfortably with back straight and chest lifted or lie down on your back. 2. Slowly breathe in through your nose. 3. Notice how breath moves from the lungs, tummy(like a balloon), ribs, chest and shoulders. 4. While exhaling, let the breath ooze out of your lungs slowly, like a balloon losing its air, until they are empty.	Being mindful
	Ocean breath (Ujaii)	1 & 2. Same as above. 3. breath out keeping mouth closed making the 'ahhhhh' sound (feel the back of the throat pushing while making the ocean sound) 4. Try (comfortably) taking in longer breaths and longer exhalations 5. Listen to your personal ocean, imagine your own boat, and let the waves sweep you away.	
	Counting breaths	For 1 minute each: 1. Count no. of breaths (in+out = 1 breath) 2. Listen to all sounds outside yourself, note them. 3. Listen to all the sounds you hear inside yourself, note them. Share each activity with other members of the group. 4. Count breaths again and notice if it has changed.	
	Focus	Lie on floor on your back in a circle(group) with feet toward center of circle. Put hands on belly, breathe for 1 min. (This is part of a focusing activity containing other factors like smiling, etc.)	Focus
	The Hara	Slowly, deepen breath, let out any natural sounds, stay relaxed and loose, slowly picking up the pace. On the exhale, let the sound of HA become increasingly strong.	Invigoration
	Brushing Floor	Stand with feet comfortably apart, swinging arms forward and back. Knees slightly bent, press feet into ground, exhale HA as you bend forward brushing floor with fingertips. Inhale, return to standing as you swing arms up over head, repeat. Lightly bounce knees and ankles as the arms swing down and again as the arms swing up.	
Pregnancy [26]	Just Breathe	Slow, deep breathing is particularly effective. The "right" way to breathe is whatever feels right. Keep breathing conscious, not automatic.	Relaxation
	Pant	Speeding up the breathing and making it shallower is sometimes, but not always, more effective.	During stronger labor contractions
	Comfort	In addition to breathing, do comforting activities like moving, changing position, slow dance, massage.	Comfort

	Focus	Focusing on something, either with eyes closed or open, can help maintain the rhythm of the breathing.	Focus, mindful, relaxation
Therapy	PLB [36]	Pursed Lip Breathing	COPD Recovery
	Rhythm [36]	Breathing rhythmically on counts	
	In-Hold-Cough [36]	Breathe in, hold, cough	
	Calm breathing [43]	Slow-paced, rhythmic breathing	ADHD recovery, focus, relaxation

There exist breathing exercises that are either specific to a single domain or useful in multiple domains, fulfilling similar or different goals[3], as can be observed in Table 2, which shows the breathing exercises participant interviewees from various domains use in practice. We see this in Table 2, in exercises that are suggested and used by interviewees in their respective domains. This makes it a possibility to design a cross-domain breathing exercise game, to fulfil several goals related to breathing. However, within a given domain, there may also exist differences, like in mindfulness, Zen meditation involves much less breathing exercises as compared to Yoga.

Music, apart from the obvious likeability and entertainment factor, can also help in designing such games, as it can be a guiding force to consciously and subconsciously affecting breathing, heart rate and emotions. There already exist a number of interactive breathing games for specific purposes like a specific type of therapy or for a specific goal like relaxation, with the help of creative solutions involving different types of breath sensors, computer interfaces and clever audio design [32, 43, 44, 36, 4]. While these research do an admirable job in creating working games (or prototypes) that are useful to fulfil goals of a specific therapeutic purpose (eg: *DuckieDuck* [4] is a game to facilitate breathing goals in DMD therapy), applications that facilitate more than one type of therapy in the same game/suite of games seems to be fairly unexplored. So, there exists research wherein breathing exercises exist either only for one domain, or consisting of one breathing exercise that is useful for multiple domains (*Life Tree* [32] supports PLB which is useful for mindfulness, COPD and ADHD therapy). Also, in the literature review conducted, interactive breathing exercise games designed each for singers, wind-instrumentalists and pregnant women seems to be fairly unexplored. The fact that there exists a relationship between exercises and goals between different domains domains, as explained in the paragraph above, suggests that there is scope to broaden the horizons of breathing exercise game design. At the end of the Research Topics phase, with the insight obtained from literature and interviews, we set the target of this project to design and develop breathing exercise game prototypes that could possibly be used in different domains and put together the following design considerations for it:

- **Understand the user**. While setting up the game, the user should be able to make known what they are using the application for, in addition to an initial 'test' which can help in calibration of the breathing game specific to the individuals size and breathing capabilities. There are also typical differences in breathing pattern with regards to age, gender and condition, which also should be taken into consideration.
- Consider using breathing exercises that could **possibly fulfil goals across domains**, while also trying to fulfil multiple goals within one domain.
- Think of creative ways to give **instructions** in the most **natural and concise way**.
- The goal of **'Understanding' the right way to breathe** is one that is common across all the explored domains. Exercises fulfilling this goal should be one of the first steps in the game.

[3]The names of the goals and exercises in Table 2 are either taken directly from interviewee's comments or are interpreted from statements made therein.

Table 2: Breathing exercises with the number of interviewees from each domain who have suggested each exercise. (S: Singers, W: Wind-instrumentalists, P: Midwife (for Pregnant women), M: Mindfulness expert, T: Therapy which includes breathing exercises)

Exercise short form	**Exercise instructions**	**Suggested by**
Vocalize	Link breathing to voiced and unvoiced sounds	4S
Hissing	Inhale, Exhale at a constant rate with the 's' consonant sound	3S
All out	Remove all breath from your lungs and then breathe in	2S
Alternate bursts	Breathe out-4-bursts in. Then out in one go-in through nose in one breath, 4 bursts out. Repeat, increase bursts	1S
Candle	Keep one arm forward with your index finger pointing up. Think of the finger as a candle and blow air on it. Try varying the distance of the finger from the mouth	1W
In-in	In- 3 more in, then out till you're out: to understand full capacity	1W
21_22	Rhythmic breathing, inhale for the time taken to say '21', exhale for the time taken to say '22'	1P
Counting breaths	Count the number of breaths you breathe until 10, restart, repeat.	1M
Lie	Rest supine on a flat surface / Stand against a wall and breathe	3S, 2W
Bend over	Bend your back like a cat and breathe in while straightening your posture	2S, 1W
In-diffOut	Short inhalation followed by different counts of exhalation	1S, 1W
Rhythm	Rhythmic breathing	1S, 1W
Breathe notes	Breathe out while vocalizing/playing a single prolonged note	1S, 1W
Nadi shodhana pranayama	Breathe in keeping one nostril closed with your finger, then close the other nostril and release the first, repeat, alternate	2T, 1M
Fire breath	quick series of exhalation, followed by calm inhalation	1T, 1M
Transformation breath	Short and large breathing via mouth	1T, 1M
In-Hold-Out	Inhale, Hold, Exhale on counts. Increase exhale and hold time and decrease inhale time gradually	4S, 1M, 1T
In-Out	Inhale, Exhale on counts. Increase exhale time and decrease inhale time gradually	3W, 1M, 1T
Dog	Panting like a dog. *For pregnant women, pant-exhale 7 times before each inhalation	2S, 1M
Reflect on own breath	Visualize / Realize / Feel the correct movement of chest/abdomen while breathing	4S, 1W, 1P

- Choose wisely between creating a **suite** of multiple games, **or a single game** with multiple goals.
- **Use in-game music creatively**, such that it is involved in the process of playing the game, while also setting the correct mood. Music can be either used as an entity to drive the game, or can be driven by the player's performance, or both.
- Consider **personalizing in-game music** according to the choice of music of the person playing the game. For game players with no specific choice, use typical musical features that induce the desired physical and emotional effect.
- Try **minimizing equipment to setup** the game. Easy setup of game controllers (breath sensors in this case) can be helpful to avoid irritability among users.
- Give subtle and appropriate **performance feedback** to players, as understanding how one performs could prove to be a strong indicator to how the player should play the game, i.e. breathe thereafter.
- Use **motivation** techniques like social elements, daily challenges, rewards and visible personal development to make users want to regularly play the game, thereby benefiting by performing the breathing exercises.

Along with these aspects of understanding how breathing and breathing exercise games are relevant in this research, we also laid a foundation to be able to sense breathing data, so as to be able to use one's breathing as a game controller. The *Breathline* breath sensor, which consists of 2 soft elastic belts to be worn - one around the chest and one the center of the abdomen, each of which can detect breath levels of the chest and abdomen respectively was used for this purpose. The device could be deemed functional and programmable, although the breathing patterns of different exercises were still only 'visibly' distinguishable with graphical representations. This meant that additional analysis and processing of incoming data needed to be done, so as to be able to use the sensor as a game controller.

Using all of these foundations laid, we could formulate a set of goals to be achieved in this research, in the next chapter.

3 Goals & Approach

In the previous chapters, we see the importance, diversity and inter-domain similarities and differences of breathing exercises. We also found that practices that require breathing exercises use games, music and sensor technology to facilitate performing breathing exercise among the people who need to perform them. With all these in mind, we formulated a set of research questions in Chapter 1. In this chapter, we look at how we plan to tackle each of these research questions in this project.

1. **Given a breath sensor, how can we use the obtained data to develop an efficient game controller, using breath as the game input?**

   During the Research Topics phase, we only had graphically distinguishable data from the breath sensor. Hence, the next step is to be able to properly distinguish inhalations, exhalations, their duration and amplitudes, so as to be able to use the sensor as a game controller. Statistical analysis and processing of this input breathing data would also be part of this goal, so as to make it truly usable in the game. This is because the breath sensors need to give us clean, readable data, which would also need to function on a game development platform such as Unity, to give near-seamless game control possibilities. This point is discussed in Chapter 4.

2. **Since we know that there are several breathing exercises used in different domains, what elements of gaming (controls, level design, visuals, in-game audio/music, etc.) could be altered such that these exercises can be performed with the help of games?**

   For this, we need to understand existing games, how they can be played with different types of controls and form a basis of how games in general can be thought of as configurable to a breathing exercise game. With this, we can create a basis of how we can change various aspects in the game to fit several breathing exercises in different types of games, thereby making the games transferable between breathing exercises within the same domain, as well as different domains. explained in Chapter 5. In Chapter 6, we talk about the different roles that the audio can play in games. We also talk briefly about what elements of this audio can be changed as per the domain in question.

3. **First considering one domain of work - singing, what do potential users of such a game want in it, such that the game is useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises? How can music play a role in such a game?**

   Since we already know which breathing exercises are used for different purposes and the goals that they fulfil with the help of the interviews conducted in the Research Topics phase, we now need to further understand how potential users (participants - singing teachers & students) would like a breathing exercise game to be and what aspects of game design and music would be suited to their purpose of regularly and correctly performing breathing exercises. This process of understanding users' needs, which involved interacting with participants, is explained in Chapter 7. Then, after formulating game and interaction ideas with inputs given by participants in Chapter 8, we once again involve participants in the design process by taking their feedback and validation as discussed in section 8.1. This would give us a solid enough foundation to start making breathing exercise game prototypes. With the help of all this participant input, we then look at the process of building a functional prototype for breathing exercise games for singers in Chapter 10. These prototypes would be built with the help of the foundations laid in the chapter 4 and would be functional with breath sensors being used as game controllers, while being able to give a visual and auditory representation of the game-elements and audio related elements discussed in the chapters before that. After that, we again involve participants to qualitatively evaluate ideas of game and audio elements that can be useful in such breathing exercise games and get their views about having such an application. This is discussed in Chapter 12.

4. **How can such a breathing exercise game be translated to other domains of work?**

   Since the project is to create a multi-purpose, cross-domain breathing exercise game to begin with, we need to discuss how the breathing game created for one domain can be translated to other domains. The basis for this would be from the outcomes of the Research Topics phase and the outcomes of the points mentioned above. These discussions will be scattered across the report at the end of relevant chapters - (5 and 6) and also at the end after evaluating the prototypes with participants.

4 Turning the Breath Sensor into a Game Controller

To be able to play a breathing exercise game using a person's breath to control the game requires accurate detection of certain features of breaths, such as whether the person is inhaling or exhaling or holding their breath, the duration of their breaths (in or hold or out) and many more, as discussed further in this chapter. For that, we require a device or technological intervention to sense these aspects of one's breath. In the Research Topics phase, we discussed the use of different types of sensors [12]. We narrowed had two options for breath sensors to choose from in this project. (1) a mouth-based sensor used in [4], which consisted of a box containing hardware and electronics and a pipe coming out of the box, into which a person can blow air into, with the amount of air blown into the pipe being detected. and (2) the *Breathline* breath sensing belts (by Ben Bulsink) which consists of 2 soft elastic belts to be worn - one around the chest and one the center of the abdomen, each of which can detect breath levels of the chest and abdomen respectively. The *Breathline* sensor had some advantages in its practical usage, which are as follows:

- Both chest and abdomen breathing data can be acquired separately, which is useful to detect the "correct" way to breathe, as the teachers and practitioners interviewed suggested that the movement of chest and belly matters as per the exercise prescribed. We can, for example detect the incorrect breathing technique called "shallow breathing" in which a person only breathes into their chest, while not expanding their diaphragm in their belly.
- While playing the game, the player would not need to hold the hardware or worry about holding the pipe. Instead, they would just need to wear the belts once before the game.
- The *Breathline* device was plug-and-play with no additional configuration and server connection required, thereby giving raw breath readings upon plugging it in.
- Option to have wireless connectivity between the sensor and the computer.

In addition to these advantages, initially, we were also skeptical and unsure about the later evaluation phase of the project, where much would depend upon how the COVID-19 pandemic situation would unfold. Keeping that in mind, we decided that we should not move further with the mouth-based device, due to additional risks, while the *Breathline* is safer to use as it is to be worn over the clothes of a person. Hence, owing to the advantages, safety and availability, we use the *Breathline* sensor in this project. In the remainder of the report, every reference to a breath sensor, viz. 'breathing belts', 'breath-sensing belts', 'breathing device' and 'breath sensors' refer to the *Breathline* sensor.

The *Breathline* sensor, upon connection with a computer's serial port, already gives data packets consisting of 11 to 13 hex values in each packet. Each packet consists of at least:

Start Byte
Header byte
Payload byte 1: High byte of abdominal belt value (unsigned)
Payload byte 2: Low byte of abdominal belt value (uvalue nsigned)
Payload byte 3: High byte of chest belt value (unsigned)
Payload byte 4: Low byte of chest belt value (unsigned)
Payload byte 5: Accelerometer reading X (one byte, 2- complement)
Payload byte 6: Accelerometer reading Y (one byte, 2- complement)
Payload byte 7: Accelerometer reading Z (one byte, 2- complement)
Packet number (one byte) (unsigned)
End byte

In addition to this, there could be an escape-byte if a byte from the payload is equal to any of the other reserved bytes, and a timestamp which is added to the packet every 10 seconds. The bytes of interest to us in this

project that need to be fetched from each packet are the payload bytes 1-4, i.e. the high and low bytes of the abdominal and chest belt values.

In order to get the breathing data into our computer system, we initially used the Python serial packages to read the incoming packet data from the breathing device in the Research Topics phase. However, game prototypes would need to be built on game development engines. We chose *Unity* for this purpose because of its ease of use and large documentation & tutorial base. Now, since we need to get the incoming breathing data into a game development engine - Unity, we tried several possible ways, such as connecting Unity to a python script externally or directly accessing the breathing device from Unity. The latter worked with the help of the Serial Port Utility Pro[4] Unity plugin. The free version was sufficient to get data from the breathing device, which is exactly what we need. The incoming data was in the form of packets, so the relevant chest and abdominal breath values needed to be extracted from each incoming packet. This was done via a C# script written to extract the relevant values in integer form. With data incoming and accessible in Unity, in order to analyze the data, it would need to be saved. So, created some Unity tools with the help of Unity C# scripts, in order to save the incoming data into a CSV file.

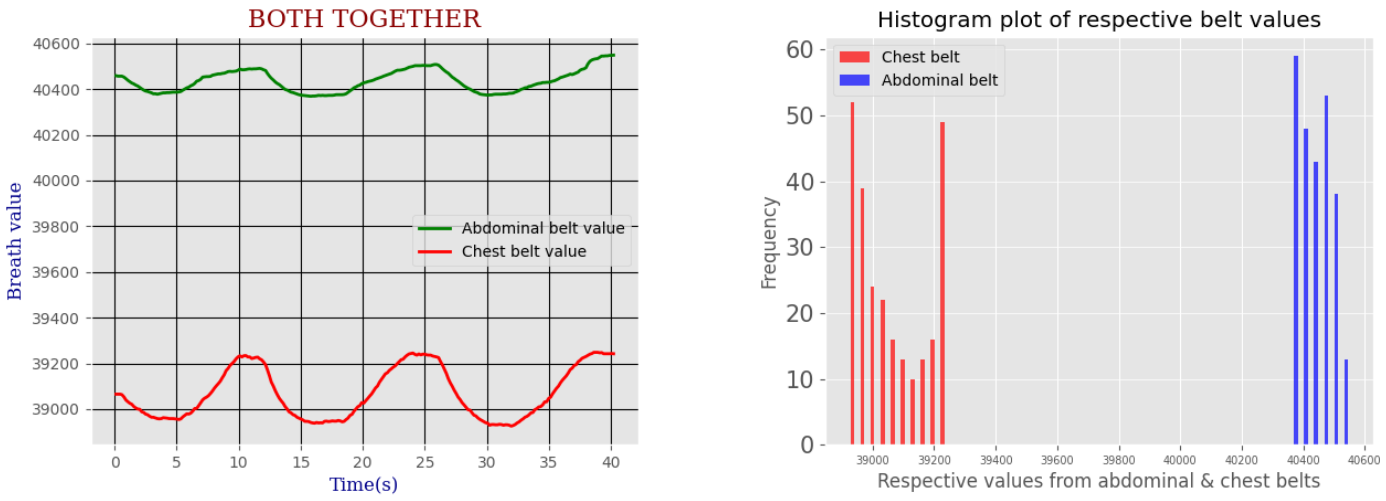
4.1 Statistical analysis of breath input data

In order to be able to effectively control the breathing exercise game, the input values from the breath sensor need to be analyzed thoroughly first. The data in each recording consisted of 3 full inhalations and exhalations. used myself as the test subject to avoid inter-person differences, such as difference in size and breathing capabilities. Before providing statistical information about the data, there were certain basic issues to look out for:

4.1.1 Cleaning input data

Global outlier detection and removal

The first point to be noticed was the fact that there exist outliers in the data that could adversely affect the game, as such unwanted spikes in input values could completely spoil the user's breath controller input to the game. These outliers are as shown in figures 1 and 30:

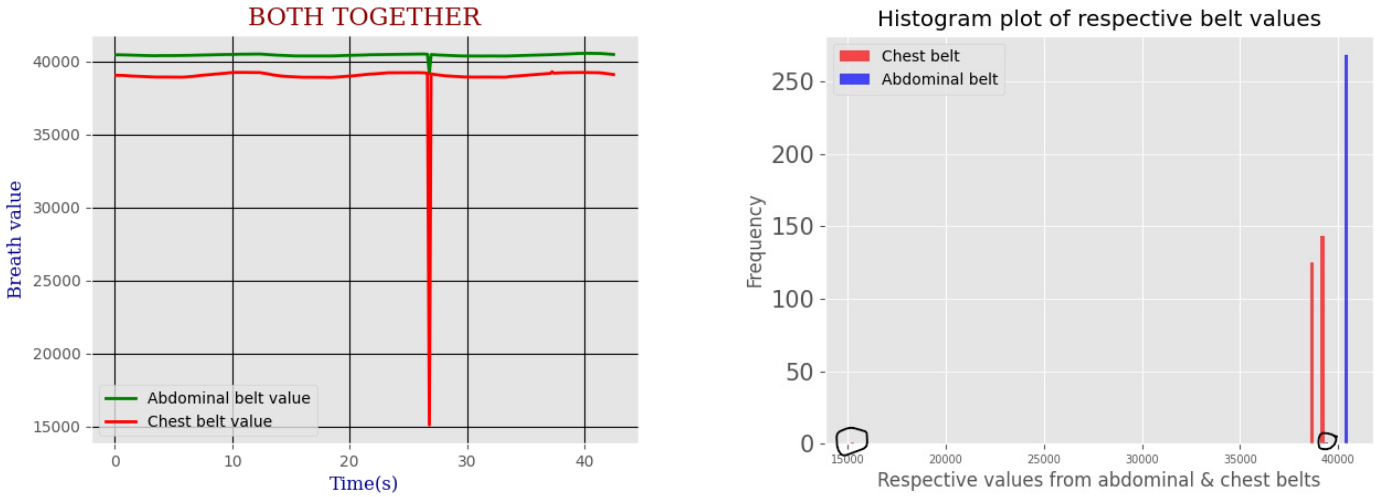


(a) Graphical Representation

(b) Histogram Representation

Figure 1: Input Breath Data without Outliers

[4]link: https://portutility.com/



(a) Graphical Representation **(b)** Histogram Representation

Figure 2: Input Breath Data with Outliers

These outliers need to be dealt with and removed, so as to not hamper the game performance. Another point to be noticed is that these outliers are present at the same moments for both belts, as made clearer in the images below. Therefore, we can detect these outliers with the help of standard deviations in the readings. This, however, would require a calibration step before the game. If a given input value is more than a set number of standard deviations (1 or 2) away from the mean value of the calibration recording, that value can be discarded. Discarding these values would not make much of a difference, as incoming values are received at the rate of around 6-8 packets per second. An alternative to this would be to use a moving median filter, but we thought it would be best to discard these outliers, in case there are more than one outlier in a moving median window, which could still possibly give outliers.

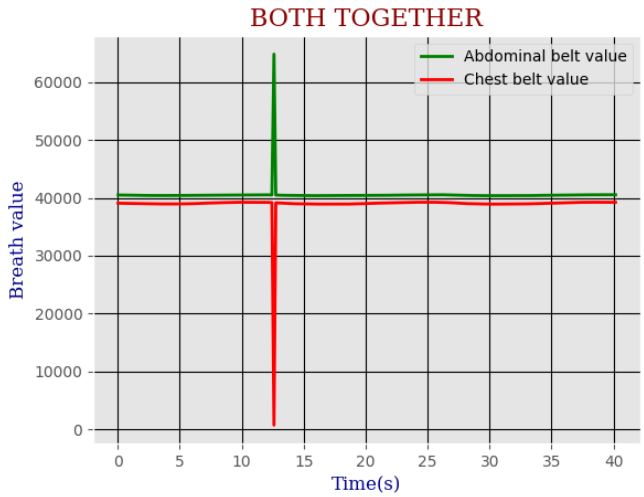
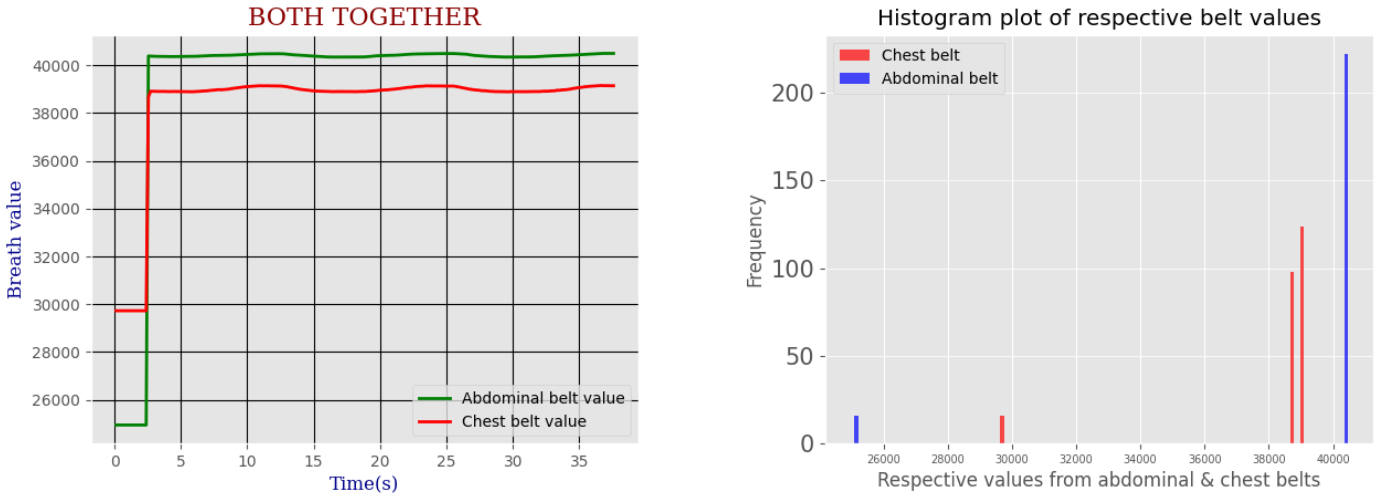


Figure 3: Outlier spikes arriving at same point in time for both abdominal and chest belts

Different value range in the beginning of readings

Apart from these unwanted spikes in the incoming readings, another problem we notice is that many a times,



(a) Graphical Representation

(b) Histogram Representation

Figure 4: Graphical representation of initial faulty range values

the initial 2-3 seconds of incoming data is in a completely different range, as seen in figure 4:

The initial range of values, as seen in the above images from two different recordings, are totally separate from the later values that are compliant with the breathing pattern of inhalations and exhalations. Hence, we will discard the first 30 breath values in the game/calibration of the breathing device, as that will comprise approximately 4 seconds of data.

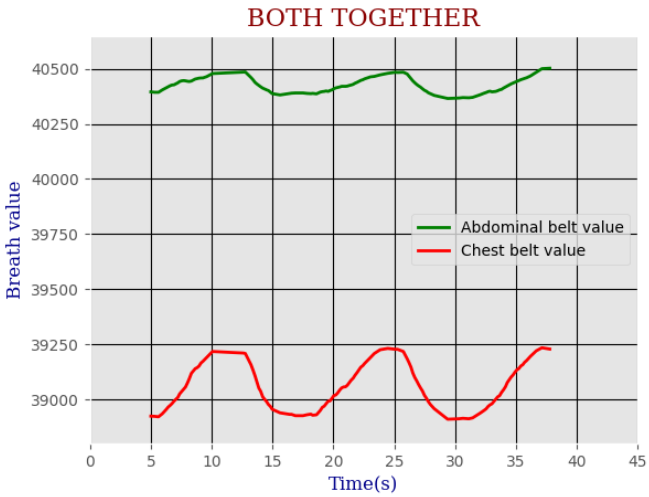
Preparing Calibration and normalisation: how stable is the input data?

Now, as discussed earlier, we require a calibration and normalisation phase. The incoming data values for abdominal and chest breath levels from the breath sensor show values in the range of roughly 40000 (+- 4000). It would be useful to calibrate these values according to the user and normalize the input breath values between -1 and 1, or 0 and 1, as required by the game, so as to be able to use the sensor as a game controller efficiently. But we first need to know when and how many times the player would need to calibrate the device and how often the normalisation thresholds need to be re-set. For this, we first need to know when the range of input breath values is changing: how stable are the value ranges of this device in relation to breath strength and depth? To notice the difference between ranges of breath values, we have a look at readings from each case as will be shown later in this section. These values are now evaluated without outliers and without the first 4 seconds of data, as we need to look at the accurate maximum and minimum values. In order to validate that the incoming data is approximately in the same range each time for the same breathing pattern (sequence of 3 consecutive inhalations and exhalations), we recorded data five times each in 4 different conditions:

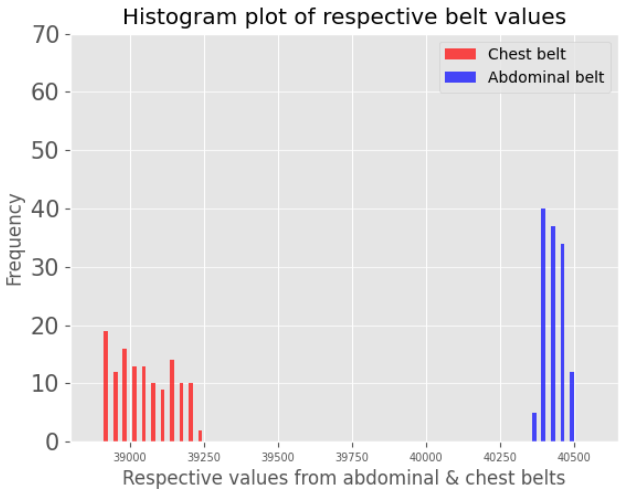
1. **Same Session -** All five recordings were recorded in the same Unity session without disconnecting the belt.

   As we see from the Figures 5-9, the range of values within a same session is roughly the same. The histogram plots also comply with this observation. The table below also shows that the 'Same Session' maximum and minimum values are roughly in the same region for both abdominal and chest belts, for one person.

   However, the maximum values still are not close enough to set as an explicit 'Maximum' for either belt. We do notice that the maximum values for both belts are too far apart and can be comparable to the standard

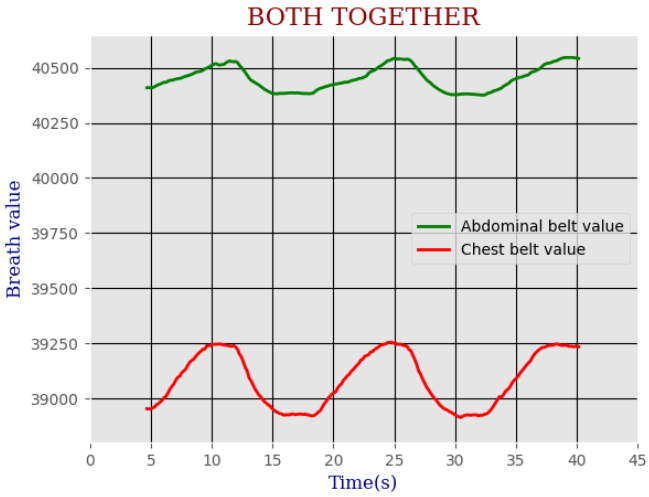


(a) Graphical Representation

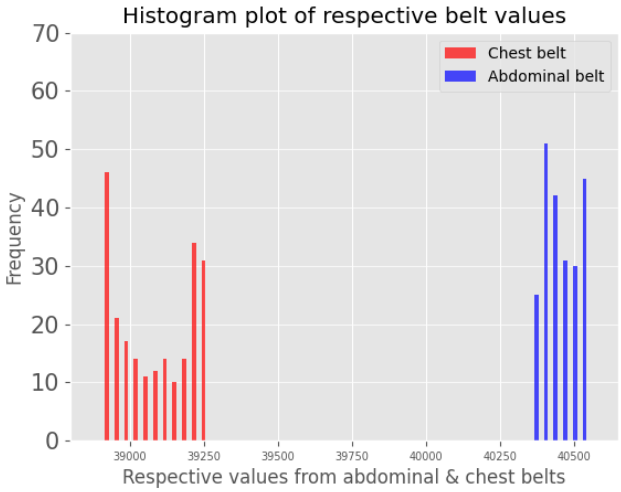


(b) Histogram Representation

Figure 5: Recording 1

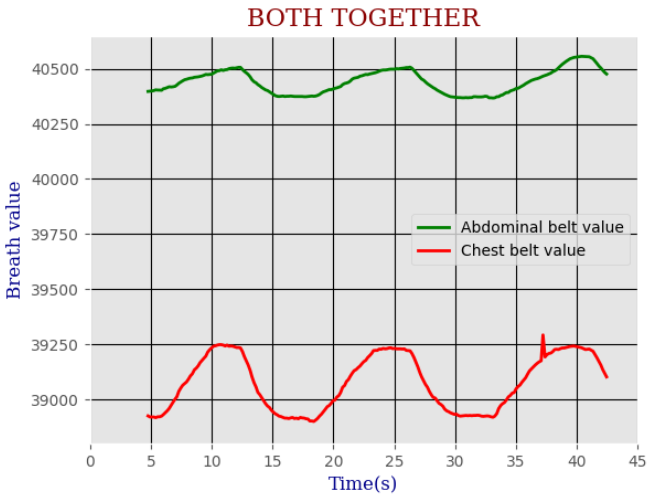


(a) Graphical Representation

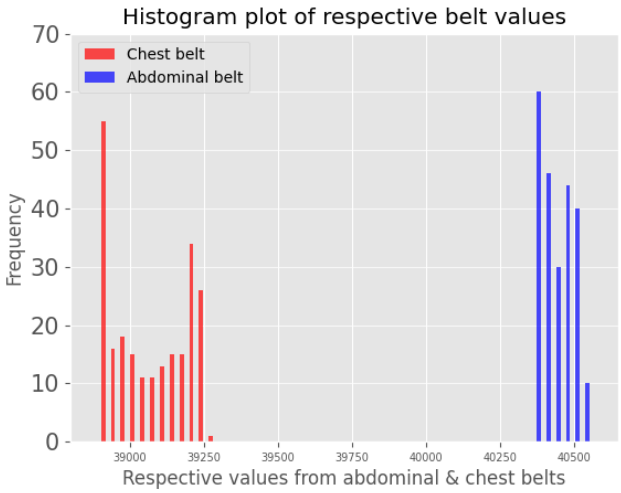


(b) Histogram Representation

Figure 6: Recording 2

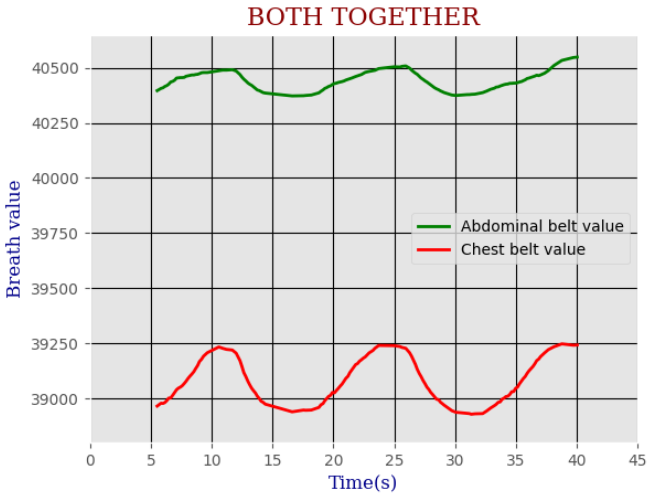


(a) Graphical Representation

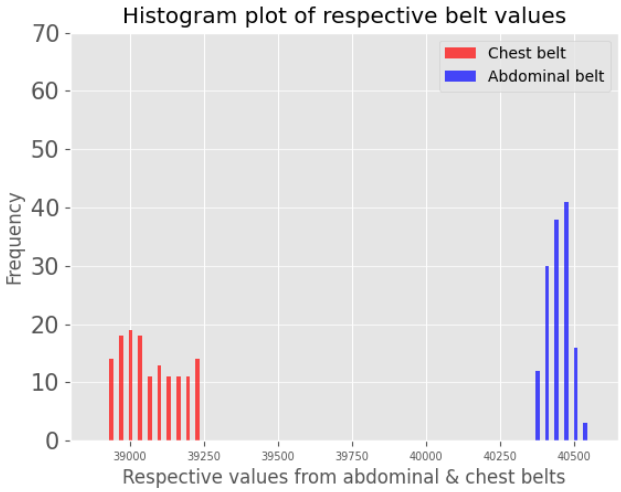


(b) Histogram Representation

Figure 7: Recording 3

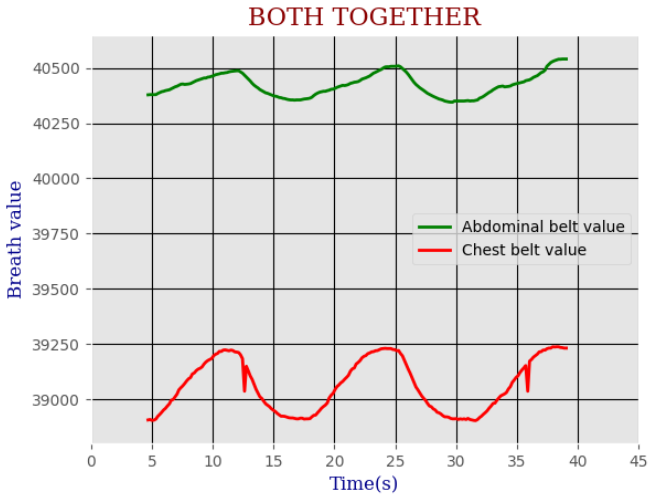


(a) Graphical Representation

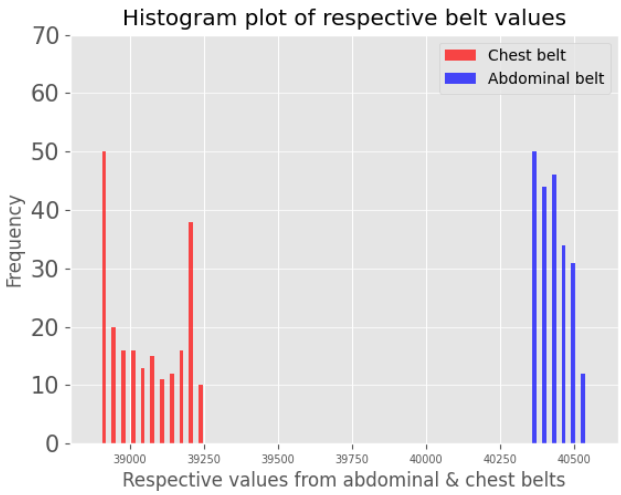


(b) Histogram Representation

Figure 8: Recording 4



(a) Graphical Representation



(b) Histogram Representation

Figure 9: Recording 5

Table 3: Overview of Breath Readings in the same session (Legend: abd = abdominal breath values; ch = chest breath values; max, min, mean, std = Respective maximum, minimum, mean and standard deviation values for abd, chest recordings; min = minimum values for respective abd, chest recordings values;)

Rec. no.	abd_max	abd_min	abd_mean	abd_std	ch_max	ch_min	ch_mean	ch_std
1	40502	40365	40425.16	31.805	39235	38911	39057.7	95.244
2	40546	40376	40450.97	55.296	39256	38914	39087.33	123.224
3	40556	40367	40437.46	51.699	39293	38901	39073.47	124.126
4	40548	40372	40440.75	38.129	39248	38929	39077.73	93.7
5	40540	40345	40422.69	51.915	39238	38904	39062.2	118.899
Average	40538.4	40365	40435.41	45.7688	39254	38911.8	39071.68	111.0386

deviations. The same can be said of the minimum values too. For the chest belt, the range of maximum (or minimum) values are about half the standard deviation apart, while for the abdominal belt, they are about one standard deviation apart. Hence, we can set the post normalization maximum value of 1 to correspond to the input maximum value + 50. Similarly, for minimum values, -1 or 0 could correspond to the input minimum value - 50. If there arises an input value greater than the maximum or less than the minimum value that has been set, it would most likely not be much higher or lower than the set values. Such can be approximated to 1 for a value greater than the maximum value and to 0 or (-1) for a value less than the minimum value.

Therefore, within a single session, theoretically, there would be a requirement of only one calibration stage per gaming session, in which the absolute maximum and minimum values used for normalization and the determination of maximum and minimum thresholds can be decided.

For the next conditions, the images would be similar to those of the above case. Hence, we take a close look at the tabular data.

2. **Different Connections -** The five recordings were made at different times, by disconnecting and reconnecting the belt. The question now is, does this affect the range of incoming breath values more than that of within a single session? The table below could guide us to the answer to that question.

   The table 4 shows that upon disconnecting and reconnecting the breathing device, again, similar to the

Table 4: Overview of Breath Readings, each recording made after disconnecting and reconnecting the breath sensor

Rec. no.	abd_max	abd_min	abd_mean	abd_std	ch_max	ch_min	ch_mean	ch_std
1	40468	40311	40377.87	41.342	39087	38823	38933.56	76.372
2	40435	40280	40348.63	39.412	39133	38853	38979.46	78.214
3	40452	40288	40364.92	55.639	39131	38849	38976.43	100.325
4	40502	40346	40416.44	38.851	39147	38892	38994.92	74.715
5	40502	40365	40425.16	31.805	39235	38911	39057.7	95.244
Average	40471.8	40318	40386.6	41.4098	39146.6	38865.6	38988.41	84.974

Table 5: Overview of Breath Readings, each recording made after restarting Unity each time

Rec. no.	abd_max	abd_min	abd_mean	abd_std	ch_max	ch_min	ch_mean	ch_std
1	40468	40311	40377.87	41.342	39087	38823	38933.56	76.372
2	40556	40367	40437.46	51.699	39293	38901	39073.47	124.126
3	40460	40297	40373.81	50.63	39103	38821	38948.56	88.8
4	40452	40290	40363.88	53.459	39086	38826	38936.79	91.194
5	40483	40338	40402.41	34.189	39129	38858	38971.72	74.802
Average	40483.8	40320.6	40391.09	46.2638	39139.6	38845.8	38972.82	91.0588

'Same Sessions' case, there is not much drift between the ranges of input breath values. A buffer on 100, either side of maximum and minimum values for both belts, would still work for the calibration.

3. **Different Unity Restarts -** The five recordings were made, each of which were in a different (restarted) Unity session. Here too, there is not much difference between the input breath values' ranges.

4. **Different Restarts** - The five recordings were made, each of which were done after restarting the computer, which essentially means restarting everything - the computer, Unity and the sensor. Here too, there is not much difference between the input breath values' ranges.

Hence, we see that the range of input values is quite stable and a buffer of +-50 should be sufficient to calibrate the device for a particular user in a particular game session. However, a user's breathing capability is subject to change/improvement. If for example a user's breathing capacity increases with practice, there might be a requirement of another calibration.

If we look at the box plots of the maximum & minimum values for the abdominal and chest values for each separate condition as shown in the image above, we notice that although the maximum and minimum values are not very far apart between the different conditions, they are much closer to each other in the 'Same Session' condition.

Table 6: Overview of Breath Readings, each recording made after restarting the computer each time

Rec. no.	abd_max	abd_min	abd_mean	abd_std	ch_max	ch_min	ch_mean	ch_std
1	40546	40376	40450.97	55.296	39256	38914	39087.33	123.224
2	40502	40346	40416.44	38.851	39147	38892	38994.92	74.715
3	40568	40375	40464.15	56.905	39162	38858	39002.06	108.394
4	40640	40433	40526.2	60.006	39255	38932	39071.97	106.868
5	40483	40338	40402.41	34.189	39129	38858	38971.72	74.802
Average	40547.8	40373.6	40452.03	49.0494	39189.8	38890.8	39025.6	97.6006

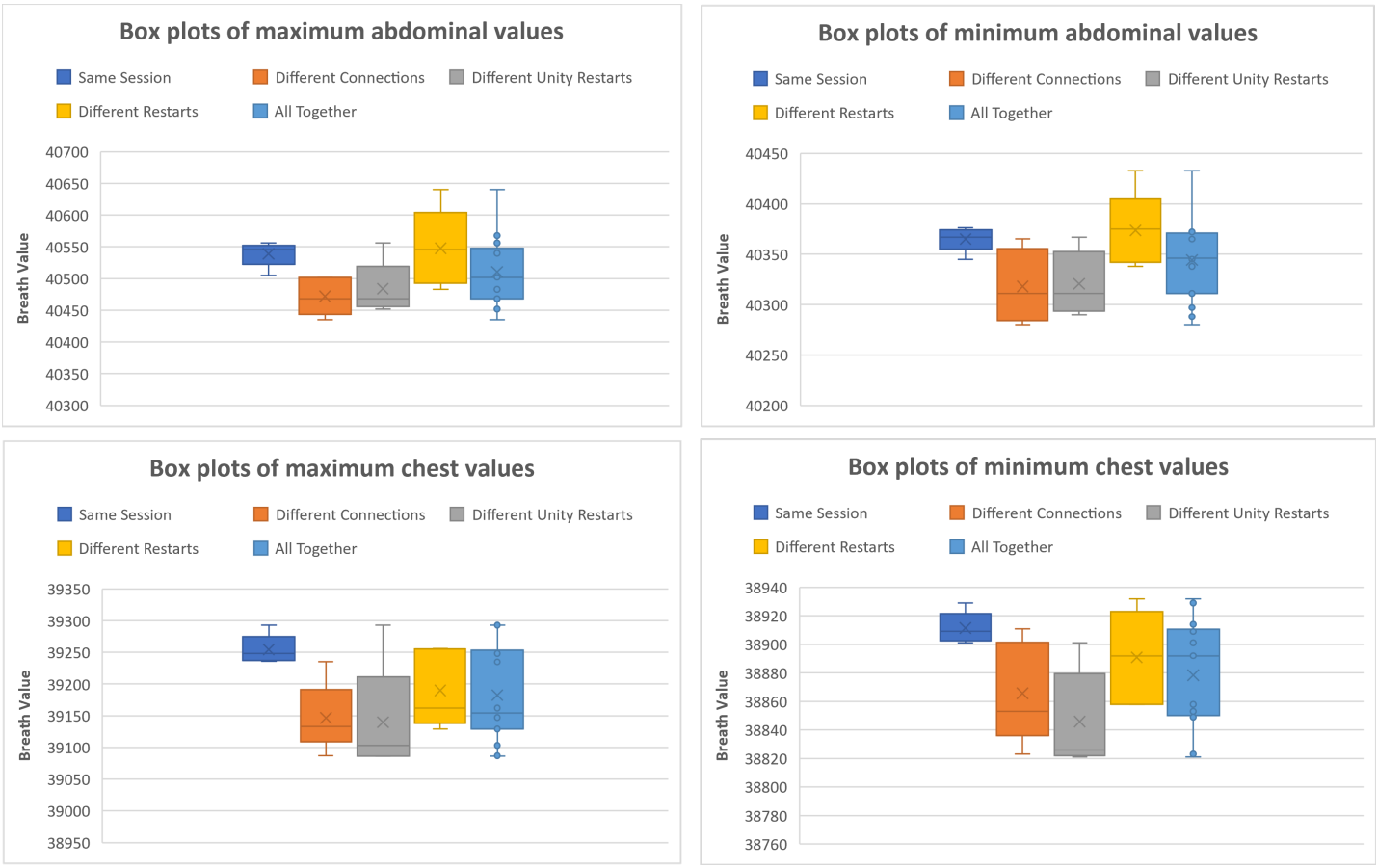


Figure 10: Box plots of maximum & minimum values for abdominal and chest values for each condition

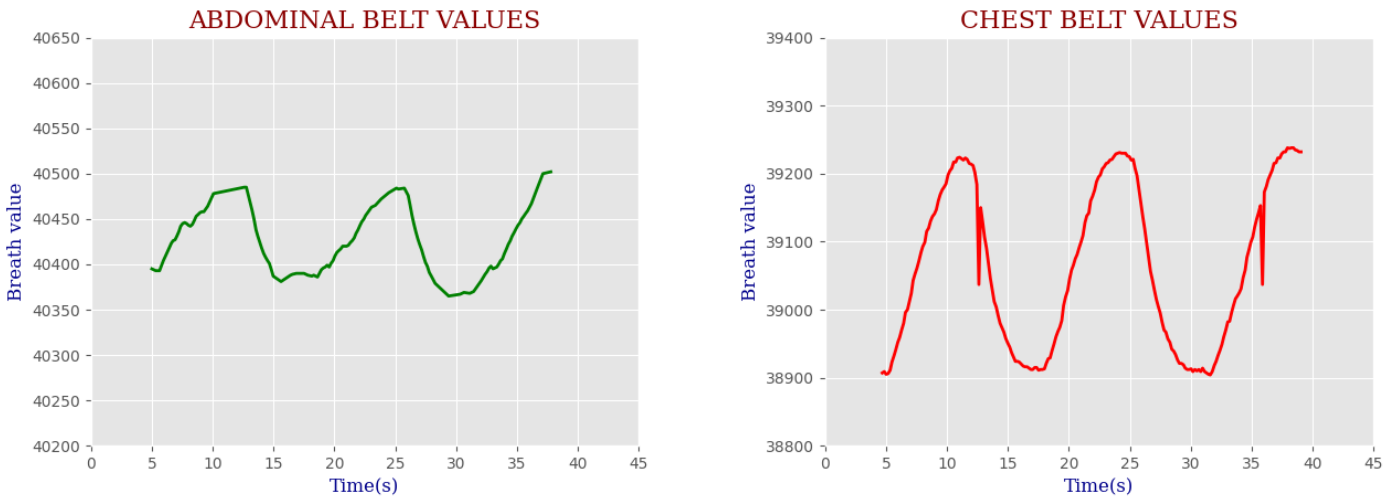
Therefore, we would like to suggest that a calibration of the user's breathing capacity should be done once at the beginning of each game session, to avoid confusion and other variables as discussed previously in this section. This calibration, in fact, could also be gamified and be treated like a test of the breathing capacity of the user, as the maximum and minimum ranges of breath could change with time, practice (improvement), change in body shape and possibly also depending upon whether the user has just had a heavy meal to eat.

4.1.2 Smoothing

In the example images below, we see that although the major disruptive outliers have been removed, there still exist irregularities in the data. The breath action done was smooth, continuous inhalations and exhalations, while the graphs show slight deviations between consecutive values. This might cause disparity in the incoming values, as we need to accurately detect whether incoming values are increasing or decreasing.

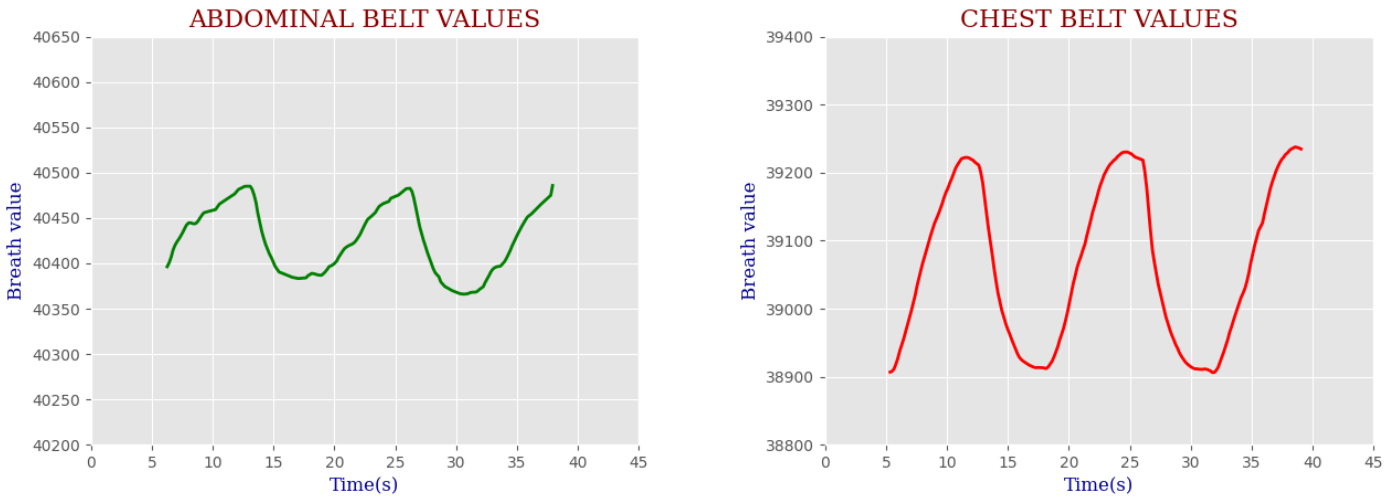
To solve this issue, we will use a moving average smoothing with window size = 4 for the incoming values. To compare the data from the unsmoothed data containing irregularities (figure 11), we see the images below:

We see clearly that the input values are much more regular in figure 12 as compared to those in figure 11. The larger irregularities can be called 'local outliers', which can also be discarded by checking if the difference between the current value and the previous value is significantly large. According to our observations, these local outliers exist at a difference of at least 70 in the recordings taken. Hence, after keeping a buffer, we check if the difference between the current value and the previous value is greater than 50. Theoretically, the graphs can get even smoother by increasing the window size, but that would cause some problems. Firstly, there needs to be a trade-off between smoothing and accurate incoming values. It is possible that game users might actually breathe



(a) **(b)**

Figure 11: Irregularities in data



(a) **(b)**

Figure 12: Graphs after Moving Average Smoothing

erroneously and we need to detect that erroneous behaviour. If the values are over-smoothed, those erroneous breathing behaviours will be left undetected, as the program will show that the user is breathing in a regular incremental/decremental manner. Secondly, increasing the window size will bring a larger time lag (delay) to the game input - game action coupling, as the incoming data from the device ideally arrives at 8 packets per second (practically 6-8 packets per second). Theoretically, in case of 8 packets per second, with a window size of 4, there will be a delay of about 0.5 seconds between the time that the first incoming value arrives and that of the first smoothed value. Practically it would be slightly more, since there are not always 8 incoming packets per second, but that delay would still be less than 1 whole second, which could have been more pronounced, noticeable and possibly more annoying to the user. Figure 13 shows a few readings of the time difference between the start time of a data recording without smoothing and the start time of a data recording with smoothing. We see that there is often a time difference or delay of roughly 0.6 seconds between when the first value is supposed to arrive in the system and when the first value actually arrives after smoothing. This window size, however, can also be changed,

```
Start time before smoothing(t[0]) MaxBreath_SameSession_ 2 :
4.663
Start time after smoothing(t[0]) MaxBreath_SameSession_ 2 :
5.309
Time Difference:  0.6459999999999999


Start time before smoothing(t[0]) MaxBreath_SameSession_ 3 :
4.754
Start time after smoothing(t[0]) MaxBreath_SameSession_ 3 :
5.3839999999999995
Time Difference:  0.6299999999999999


Start time before smoothing(t[0]) MaxBreath_SameSession_ 4 :
5.34
Start time after smoothing(t[0]) MaxBreath_SameSession_ 4 :
5.986000000000001
Time Difference:  0.6460000000000008


Start time before smoothing(t[0]) MaxBreath_SameSession_ 5 :
4.673
Start time after smoothing(t[0]) MaxBreath_SameSession_ 5 :
5.319
Time Difference:  0.6459999999999999
```

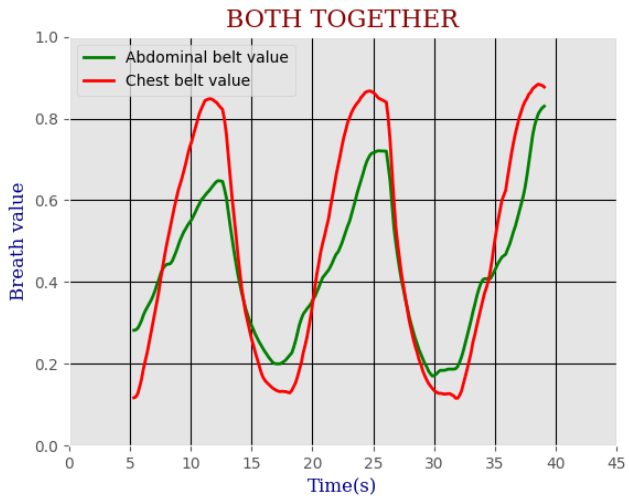
Figure 13: Some start 'time' values before and after smoothing

depending upon the game requirement.

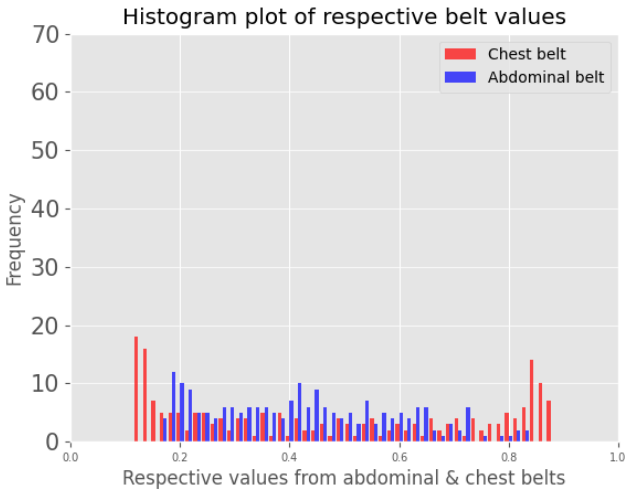
4.1.3 Normalization

The cleaned integer value inputs from the breathing device are in the range of roughly 40000 (+- 4000). These high values are not optimal for the game design, as these values will need to comply with the game requirements. The values need to be multipliers in case of acceleration requirements in the game and be in a fixed range, so that thresholds for game-state changes according to inputs can be fixed to a predetermined value. For these reasons, we decide to normalize the input values to between 0 and 1. This will give us a clearer picture of what level of breath one is at. As discussed in [section Deciding Calibration], 0 would correspond to the (minimum value of the respective breath sensing belt - 50) while 1 would correspond to the (maximum value of the respective breath sensing belt + 50). These mappings would be done in the calibration step of the game. Figure 14 show the

normalized mappings of the input values and the histogram plot for the same.



(a) Abdominal and Chest Belt Breath Values after Normalization



(b) Histogram after Normalization

Figure 14: Graphs after Normalization

These normalized input values can be the final input from the breath sensing device to control the game.

4.1.4 Detection of increasing and decreasing input values

Another advantage of using the 4-window smoothing filter is that we can use the same window to detect whether the input value is increasing or decreasing, i.e. whether the user is inhaling or exhaling. Since the window size is 4, it will have 3 value shifts between each value present in the window. The direction of breath, i.e. inhalation / exhalation can be decided by direction of the maximum number of changes in the window values. For example, if the window consists of 4 values: 2,3,4,3, this would indicate that there are 2 increments and one decrement in the window. We can then say that the user is currently inhaling. We believe that this would be more reliable than merely checking for the previous value for increments / decrements. Apart from this, the acceleration/deceleration of the breath values can also be detected with the window of 4. If the variance in the window is low, ideally, it would indicate a slow inhalation / exhalation. Conversely, if the variance in the window is high, it would indicate a faster inhalation / exhalation. Similarly, an extremely low variance could indicate that the gamer is holding their breath. The thresholds of these variances can be changed according to the game requirements. Using this variance in the window is not affected by major outliers, since these large global outliers are removed in a previous step. However, they might be influenced by the smaller local outliers, since we use the same smoothing window to address those local outliers to calculate variance. This is a drawback that would need to be addressed in future versions of using this sensor.

4.2 Working with the Breath Sensor in Unity

Statistically analyzing data is a process done with recorded data. However, getting game input-ready normalized breath values in Unity posed its own challenges.

As discussed in the beginning of Chapter 4, incoming data from the *Breathline* breath sensor were fetched into Unity via the *Serial Port Utility Pro* Unity plugin. From the C# script used in that plugin, data packets were fetched continuously with the help of a C# script, thereby giving live input. However, these packets needed to be

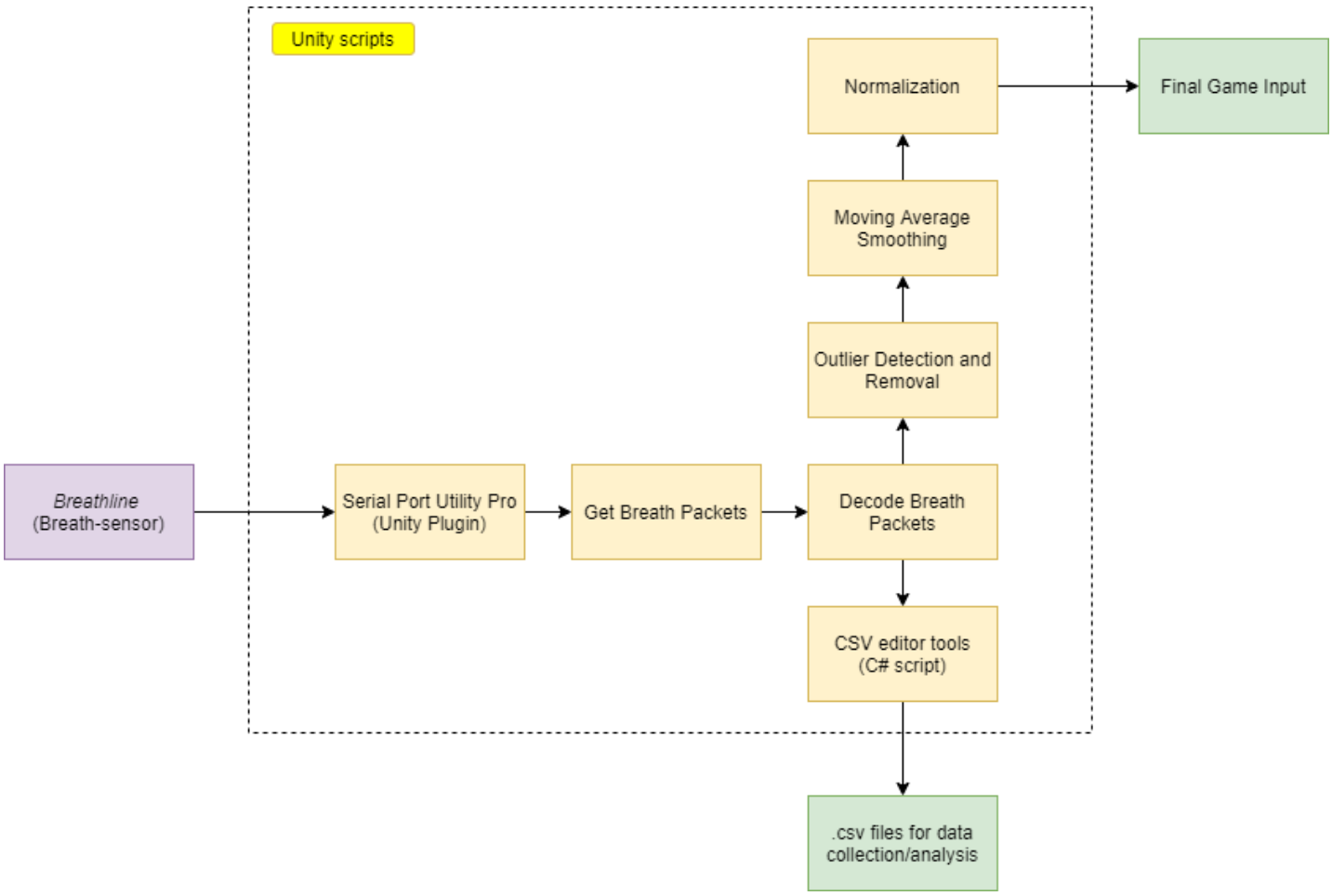


Figure 15: Sensing Architecture

decoded, cleaned with the help of the escape sequence logic to avoid extreme outliers, and separated into bytes, such that the high and low bytes of both the chest and abdominal belts are obtained.

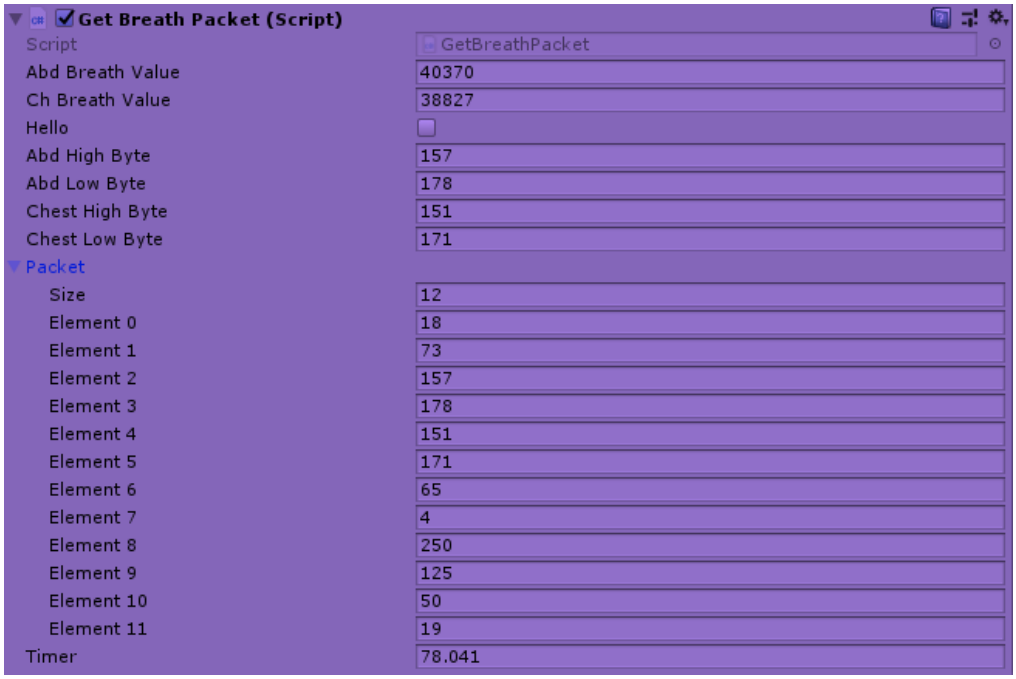


Figure 16: Functioning of script that gets breathing data from Serial Port Utility Pro

With these high and low bytes, the integer values for abdominal and chest belts are calculated as shown in Figure 16, where the fields 'Abd Breath Value' and 'Chest Breath Value' show the integer values of the respective breathing belts. These integer values are fetched into another script such that all other processes required to calibrate the device can be done in it. With the help of this script, the calibration of the breath sensor happens in 3 steps.

First, upon the press of a button, the process of calibration starts. This means that the continuously incoming abdominal and chest breath values are appended to a list, as seen in Figure 17. While these 'calibration lists' is being appended, the user wearing the breath sensing belts needs to perform at least one full inhalation and exhalation, so as to get a list of abdominal and chest breath values, similar to what was obtained for the statistical analysis as seen in section 4.1.

Second, once the user has finished performing the inhalation and exhalation series, they can press another button which would indicate that the calibration has been completed. Upon the press of this button, the calibration list stops getting appended with incoming breath values and calculations required for the final game input begin. These calculations include maximum and minimum abdominal and chest values, their standard deviations and means, as seen in figure 18.

Finally, with the press of a third button, which could be termed as 'Start Game', live incoming data that is normalized between 0 and 1 and smoothed with a moving average smoothing filter is obtained. In addition to just having the smoothed and normalized breath values, we also are able to determine if the user wearing the breath sensing belts is inhaling or exhaling, and if they are inhaling or exhaling quickly or slowly or if they are holding their breath. This is done exactly in the way discussed in section 4.1.4. Figure 19 shows how these values are visible in the Unity editor. Another possibility is that we can use threshold crossings to determine whether a person has inhaled or exhaled to (or close to) their maximum capacity. These threshold values can be altered in the editor in the 'Low Threshold' and 'High Threshold' fields.

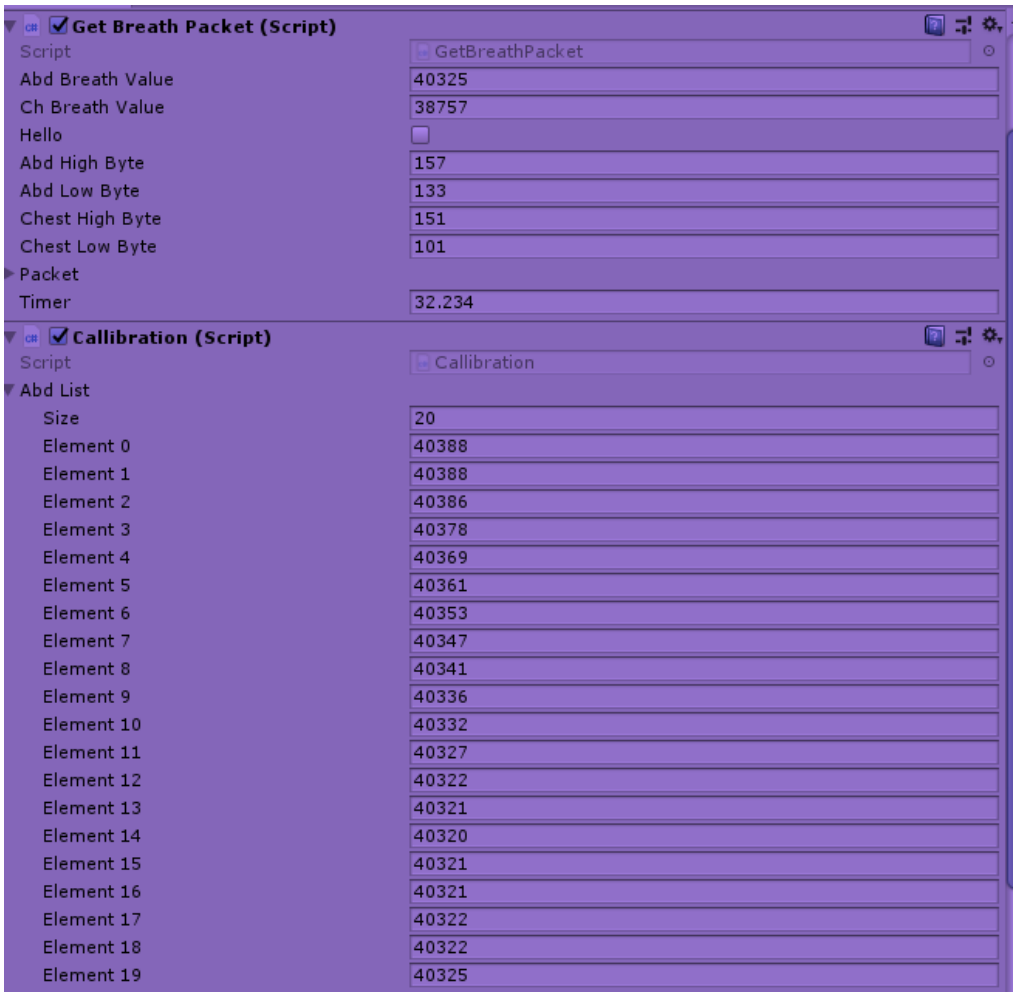


Figure 17: Appending abdominal belt integer values to a list

Figure 18: Required calculations made from list

4.1.

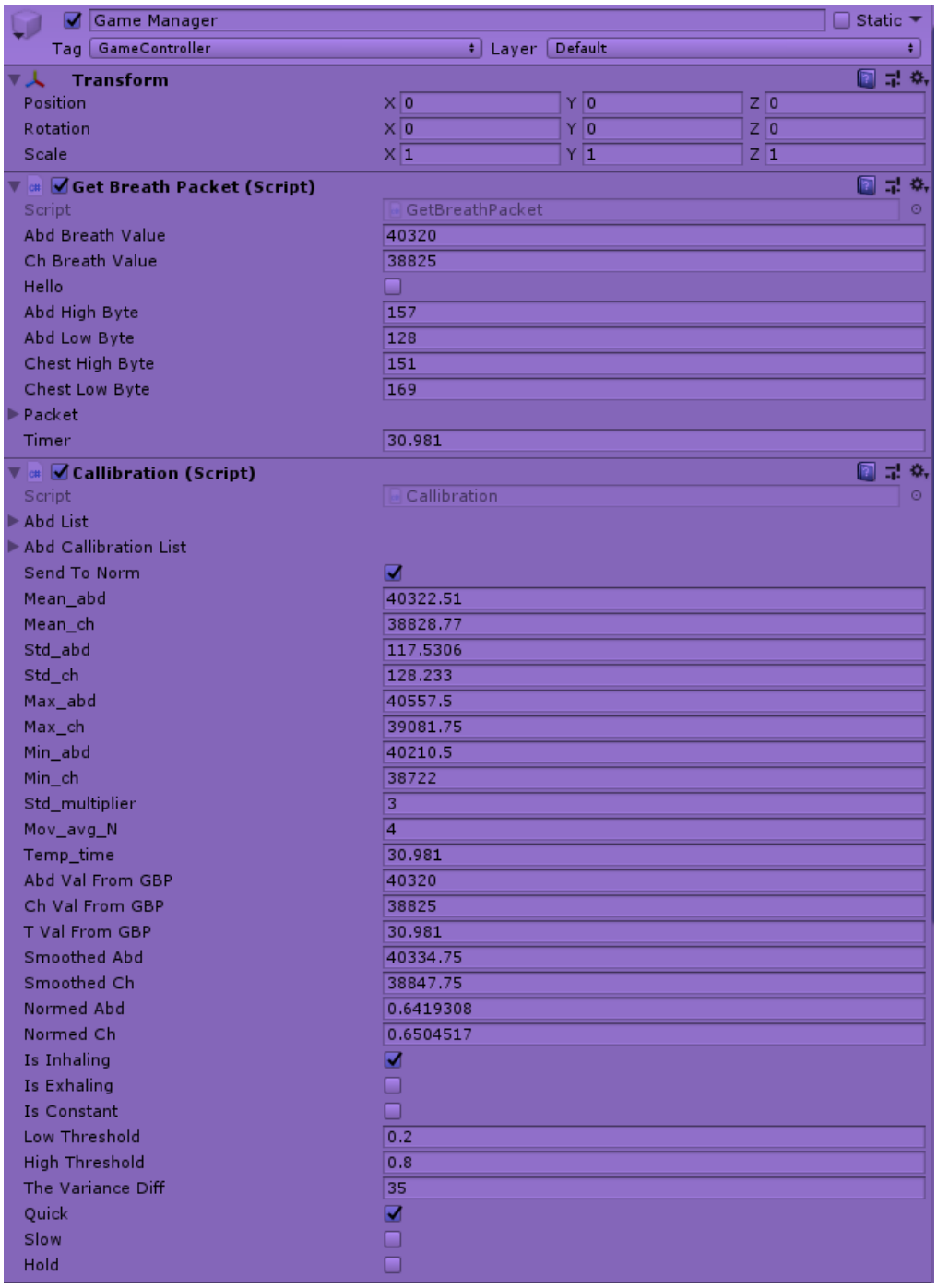


Figure 19: Breath values and other usable features to use sensor input as game control input

Now, having obtained everything required for the breath sensor to give more meaningful readings, we could consider the *Breathline* breath sensing belts to be usable as a game controller in this project. To reduce scripting complexity while building prototypes, only the 'isInhaling' and 'isExhaling' features of the breath sensors were used by making use of the abdominal breath values. More features that can make use of both chest and abdominal breath values can be explored in the future, as discussed later in chapter 14. With this technical element of the project completed, we move onto developing some theory and ideas for using the breath sensor to create game prototypes.

5 Game Controls and Configurability

To create an interoperable, cross-domain game, the exchange of game-related information between games could enable players and game designers to use common items that can be carried over from one game to another [31]. Physiological game controls should also have a natural mapping between the real-world actions of the gamer and the in-game reactions to those actions. For example, having a warm exhalation to melt the in-game snow [28]. However, in order to have configurability between games, such that video game developers can easily re-integrate these action-reaction couplings among different games with different input devices, there should be some sort of classification that says what action 'type' should cause what 'type' of reaction. The action types are defined by what action is done with the game controller input device. For example, in a physical design assessment of Nintendo Switch controller, Ramolete et al. divided the inputs from the controller as Non-trigger (XYAB buttons, directional buttons, +,- button, print screen, home, power buttons and joystick) and Trigger (as if pushing trigger of a gun: L/R, LZ/RZ, SL,SR buttons, SL/SR bumper, as described by the authors) inputs [37].

The Game Ontology Project [57] aims to create a common vocabulary of game design concepts, by providing a framework of exploring, dissecting and understanding relationships of different game elements, without taking into account the game content. It forms a way of understanding games and game design abstractly, so as to aid game designers streamline their game design process. It focuses on the mapping of user inputs to in-game actions on an interface and rules that govern the whole game world [56]. For our configurable multi-purpose breathing exercise game, we need to understand the way the input to game action control works, so that we can map different ways of breaths like quick/slow inhalations/exhalations to those in-game actions across several games. The study Tang et al. [48] gives some information about these couplings and names them 'Event Triggers'. They are events that cause a transition between game sections / activations / events. The authors divide these triggers as Input triggers (based on controller input), time trigger (countdown / time-based in-game events), proximity triggers (collisions between objects, closeness to objects) and game mechanics trigger (how game objects behave based on what is happening in the game). To use our breath-sensor in the most configurable way, we need to distinguish between the first of these types, i.e, the 'Input Triggers', as will be explained in forthcoming sections. Tang et al. however, do mention that an Event trigger is linked to a 'Game Act' which is the script according to which the game object should behave and interact in the game-world [48], which is a good starting point to build the distinction that we need. An example of game control is also given by them, where a mouse has several input events like move, roll over, roll out, left/right button up/down can be used to trigger different actions depending upon the state of the gameobject. While there has been admirable work done to simplify the process of 'how games work' and 'how elements of games can be transferred across multiple games', there has been no depth found into the segregation of the in-game events and their trigger types. The segregation done is only on the basis of what kind of event occurs, for example, a player avatar action, a game setting change, starting, pausing and ending games, etc [31].

In a video game reality-based locomotion study [55], natural user interfaces are explored. Here, the locomotion of an American Football based quarterback's locomotion is used for testing. There is some distinction between the types of movement of the quarterback, which relates to in-game action. These movements are defined as: Running (locomotion down the field to score), Maneuvering (intricate movements to avoid tackles) and Evasion (jump, spin, juke, etc.) They have created controller events to trigger these in-game actions, however, they have not used a specific framework which says that a given 'type' of controller input is mapped to a given 'type' of in-game action. Smith et al. [42] used eye-tracking as a game control input in 3 different ways: to control the orientation of a first-person shooter, communicating with an avatar to move to a given location and targeting moving objects to aim and shoot. All these actions are essentially actions which require the continuous input action provided by the eye-gaze, to give directional/motion/aiming capabilities to the player. But, we believe that there can also be single action triggers, for example the 'Evasion' movement suggested by [55] can be triggered by a single button press or an eye-blink or in our case, a quick breath. Nacke et. al. have explored the use of direct and indirect physiological control to enhance game interactions [28]. In their study, they created 6 game mechanics,

i.e. actions that a player can take in a game, such as adjusting player speed, jumping and shooting (flamethrower) which require either direct (voluntary control like breathing, EMG) or indirect (involuntary control like heart rate, skin temperature) physiological control from the person playing the game. They created 3 game conditions for testing with participants, in which 2 conditions consisted of 2 direct and indirect controls each, while the third condition consisted of only external controller input (gamepad). While their study provides encouraging results that favour the use of direct physiological control inputs like breaths in terms of immersiveness and novelty, they do not focus on the types of real-world input actions used to perform in-game actions. However, they do suggest that having a natural relationship between the player real-world action and the in-game action is one of the most likeable aspects of using physiological inputs.

Blomberg [1] in his phenomenological approach to understanding and presenting the semiotics of game controllers, suggests that the controller to game pair is connected intimately, while having distinct actions. The controller action represents an action in the game world, for example, mechanical actions like shooting corresponds to a specific controller action. Blomberg highlights 3 different semiotic grounds for establishing this relationship between the game and the controller. These are resemblance (iconicity), contiguity[5] (indexicality) and convention (symbolicity), which are a good way for designers to try and create optimal game controls for their game. He suggests that controller action or a combination of controller actions can fulfil a multitude of actions in the game world. This would depend upon how the controller is configured, such that it can both constrain and enable how a game is played. Building upon this, we come up with a paradigm that forms a link between controller action and game action. By establishing this distinction between controller action and game action, we believe that game-actions can be designed on the basis of the available input devices and their 'type' of input provided to the game.

In order to attain configurability in breathing exercise games, such that a large number of breathing exercises of different domains are present, we first look into the underlying game control possibilities of existing games. Figure 20 shows a few games of different genres and game-controllers.

These games, as illustrated in the figure, have a number of in-game actions such as shooting the ball in 'FIFA', running and jumping in 'MARIO' and so on. There are also some physical actions that the gamer playing the game performs with hardware input devices (controllers), in order that the in-game action is performed, such as pressing a certain key repeatedly to run faster in the classic game 'Hyper Olympics'. All of these external physical actions can be described as events that trigger the in-game action. We will call this coupling for each such event as the 'Game Action Control Event' (GACE). For playing any game, we believe there are two main types of GACEs:

- **Single Action (SA):** These are events that trigger an in-game action with a single gamer action, such as a button press or a screen swipe. For example, shooting bullets in 'CS:GO', jumping in 'Mario', etc.
- **Continuous Action (CA):** These are events that require continuous action from the player, requiring sustained action game-controllers. For example, player movement in various games, motion sensor, mouse pointer action, etc.

Any game action can be defined as either a Single Action or a Continuous Action or a combination of the two. These actions can either be standalone or requiring either direction control or amplitude control. Directional control (D) examples include aiming, turning, etc. while Amplitude control (A) includes controlling shooting power, jump height, etc.

Any game action can be placed in any (or multiple) empty cells in Table 7. We theorize that any of these actions can be performed by using breath control.

[5]Contiguity - the sequential occurrence or proximity of stimulus and response, causing their association in the mind.

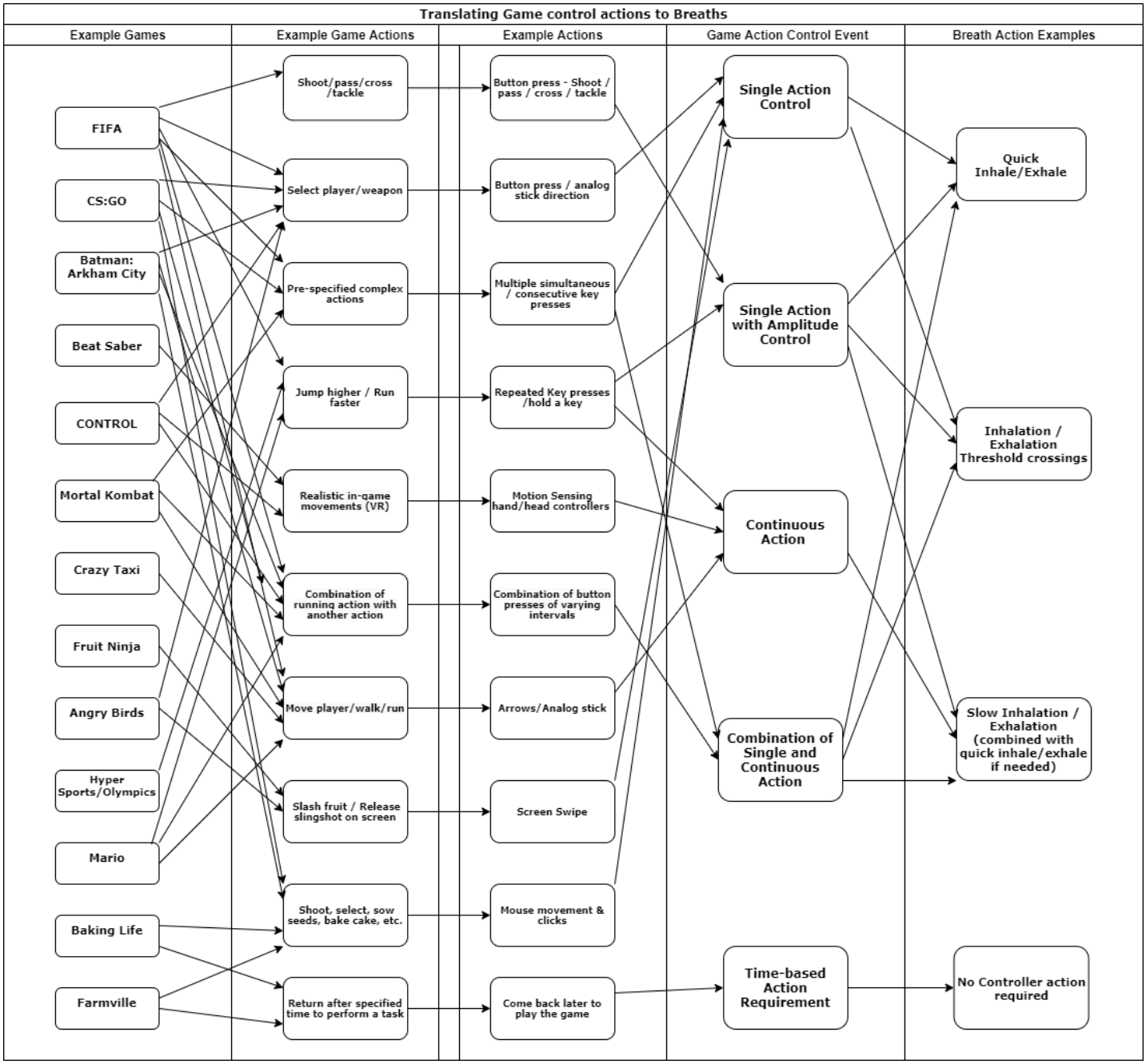


Figure 20: Translating game control actions to breaths

GACE	Standalone? (S)	Direction Control?(D)	Amplitude Control?(A)
Single Action (SA)			
Continuous Action (CA)			

Table 7: Different Possibilities for Game Action Control

5.1 Examples of how generic existing games can be converted to breathing games

To understand the above theory in more detail, a few examples of existing non-breath controlled games and their required controls are presented here, with alternative possible breath-control possibilities. For ease of use, we call Single Action as 'SA' and Continuous Action as 'CA' and Directional and Amplitude Control are abbreviated as 'D' and 'A' respectively. A 'SA' with a 'D' could be written as 'SA/D', and so on. Breath controlled game-actions are shown in the green boxes, while other standard controller actions are shown in yellow/blue.

5.1.1 Example 1: Super Mario Bros (PC game - keyboard only)

Figure 21: Super Mario Gameplay

In *Super Mario Bros*[6], the player is supposed to progress in the game by moving forward (right), avoiding obstacles and enemies by jumping over them or shooting them. As shown in the figure 22, the required inputs to this game can entirely be fulfilled by breaths alone.

5.1.2 Example 2: Beat Saber (VR game - hand controllers and HMD)

In *Beat Saber*[7] too, like in Mario, almost all game controls can be performed by breaths alone, while wearing the HMD. Slashing blocks and moving away from obstacles are both Single Action Directional GACEs, which can easily be replaced by breaths as shown in figure 24. However, it would not be as simple as using hand-controllers. For instance, the directional slashes would need to be paired, for example, slashing blocks upward and leftward could be done by inhaling while slashing blocks downward and leftward could be done by exhaling. Also, slashing multiple blocks at the same time can easily be made possible with the hand-held controllers because we have two of them, but since humans have just one breathing mechanism, only one control can be administered, thereby making it difficult to add such a functionality with breath control. It is possible to achieve this by using breaths

[6]Figure 21 via: https://www.alphabetagamer.com/super-mario-bros-lost-land-alpha-download/
[7]Figure 23 via: https://www.vrfitnessinsider.com/top-12-beat-saber-tips-tricks/

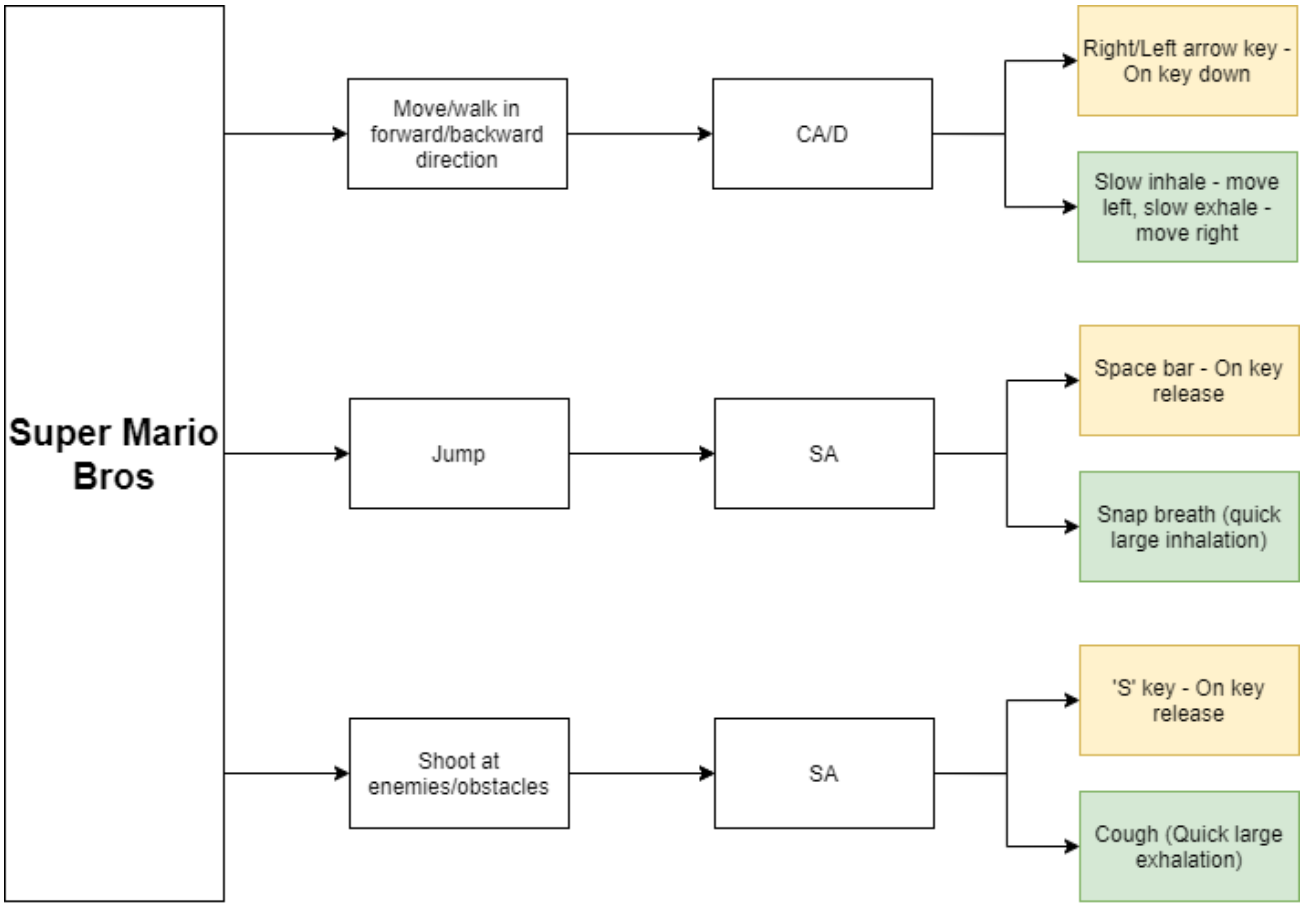


Figure 22: Translating Super Mario game controls to breath control

Figure 23: Beat Saber Gameplay

sequentially, like ‘quickly breathe in and out to be able to slash 2 blocks simultaneously’, which is becomes more challenging to the gamer. The game can also be designed such that even though only one breath-controlled action (such as a quick exhalation) is performed, both incoming blocks get slashed, but that would not make a difference, as it would effectively be the same function as a single incoming block. *Super Mario Bros* and *Beat Saber* show

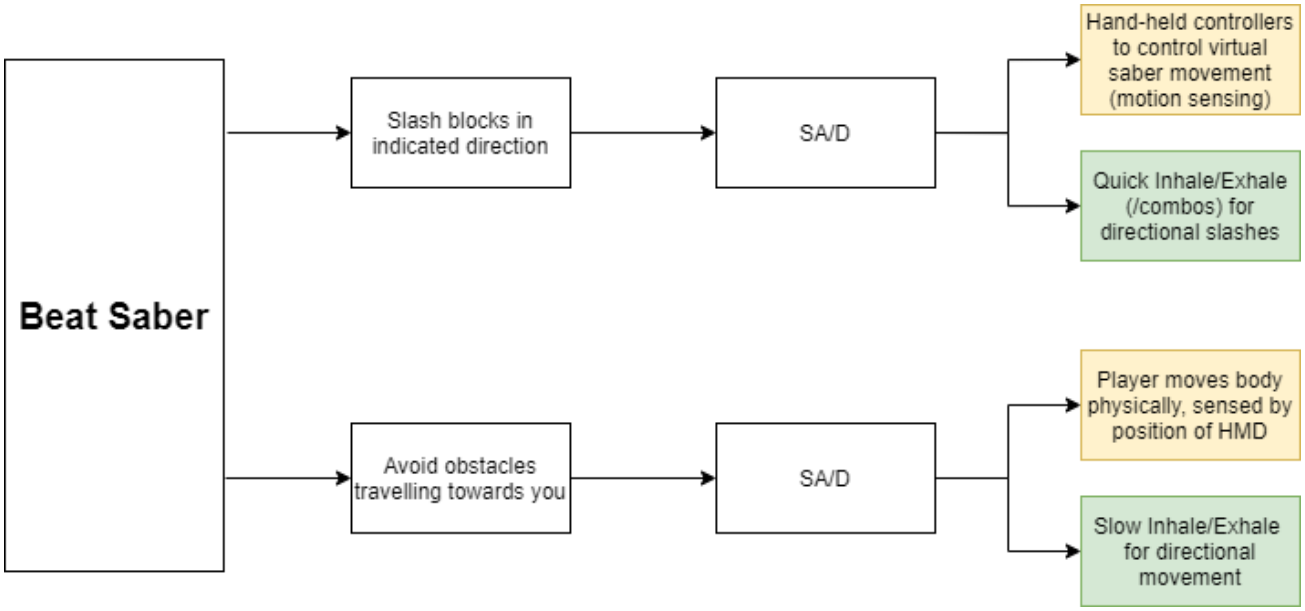


Figure 24: Translating Beat Saber game controls to breath control

that breath actions can be used to control games effectively and almost entirely.

5.1.3 Example 3: FIFA (PC (keyboard) and console (hand controller) game)

Figure 25: FIFA Gameplay

When we look at a slightly more complicated game like *FIFA*[8], with more advanced gameplay, we notice that although the game can be controlled by breaths by adding several different kinds of breath inputs, it would be too cumbersome to control the entire game by breaths alone. Most functions occur in combination with one another. The most basic elements of football can only take place while controlling the direction of running, passing, shooting, as at least one of the directional keys are required to be pressed at almost every moment in the game. So, while there exist breath controls that belong to the GACE table, there are just not enough breath actions possible for the entire game to be played with breaths alone.

5.1.4 Example 4: Batman Arkham City (PC (keyboard & mouse) and Console game (hand controller))

When we look at more complex FPS games like *Batman: Arkham City*[9], we notice that several functions of batman can be realized by breaths, while many cannot. Game actions that require simultaneous control of individual game elements, for example, running and fighting, or aiming and shooting, etc. are not impossible to fulfil by breaths alone, but it is not practical to use breaths so much for such types of games. That said, breaths could be used in combination with a controller, for certain game elements in which breath will be an intuitive enough form of control, such as a quick large exhalation for shooting, while using standard game controllers for aiming and movement. This is true even for the *FIFA* example and several other games which require simultaneous control. One such example which uses breaths as just one of the game-controls can be found in the game *BreathVR* [45], in which there are four specific breath types (gale, waft, gust, calm) only form a part of an immersive virtual reality game (such as a FPS or ball game), which involves the use of other control actions with the VR motion detection and hand controllers.

5.2 Game and game-control design guidelines

The above examples show that breath control can be used to control games, either alone or in combination with another standard controller. For recreational purposes, it is possible to incorporated breath as a game control mechanism in the examples above, as described in the images. However, for the purposes of breathing exercise games, several other aspects of game design need to be taken into account, for example, posture, physical & mental stress and most importantly, fulfilling the purpose of completing the prescribed breathing exercises successfully and regularly. Due to this, breathing exercise games need a careful design for players to get the maximum benefits of breathing and recreation from it.

We therefore come up with some game design guidelines for the control aspects of breathing exercise games:

1. These games should not be too complicated, involving simultaneous control of several elements of the game. For example, using breaths to control movement and shooting together is not feasible.

2. Reduce the workload on the player while playing the game by having minimalistic controls, so that breathing exercises do not lose focus.

3. Controlling some highly directional aspects of a game, such as aiming and turning can be cumbersome using breaths, as getting the accuracy of directional control via a mouse or a joystick could be difficult. Angling one's breaths according to the required direction could disrupt the posture and technique required to perform breathing exercises. Hence, unless the exercise calls for altering body position and movement, avoid this or if it is unavoidable, use a simple standard controller to control these highly directional aspects in the game.

[8]Figure 27 via: https://press-start.com.au/news/playstation/2019/06/05/the-first-fifa-20-gameplay-changes-have-been-detailed/
[9]Figure 23 via: https://www.gamed.nl/view/92199

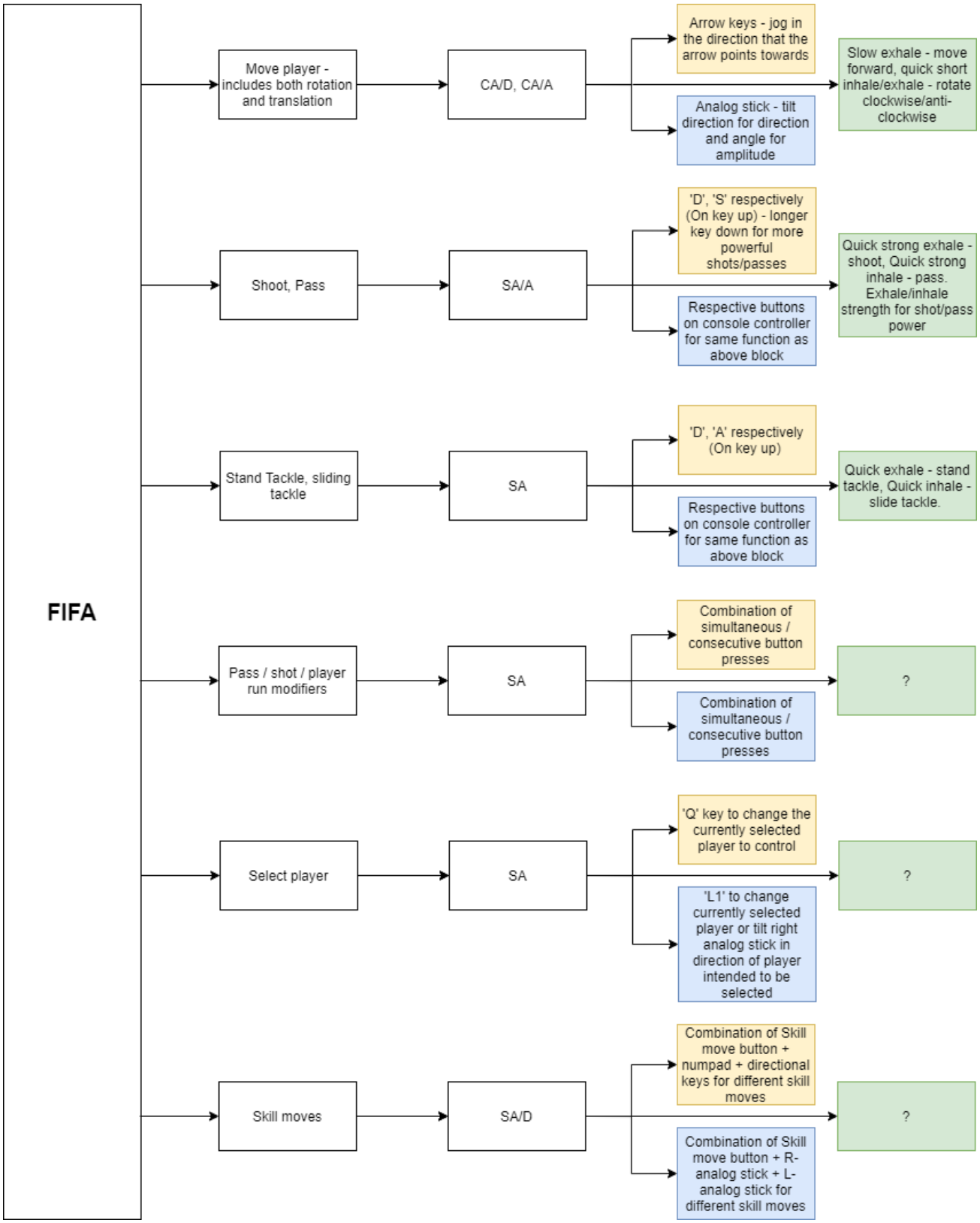


Figure 26: Translating FIFA game controls to breath control

Figure 27: Batman: Arkham City Gameplay

4. Level design should be such that the player is challenged to do well, not only in the game, but also to do the breathing exercises well. Players should be challenged to breathe longer, stronger, deeper, quicker and whatever else is prescribed by the therapist/teacher.

5. Use GACEs such that they can easily be incorporated via breaths. There might be a need to automate an element in a game, so as to incorporate GACEs in it. For example, if the game involves driving a car, it would require both the forward movement (acceleration / deceleration) as well as directional movement (turning left / right). However, incorporating both via breaths can be cumbersome, while incorporating one of them, with the other happening automatically is more feasible.

6. Since this is a breathing game, the player also needs to be able to catch their breath. So sufficient breaks should be incorporated where the player can breathe normally.

5.3 Existing breathing exercise-game controls

As shown in the figure 29, existing breathing exercise games that use breaths as input game control use the same GACEs as described previously. Different breath actions[10] are mentioned in the figure to control different GACEs. BreathVR is a game designed purely for entertainment, with breaths providing an additional control mechanism apart from standard game controllers [45]. The other games are used for therapeutic purposes, however, each game only makes the user perform one exercise. For example, Life Tree makes the user practice rhythmic pursed lip breathing effectively, keeping in mind factors like simplicity, posture and intuitiveness [32] and Chillfish is used to calm down children with ADHD [43]. Using the GACEs, the same game can be used to perform several other exercises, by simply tweaking the level designs. The game can be designed such that a quick inhalation (SA) can show energy being received to the player from the tree and a slow exhalation (CA) can show life being sent to the tree, the latter being the same as the initial design. This would fulfil the 'In-Out', 'In-diffOut' exercises. Similarly, others functions could be designed with more breathing patterns like holding breath, slow inhalations, series of quick exhalations, etc., thereby fulfilling even more exercises. However, care must be taken

[10]Not all breath actions are present in the figure, for eg: the slow inhalation is not present

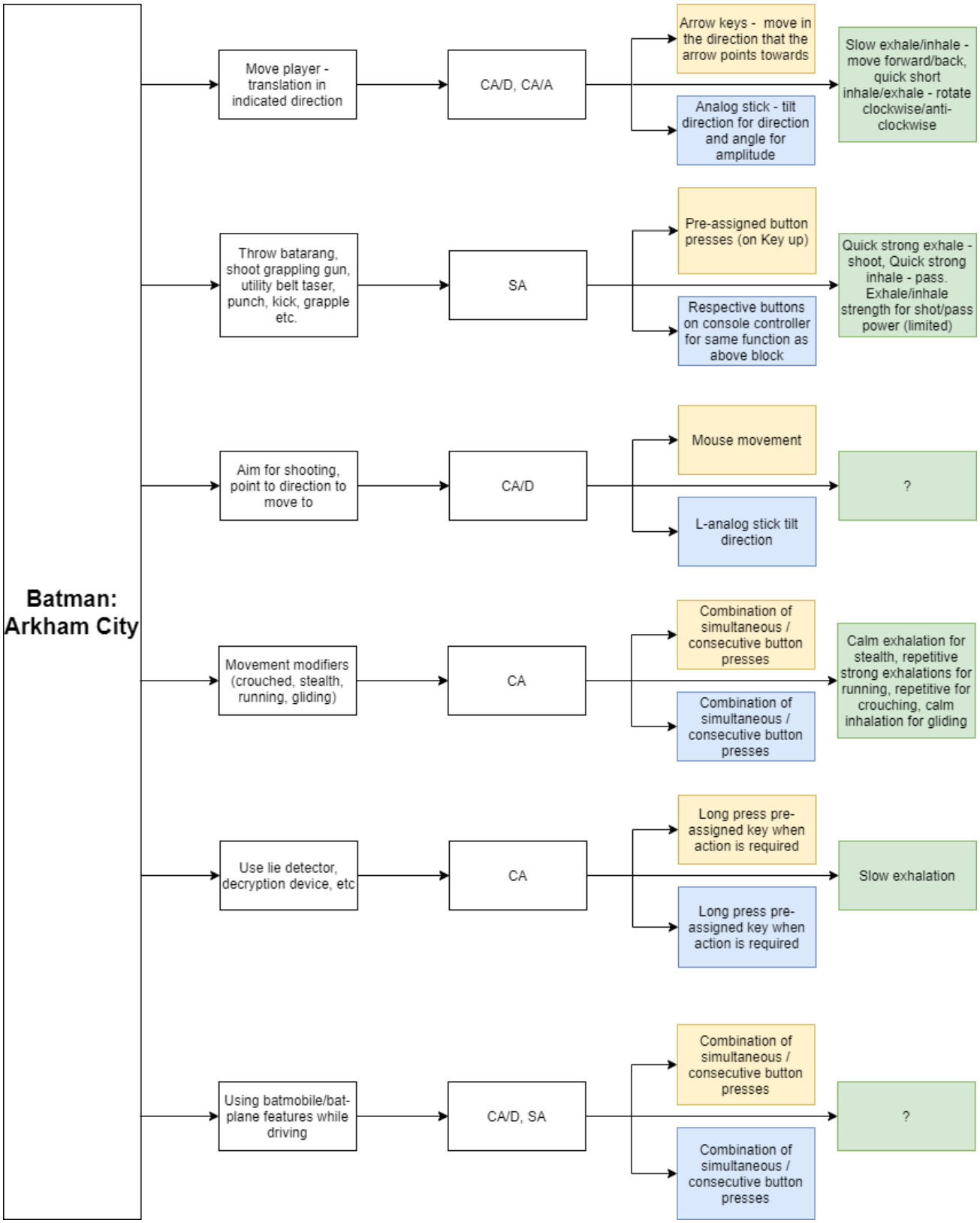


Figure 28: Translating Batman:Arkham City game controls to breath control

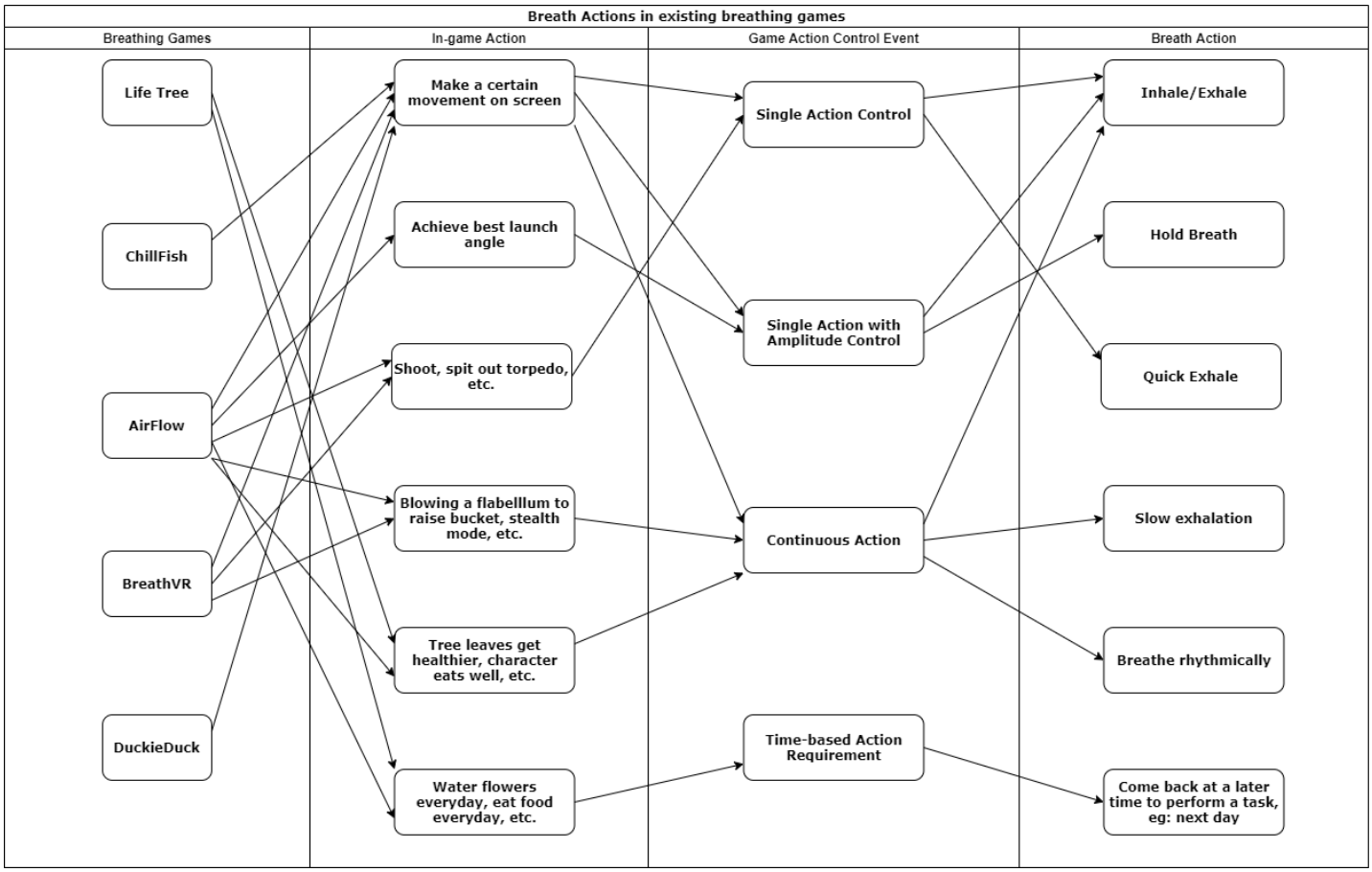


Figure 29: Breath Actions used as game control in existing breathing exercise games

that each breath control and its following breath controls are physiologically possible and logical, for example, an exhalation for too long, say, to accelerate a car should be avoided by adding inhalations to perform other actions at regular intervals, or not having another inhalation requirement soon after one inhalation has been performed. This is to ensure that playing the game is not made impossible. Additionally, it could possibly be beneficial for the teacher/therapist to be able to tweak exercises themselves, such that the exercise can be done the way they want them to be done by the student/patient. This ability to reconfigure GACE mappings will give the game true configurability, where the teachers are also involved in the game design process, customizing the game according to the needs of the patient/student and the desired exercise (parameters).

5.4 Configuration of Breathing Exercise Games Possibilities

To illustrate this configurability in greater detail, let's take an example of a game that was made as an early technology prototype: a generic Endless Runner game built in Unity.

5.4.1 The Game

Simple endless runner evading hurdles by jumping over them. Avoid falling objects by either dashing past them or stopping before they fall. To progress in the game, the player moves in the right (forward) direction and every hurdle crossing is a point added to the score. The player can stand still, run, sprint, jump and double jump in order to avoid hurdles and falling objects. The game in its basic version contains a small handful of simple game actions to make the character move and act, each with its own type of GACE required to trigger that action.

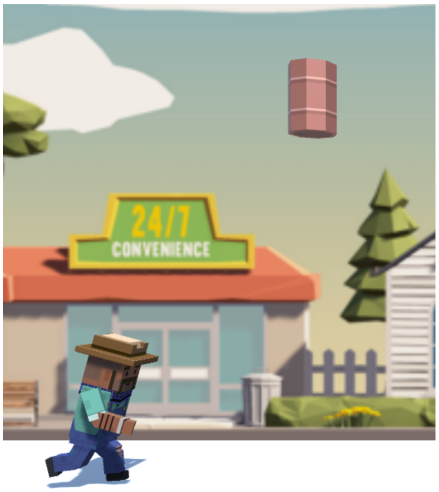
- Stand still - This is the default that happens when the player does not apply any control.
- Run - CA. When the preassigned key is pressed, the player runs at normal speed.
- Jump - SA. Jump up while still moving forward to clear a hurdle.
- Double Jump - SA. Jump twice by quickly sending the jump action twice, to clear a bigger hurdle.
- Sprint - CA. When the preassigned key is pressed, running speed is higher.

The basic version uses the keyboard to control the game:

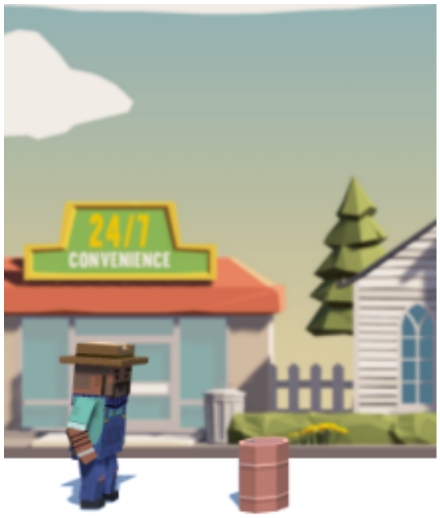
- Run - 'S' key.
- Jump - Spacebar
- Double-jump - Spacebar to jump and spacebar again to jump once more mid-air
- Sprint - 'D' key

The basic breath controlled version of this game could look like this:

- Run - Continuous slow exhalation
- Jump - Short strong exhalation
- Double jump - 2 short strong exhalations
- Sprint - Continuous slow inhalation



(a) In-game scene with object falling from the sky, meaning the player needs to stop running. The game control action would then be to hold breath.



(b) In-game scene when the gamer holds their breath. Object falls from sky and falls into the ground after which the player should run again

(c) In-game scene where player needs to jump over an obstacle. The gamer needs to perform a quick exhalation and then continue a slow inhalation/exhalation to continue running/sprinting forward.

Figure 30: Example possible game actions controllable via breaths

Using the figure representation used earlier, this game would look as shown in Figure 31. Several breathing exercises could be incorporated using this game by just changing one (or multiple) of 6 possible places to make changes:

1. **By creating different level designs:** By designing different levels that are well thought of, this game can already be used to make several exercises without changing the GACE configuration or game-control mapping. If obstacles fall from the sky in a certain pattern, the player needs to run fast or slow (or even stop and wait) in order to evade them. and since some fixed obstacles are there, the character sometimes needs to jump to evade them. Placing/spawning these obstacles and falling objects at strategic times can already create a few breathing exercise game scenarios. Hence, we can easily recreate the exercises: **Dog** (dash - jump jump jump jump etc); **In-diffOut** (dash-run for certain time); **in-in** (dash-wait-dash) and In-Hold-Out (dash-stop running-run for certain time) The current GACE mapping does not contain a mapping for quick-inhalation. So e.g. rhythm of quick in/out alternation cannot yet be defined merely by making a different level design with the available game actions. Hence, we look at other possibilities.

2. **Enabling other exercises by changing the GACE mapping:** With the same game actions and their control events we can map different breath events to allow levels that embody "Alternate bursts" or "In-diffOut" with snap inhalations required. If we re-map the game controls such that the player's dash mode (sprint) is triggered by a quick inhalation (SA) instead of a slow inhalation (CA) and we keep the jump at "quick exhalation", we can make a level that embodies the exercises mentioned above by strategically spawning falling objects that can only be evaded by a short dash. The "Alternate bursts" would look similar to the above image, with more falling objects in front of the obstacles. In figure 33, we see how the "In-difffOut" exercise can be designed using only falling objects.

   Figure 34 shows the changes made to the GACE mappings in the highlighted blocks. The CA GACE in the previous controls is changed to an SA, thereby enabling the new set of breathing exercises.

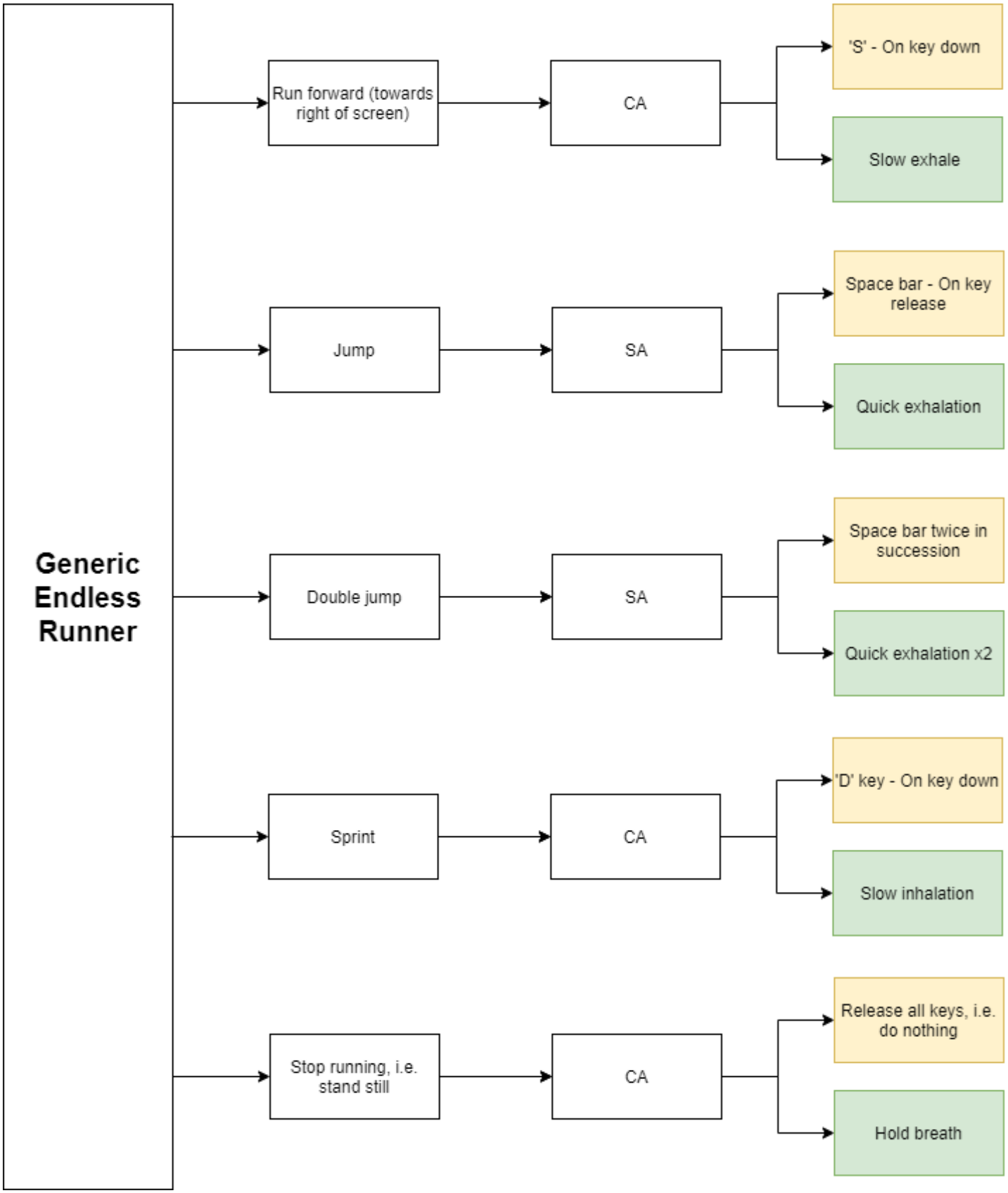


Figure 31: Translating the created 'Endless Runner' game controls to breath control

Figure 32: Example: 'Dog' breathing exercise where player needs to dash to avoid the falling object and jump over series of obstacles

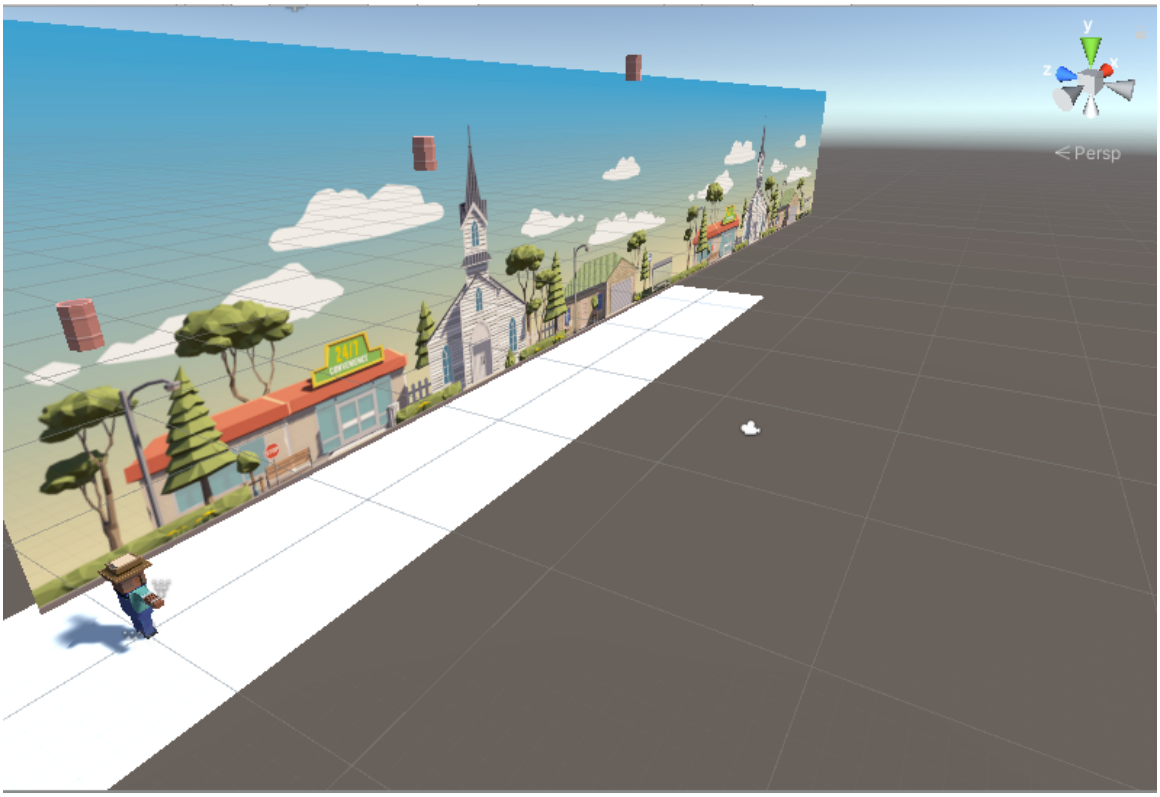


Figure 33: Example: Gamer needs to perform a quick inhalation to sprint and avoid falling barrels, slow exhale to run normally until its time for the next quick inhalation to avoid the next falling barrel.

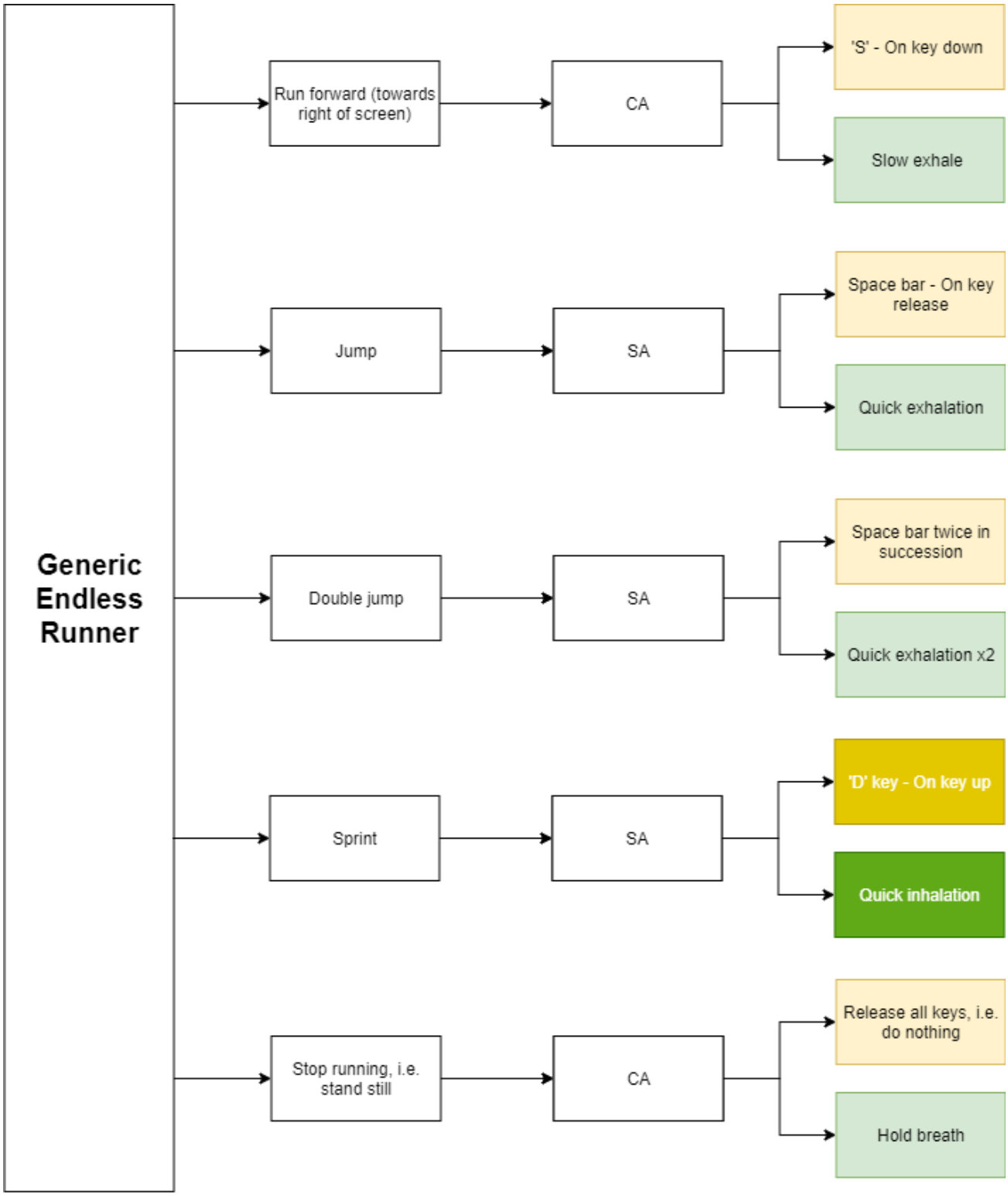


Figure 34: How new game controls can be incorporated

3. **Changing the breath control required to trigger actions:** In past versions, running normally was done by slow exhalation. But we can also send "run" only while the gamer is doing a rhythmic slow mindful relaxed breathing. Which means, that the in-game player keeps running as long as the breathing rhythm of the gamer is maintained and stops running when the rhythm is disrupted. For example, the transformation breaths, which are short and large series of inhalations and exhalations can control the running of the player. Similarly, jumping could mean a quick inhalation, sprinting could mean holding the breath and so on. So by recognizing different breath behaviors than in the simple version, and mapping such compound behaviours to GACE, we can also make different exercises.

4. **Changing the control event type for more variability in what one's breath can do:** If a certain exercise does not quite fit in the breath controls of a game, you can also modify the game paradigm. For example, instead of 'run' being 'CA', say 'run' could be 'CA/A', allowing one to make exercises where the strength of breath matters. This would mean that as the player breathes out continuously, the player will run faster (the 'A' in 'CA/A'). Also, the direction of breath (inhalation/exhalation) could mean different things, not in this game, but in a game that requires control of two directions, like moving left/right. In turn, that might also require a new mapping, for example, inhaling to slow down a running horse upon which an in-game character is seated could make more sense as compared to just inhaling to slow down an in-game character who is running, as that might intuitively be linked to moving backwards. These are interventions in the game side, rather than on the control & mapping side – potentially modifying the whole game activity paradigm.

5. **Enabling other exercises by adding new functions to the game:** Adding enemies that should be shot, ducking over obstacles flying towards the player, adding strategically placed collectibles, etc. are examples of additional functions that can be added to the game, each of which could require a new game action, a new control event, allows you to map one more breath event, plus allows you to make more varied levels, in turn fulfilling more number of exercises.

6. **Modifying parameters to change exercises:** Player speed, number of obstacles, duration of required dashes, etc. changing the thresholds in the breath recognise / GACE mapper or changing duration/length-/placement of certain obstacles can make the same exercise slower/quicker/harder/easier can also be done. This is where we presume that the professional prescribing the breathing exercise games would like to have influence as it has the potential to tailor the exercises according to the needs and capabilities of their clients.

In addition to these configuration changes, another possible factor to change in the games could be the on screen game objects. This would be in order to customize the game according to the specific domains. For example, if a game has collectibles, a pregnant woman would possibly prefer to collect milk bottles while a singer would want to collect note symbols. Also the in-game avatar of the player, backgrounds and such easily changeable details in the game could be changed according to the domain in question.

5.5 Conclusions from this chapter

As shown in the preceding sections, there are several ways to modify and configure the breathing exercise game for game developers, while involving the breathing practitioner. Clearly, we see that with a limited set of variations and settings for a game we can envision levels to embody just about every exercise, merely by selecting:

- The game
- The set of game actions and their control event types used to trigger them
- The mapping of controller inputs to these actions / event types
- The the appropriate level for that exercise

In other words, one could say that "I want to play 'game A' and do 'exercise B'" and that implies: a level, an actions set, a mapping, which breath action recognitions are used in addition to the difficulty settings. We believe that this way of creating a game that can be designed by a game developer in multiple ways, with the breath practitioner just prescribing the game, exercise and customizing the difficulty is optimal. This is because we believe that if the trainer/teacher/therapist configures every little detail in such depth, there could be a risk of over-complicating the process, thereby possibly requiring more learning to do for the practitioner as compared to prescribing. A best balance has to be struck regarding control over configuration settings versus configuration overload. This now also introduces the question of "What is the best interface for the professional and what controls would they want to have over the game?" To know more about these aspects of designing a breathing exercise game for singers, a co-design session was conducted, as discussed in chapter 7.

Table 8: Effects of music on body [15]

Music characteristic	Effect
Slow	Meditative, inner contemplation, deepens breathing, focus on the present moment
Contemporary American meditative music	Relaxation, low emotional content
Country/Western music	Emotion arousal
Smooth, flowing rhythm	Internal body rhythm
Drones	Meditational, calming effect
Pauses at slow pulse rates	Harmonize, integrate internal body rhythms - breath, heart rate
Dance music and marches	Motor response, mostly in the legs
Changes in dynamics, rhythm	Possible to drive pulse rate

6 The possible roles of in-game Audio/Music

It has already been established in the research topics [12] as well as other breathing exercise game research [4, 32, 24], that music has a major role to play in breathing exercise games, both as guidance and as ambience. When discussing interaction in games, there are different degrees of involvement and interactivity. More than the fact of interaction, it is the ways in which we interact that is most important to our conceptions on interactivity [5]. This chapter explains the various roles we suggest that audio/music can play in breathing exercise games.

6.1 Ambience

In [47], there is a statement that says that there is no such thing as silence. At any given point in time and place (room), there always exist sounds, termed as "room tones". They suggest that these room tones not only make an environment feel more real, but can also be used to set the mood of a particular place. They go on to say, "Never use complete silence in an environment in your game unless it's for an explicit aesthetic purpose (and even then, don't)." Audio and music can give this added feeling of belongingness to the game scene. To add to that, music is known to elicit positive emotions and influences motor response in people [15]. All these factors point towards having an ambient sound in the background, and the benefits that music provides points to the fact that it could be useful in the game. But what kind of music is optimal for breathing exercises? Fried [15, 16] shows in his work some specific genres, characteristics and even songs that elicit deep-diaphragmatic breathing. For instance, table 8 shows the effect that certain characteristics of music can have on listeners.

Music such as drones, contemporary meditative music with smooth flowing rhythms are optimal for applications like mindfulness and therapy as it has a calming effect. For breathing exercises in singing and wind-instrument playing, it is also important to have a rhythm to the music, which the player can follow. However, does the musical preference of the person playing the game matter? The music-related interview conducted in the Research Topics [12] had an important takeaway, in that there is a vast variety in music and an equally vast variety in cultures, which also has a part to play in a person's choice of music. Therefore, the interviewee suggested to take the favorite kind of music of a person playing the game and alter components of that while designing the game. Many other studies also suggest a positive effect of the musical preference on a person. Dwyer suggested in his study that when the perceived choice of music of people are played, there is higher exercise intrinsic motivation, as compared to when music that is not preferred by people [9]. Another study points towards the positive influence of musical preference on enjoyment and attentional focus to perform exercises [10]. They suggest that paying attention to the music (of preference) while exercising will result in more enjoyment of the activity, while not attending to the music reduces the effect of musical preference. They provide further evidence that future research could benefit from allowing participants to provide their most preferred music, since this perceived choice

in music can meaningfully affect attentional focus. In music education, student music preferences seem to be of pivotal importance to teachers [8]. This study also suggests that the greatest payoff that a student receives should be the enjoyment that a student gets when listening to / creating music and that the knowledge of music preference and the factors affecting it seem to be very important to music teachers in finding rewards for their students, in the form of music that brings enjoyment to the student. Therefore, the preference of music for students should be taken into consideration when designing lessons, choosing music, and delivering instruction [8].

Thus, since music is known to provide enjoyment, attention and activity, it can and should play a part in breathing exercise games. Moreover, the music preference of game players will also matter, since the game is not purely for entertainment, but is also (mainly) for practicing breathing exercises and techniques. That said, there is a vast variety of breathing exercises that fulfil different goals in different domains. So, it may not be possible to have the player's exact choice of music in every exercise. Thus, it is important to find a way to technologically make breathing exercises and thereby, breathing exercise games work with the player's choice in music or to at least be able to narrow down several songs that fit a given exercise and give players options to choose from. Another alternative could be to fit each breathing exercise to different genres of music, such that players can choose a genre of their choice to perform breathing exercises.

6.2 Provide a rhythm

Rhythmic entrainment, as explained by Juslin [21], is a process in which emotion is evoked by a piece of music because the rhythm in the music influences some bodily rhythm of the listener (e.g. heart rate, etc.), such that this bodily rhythm keeps adjusting to and eventually 'locks in' to a common periodicity. The rhythm and tempo of music can both consciously and subconsciously affect a person's breathing. As seen in Table 8, we see how these can subconsciously affect people. Several breathing exercises require the person to breathe to a certain rhythm, or 'counts'. In [30], one of the audio modes of operation in games is to synchronize the rhythm of music to other activities in the game. Such concepts of playing to the rhythm are also seen in other studies [33, 54]. This is seen clearly in games like *Beat Saber* and *Dance, Dance Revolution*, where spawning and timing of objects are dependent on the tempo (bpm) of the song, thereby making sense musically as well as in terms of the correlation between listening, seeing and taking action. In *Beat Saber*, the player physically moves their hand controllers so as to be able to slash objects travelling towards them, which arrive on the beat of the music. That gives the player cues in terms of audio, alongwith visuals, about when the player needs to make a game control action to slash the object. Such use of rhythms in music can be very important for breathing exercise games as they can be one of the major guiding factors to elicit the right form of breath at the right instants in the game, thereby progressing in the game, as well as performing the breathing exercise correctly.

6.3 Tutorial/instructional influence of audio

The rhythm and beats of music already provide the base for how one needs to breathe. To add to that, there can be more cues to indicate when the player should breathe in a particular way. An additional metronome sound or separate drum layer could help provide these cues. Also, different types of metronome / drum sounds could indicate differences in the way to breathe, for example, a bass drum could indicate inhalation while a hi-hat could indicate exhalations. Increasing/decreasing volumes of sounds or even of the main music at particular moments in the game could also provide cues in a similar way. To give game players a better understanding of how someone should breathe while playing the game, there could also be breath sounds that mimic the sound of inhalations and exhalations, as per how the breathing exercise is. In the game *Life Tree* [32], such subtle breath-mimicking audio is used that allows players to understand the breathing pattern they have to perform in the game while sustaining their focus on breathing. The use of rising and falling pitch frequencies in music can also prove to be useful to indicate when and how to breathe in/out, as it is shown to prompt psychophysiological responses among people [23, 17]. Gavish in his work uses such rising and falling tones as "guiding tones" to illicit inhalations and exhalations respectively [17], as "synchronicity" plays an important role to guide breathing. The results of

this research suggest effectiveness in performance and clinical outcomes with such guiding tones. The limitations of this method presented here include the lack of effective control on the breathing depth and lack of clearly understanding the breathing pattern to link with the rising/falling tone being heard. However, it is possible that this can be solved with the help of matching these tones (rising/falling tones - arpeggios, chromatic notes, etc.) with the rhythm (beats) of the song at strategic points in the game, or by using such tones within a song that has them inherently, as this could enable players to listen to and possibly understand the speed and intensity at which they need to inhale or exhale at a given moment. To make them understand and follow the tones better, we could also use the other tutorial sounds mentioned previously in this section in combination with such tones.

6.4 Negative and positive feedback

Using audio and music for negative and positive feedback in breathing exercise games subtly can be incorporated in breathing exercise games. An example of negative audio feedback could be seen in the game *Sonic Respiration* [19], where the player's breathing affects an audio signal by adding levels of white noise corresponding to the difference between the actual and target breathing rate of the player. On a similar note, there can be different types of sounds such as drum beats, chords, noises, 'clink' sounds, etc. strategically added or subtracted from the main audio/music such that the player knows if they are doing something right or wrong in the game. The strategy to using this method of feedback would depend upon several aspects such as whether it is negative or positive feedback, the rhythm and tempo of the music being played and more so about what kind of game and for whom the game is. Positive feedback could also be perceived as 'rewards' for progressing in the game, i.e. performing exercises correctly. The important factor in this is how musically sensible the feedback is. Schmuckler explains how we perceive the appropriateness of tonal (chordal) as well as temporal aspects of music [41]. This musical expectancy of having the right chord at the right time in a song could possibly be useful in the breathing exercise games to adjust the feedback given to the player. Using this, musical notes, chords and rhythms can be used to trigger brain stem reflex, which is a process in which an emotion is aroused in the listener because an acoustic feature in the audio exceeds a certain cut-off value for which the auditory system has been designed by natural selection to quickly alert the brain [21]. Therefore, strategically adding layers of audio that either musically makes sense to give players positive feedback, or are understandably divergent to the natural selection of how the music should be to give negative feedback could be used in designing breathing exercise games.

6.5 Conclusions and Discussion

As we have seen in the above sections, The use of these possibilities of audio and music in games would need to be carefully thought of while building the game, taken into account the views and feedback taken from potential users of the application. It is not necessary that all of the possible roles of audio and music explained in the above sections need to be incorporated in breathing exercise games. Figure 35 shows the different roles that different types of audio can play in the game. This figure is just an example, which game designers can build upon, by switching up these different roles of music. For example, a song can provide only an ambient effect or it can provide both ambience and feedback in the form of volume adjustments, where the volume of the song can be altered during the game, such that the song volume increases if the player performs the exercise correctly and gets fainter if the player does not, in addition to the ambient effect that the song provides. This can also be done for the metronome layer, where it can be used as a tutorial sound, to provide a rhythm as well as feedback by volume adjustments. This selection of what sound performs what role in the game can prove to be crucial in meaningfully engaging the player to clearly understand and play the game and thereby perform their breathing exercises well. It should be possible for game designers to understand their target group, their exercises, the type of music used for a target group and how simple or complicated the game should be. For example, in singing and wind-instrument playing, the music used in it need not be of a specific genre, but should be according to the requirements and tastes of the singer/wind-player. Also, their exercises can be complicated and strict, hence there can be more roles for audio such as tutorial sounds and positive and negative feedback. On the other hand, for mindfulness, there are specific genres of music that are suggested by practitioners and also seen in [15], thereby

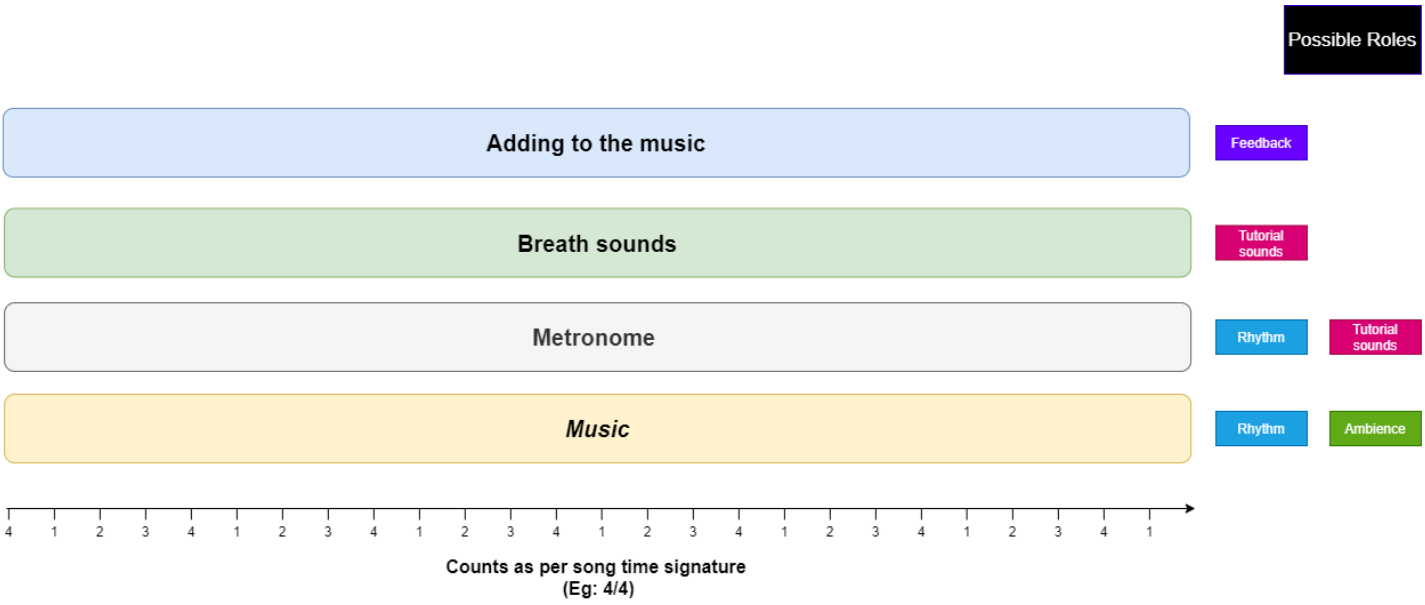


Figure 35: Possible roles of audio in games

limiting the choice of music to be used in the game. Their breathing exercises should generally not be very strict and taxing in terms of feedback via visuals and audio. Hence, with a better understanding of each domain that uses breathing exercises and their needs, audio in games can be altered so as to provide a wholesome experience while performing breathing exercises.

One way to better understand users and thereby create games for a particular user group is by involving users in the design process. Understanding users from all domains explored - singing, wind-instrument playing, mindfulness, pregnancy, therapy, would be out of the scope of this project, owing to time constraints. Therefore, we first look at one particular domain - singing, as discussed in the Chapter 7.

7 Co-Design Session - Understanding Potential User's View of Breathing Exercise Games

With the interviews conducted in the Research Topics phase, we found out what goals need to be fulfilled by students in singing, wind-instrumentalists, pregnant women, mindfulness seekers and breathing difficulty patients. In chapters 5 and 6, we discussed the several ways in which we can configure a breathing exercise game both, within a game as well as between domains with different game controls & in-game audio. To build upon our ideas and create a game design, we first look at one domain - singing, as it has been fairly unexplored in terms of breathing exercise games. For that we needed ideas for games to be built, for which we chose to conduct a co-design session with singing teachers and students.

While co-design has been shown to be especially effective to explore the unique knowledge of service usage and latent needs among users, it also helps overcome the 'stickiness' of users' knowledge and views. The problems of not having user needs readily articulated and transferred using conventional research techniques, e.g. focus groups, interviews, or surveys can be avoided here [50, 46]. It helps to overcome the 'stickiness' of user knowledge, i.e. the problem that user needs cannot be readily articulated and transferred using conventional research techniques, e.g. interviews, surveys, focus groups, can be avoided [53]. Also, co-design can help avoid an over-reliance on empathy by engaging participants with relevant first-hand experience of the domain in question [52]. As Pu suggests in her study, co-design groups were more satisfied with the design process, teamwork and team structure of a co-design session[35]. Also, participants from co-design groups were more satisfied with their product than other groups. Personally, I also thought it would be easier and more beneficial to conduct one session with many participants sharing views and bouncing ideas off each other, with me guiding them along the way because it would be less time-consuming and would provide more detailed information and ideas. It would also turn out to be great exposure for myself, as it would be the first time that I would be facilitating such a session. The session, however, needed to be conducted online, via an online collaboration tool - *Mural*, as a precautionary measure against the ongoing COVID-19 pandemic.

7.1 Goals and Session Planning

The goals of this co-design session were as follows:

1. Understand potential users' needs
2. Getting ideas for the overall flow and interaction that the game would provide.

Duration: 2 hours

Participants: Brolin Fernandes (researcher, facilitator), Dennis Reidsma (observer), 2 singing teachers, 2 singing student-teachers (students who are also teachers) and 2 designers/coders. For ease of representation, we will refer to the student-teachers as students. Among the participants, each student was a student of each singing teacher. All participants were of varying ages and levels of expertise. The reason for choosing this bunch of participants was because the eventual game would be used by both singing teachers and students of all levels. So, getting both perspectives would be very useful in making design choices in the game. Also, having designers/coders in the group may help the discussion as they have better experience with designing games, understanding technology and provide guidance in developing ideas for creating prototype applications. We do not consider demographics such as age, gender, nationality, level of expertise etc. in analyzing this session, as the ideas were discussed in groups and were subject to being influenced by each other's thoughts while brainstorming. Also, it would give a more generalized picture of breathing exercise game ideas for singers since there could be combinations of varying thoughts discussed in the session. More focused analyses of these different demographics is out of the scope of this project.

7.1.1 Preparation for the session

Pilot session: Before the final co-design session, a test session was conducted with my housemates in consultation with the research supervisors, to get used to facilitating the session and navigation across the various software required for the online session. This session lasted for about 3 hours and the insights, feedback and discussion with my housemates was very helpful to improve the flow of the session. After re-thinking the session and upon discussion with one of my supervisors who specializes in human centered design, we obtained more feedback and suggestions to ensure a smooth and useful session. With this, the final session plan as seen further in this section was created.

Before the session: Brief information about the progress in this project was given to the participants, most of whom were also interviewed in the Research Topics phase. An information document with a little bit about what the session is for and privacy statements was also sent to the participants. All participants consented to participate in the session and to have the session's video and audio recorded. The software/technical requirements for the session were Mural (web application), Discord (video conferencing), webcam, audio input & output.

A mural template for the discussion which was planned as follows:

1. Short introduction of why we are here, ground rules (2 min)
2. Warm up activities (5 mins): Where in the world (add your location to the world map on the mural), Time machine (add notes, pictures, or anything else to show the era/moment in time that you would want to be if you could time travel).
3. Explanation of 1st activity - what, why, how (3 mins)
4. **Activity 1 (15 mins):** 2 groups: Group A: 1 (UX designer / coder), 1 singing teacher, 1 singing student Group B: 1 (UX designer / coder), 1 singing teacher, 1 singing student **Visual interface:** Where would you imagine yourself while performing breathing exercises? **Considerations:** Either breathing should affect what you're seeing or the other way round, or both. Free to draw, add images, post-its, connectors, sequences of events, etc.
5. Explanation of Activity 2: 3 mins
6. **Activity 2 (15 mins): Audio -** Should audio be incorporated in the breathing exercises game? How should it be incorporated (what would you like to hear while doing the breathing exercises)? Same group setups throughout all activities as in Activity 1.
7. 5 min break
8. **Activity 3 (15 mins) Getting Feedback**: Teachers want students to perform the exercises correctly and see improvement. Students also want to perform exercises correctly and see improvements, but they also want to enjoy these exercises. So the questions are: How to make sure that the student is doing the exercises correctly? How to ensure progress in a fun way?
9. Explanation of configuration possibilities within singing domain: 5 mins
10. **Activity 3 (15 mins) Personalization:** What would you want to change to personalize the breathing game - i.e., make it your own, or specific to the student?
11. Putting it all together - open discussion (20 min): Each team gets 2 mins to discuss their best ideas. After that Open discussion on some specific ideas, what each group likes, etc.
12. Wrap up (2 mins)

After the session was complete, the co-design session Mural that was produced is as shown in Figure 36. The Mural in itself provided an organized view of the Participants' thoughts. With the help of that, notes about outcomes from all activities in a text document (link in appendix). This resulted in a list of thoughts, ideas and suggestions that resulted from the co-design session, in each area: Visuals, Audio, Personalization and Getting Feedback as per each activity. In addition to that, upon revisiting the video of the session, there were a few more ideas added to these lists. The video also helped to provide the reasoning behind the thoughts and ideas of the participants. Using these lists and the video, we formulated some requirements for a breathing exercise game for singers, putting the ideas and suggestions of the participants together, with the reasoning behind those ideas, which are described in the next section.

7.2 Session Outcome Summary

The session was full of different ideas that can be merged together or even worked with separately. The ideas coming from both groups were varied. Group A had ideas that were specific, such as in Activity 1, how exactly would they want to see the in-game action that their breath causes, while Group B had more of a bigger picture, like what the game should actually be. So, we have more 'game' ideas from group B, while we have more 'interface' ideas from group A. Some ideas that both groups unanimously agreed on in the end in the open discussion are given below:

1. Game should be like Beat Saber (VR game), with both audio and video as guidance and feedback.
2. Game should not be the same with just changing difficulty. Either have a story mode or different levels with different in-game scenarios.
3. Two standout 'game' ideas were: i. An adventure game with changing scenes and tasks or a story. ii. A car game with street signs and signboards as guiding breath instructions.
4. Some standout breath visualization ideas: i. Having a musical instrument playing a song while the breathing is done correctly ii. Having sheet music notes signify rising / falling breath patterns iii. Apple watch interface iv. Colour changing to indicate strength / length of breaths

For game audio, both groups unanimously said that it would be nice to have a background rhythmic audio / music that if possible can be customized according to the student / teacher in addition to in-game sound effects that occur in sync with breath actions. An interesting idea was to use audio as guidance, rewards as well as correction, for example, rhythmic audio as guidance, adding musical instruments as the game progresses as rewards and off-notes or faulty music as correction. These are in line with the points discussed in Chapter 35.

Participants suggested that the application be a homework / online teaching application as it is not required for in person lessons because the teacher can monitor everything the student does better in person. The feedback provided via the application should be continuous in-game feedback, to ensure correctness of the exercise, as well as a post-game overview feedback page to track progress, check scores, etc. for both teachers and students. Participants suggested that if possible, it would also be nice to find a way to have the teachers present in the same game session as the student, to provide live feedback as live criticism/motivation. Apart from that, more ways of personalization were discussed, such as initial calibration as a test of breathing capability, funny difficulty level names, avatars, picking music, picking exercises and difficulties. The final outcome of the session was to have a set of requirements and game design ideas for a breathing exercise game for singers.

7.2.1 Requirements and participant suggestions

The result of the co-design session was a list of user requirements and suggestions from participants to implement those requirements. The game should:

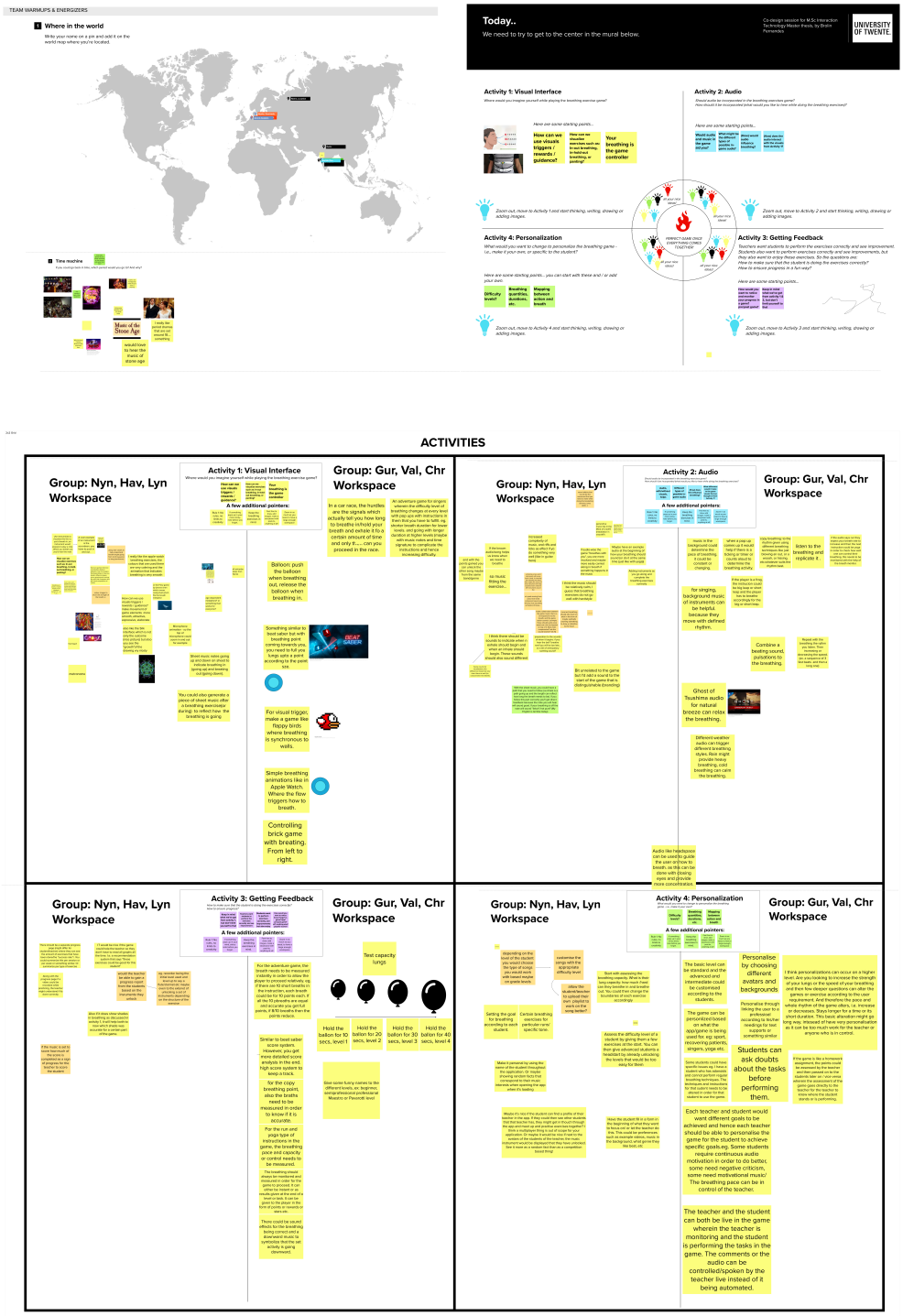


Figure 36: Final Co-Design Mural after the session

1. Be non-repetitive, have multiple/changing levels, scenes, tasks, such that players are involved and don't lose interest in the game. Reason: Players should want to regularly play the game. Doing the same sequence of events repeatedly everyday could cause them to lose interest. Making it new is interesting and also challenging. Suggestions from participants: An adventure game with changing scenes/environments and different tasks to perform like running, jumping, lighting a fire, etc.

2. Have informative visuals that are relevant to the domain in question, i.e. singing. Presence of interfaces like sheet music references, information about different beat measures like quavers, semitones, etc. Reason: These references are relevant, understandable and relatable to singers and is a good way to understand and learn these details of music for beginners. Suggestions from participants: (1) Have a visual representation of breathing in the form of moving notes in sheet music. (2) Give breathing instructions in the form of note lengths in musical terms, such as bars, quavers, crotchets and so on. (3) Use instruments to visualize breathing. For example, when the player breathes in, an instrument would prepare to play a note and upon exhalation, they would hear the note.

3. Have audio that could guide (by providing a rhythm), provide feedback (by giving audio cues of correctness and faulty breathing patterns) and provide immersion (via sound effects, breathing sounds to mimic, etc.) in the game. Reason: Will enable the player to enjoy the game and also play it well, thereby fulfilling the breathing exercises correctly. Suggestions from participants: (1) Rewards - Adding instruments as the player performs a set of breath patterns correctly and ending up with a full version of a song at the end. (2) Guidance - Rhythmic beats to help with counting the duration of inhalations/exhalations. (3) Sound effects - Breath sounds that can be mimicked, or game-environmental sounds synchronous to the breathing.

4. Music and visuals should not be harsh, flashy or loud (as also mentioned in [32]). Avoid using music like trance, EDM, hardstyle, heavy metal and avoid visuals with violence, tension, gore. Reason: Breathing is a calm process. Adding flashiness to the visuals / audio could be distracting. Suggestions from participants: (1) SilkWeave, Fischinger, Flow game by Jenova Chen, Apple watch breathing exercises, etc. for smooth visuals. (2) Audio like pop, soft rock, which have good melodies and if possible, as per the teacher / student's choice.

5. The game / application should be a homework-based application and/or an online teaching application. Reason: In person, teachers can better understand their students. However, teachers cannot monitor how their students are performing their exercises from their homes.

6. Have creative ways of guidance and feedback. Visually, as in point no. 2, have singing/music related elements in the interface, such as guiding with sheet music, or an instrument playing. With audio one could have rhythmic audio as guidance, adding musical instruments as the game progresses as rewards and off-notes or faulty music as corrections. These are in-game ways of guidance and feedback. Guidance could also be provided pre-game with instructions and trial runs and post-game with performance reviews / video feedback. Reason: Guidance and feedback are important for students to perform the exercises correctly and good feedback also acts as a motivator for students to perform better. Suggestions from participants: (1) Different colours/symbols to represent different breath strengths/durations. (2) Game scores both in terms of game performance and technical breathing exercise performance. (3) Musical cues to highlight correct and incorrect breathing. (4) Post-game video review

7. Have teachers involved in the game. Teachers should be able to solve their students' doubts via the game application. This could be possible pre-game, in-game or post game or all of these. Reason: Students often have doubts about their breathing exercises and want to know if they are performing it correctly. Teachers can set goals or even be present while the student is performing the breathing exercise to provide live and specific feedback to the student. Suggestions from participants: (1) Possibility for the teacher to be present in the same game session as the student to monitor, provide feedback, motivate. (2) Teachers should have the power to suggest breathing exercises and breathing goals in terms of breathing durations, quantities, etc.

to the students. (3) Teachers can provide feedback and tips in terms of what they are doing right/wrong with the help of their students' post-game performance analysis. This feedback could be provided by the teacher either in the next class or in the game itself.

8. It would be nice for teachers and students to be able to customize the game according to the students' capabilities. The teacher can prescribe breathing goals for the students in terms of breath durations, strengths, speeds etc according to their skill level. Students can choose whether to practice the teacher's prescription or if they need a higher or lower level. Reason: Teachers know what exercises their students need to do and at what difficulty level they need to perform it. However, it is possible that the students are not capable or more than capable of the teacher's prescription and choose whether they need a higher/lower difficulty level. Suggestions from participants: (1) Give some funny names to the different levels, ex: beginner, semi professional, professional Maestro or Pavarotti level. (2) Possibility for teachers to be able to create their own exercises.

9. Before the game begins, have a calibration "test" and a short form for the students to gauge their skill level. Reason: Every student is different, with different sizes, lung capacities and capabilities. Including a calibration step for each student would help the teacher and the student understand the requirements of the student. Suggestions from participants: (1) Test lung capacity in a gamified way, such as by measuring the amount of time a virtual balloon can be expanded with the player's breath. (2) Have the player fill out a short questionnaire before the game, indicating the player's skill level, preferred breath functions to work on, preferred music genre / artist among a select set of artists / songs, etc..

10. Have a slight social element, where the student can search for their teacher's profile / avatar and be able to view how they are performing as compared to the other students. This can be extended to any student using the application in the student's city, state, country or even global. Reason: Motivating students to perform the exercises everyday to keep up with the rest and also feel proud of their teacher's profile. Suggestions from participants: (1) Leaderboards from personal groups, friend groups, singing teacher's students, city, state, etc. to compare how the player is doing with others. Possibly chat and meet up and practice together. (2) Have an avatar or bitmoji assigned to players. (3) Assess the difficulty level of a student by giving them a few exercises at the start. Give advanced students a headstart by already unlocking the levels that would be too easy for them

A number of these requirements that resulted from the co-design session were not surprising, as they are in line with a lot of the ideas from several researches that were discussed in the Research Topics phase. Sra et. al. have provided research that shows that users could have a higher sense of presence and find the gameplay more fun and challenging when using prescribed breathing actions [45] as well as to include an informative instructional phase in the game so that players are used to having the breath sensor as a game controller. This works well with point number 1 and 8 from the above requirements list, as the combination of making the game non-repetitive and challenging combined with the presence of prescribed breathing actions could enhance the overall experience of playing the game. In Life Tree [32] and Chillfish [43] there has been emphasis given on how the breathing game should be calm, as suggested in point number 4. Vingeus studied how mimicking with breath in breathing exercise games involving PLB and interactive technology like VR can elicit immersion and breathing performance [24] as suggested in point number 3. The overarching themes of visual immersion and use of audio in different ways for instructions, guidance and continuous feedback have also previously been discussed in several research papers [32, 24, 43, 36, 4, 19, 11].

Thus, this co-design session provides further evidence and strength to the above statements from literature, forming the basis of breathing exercise game design for singers. In addition to that, the concepts of having social elements and teachers involvement for feedback, tips, instructions, etc as discussed in points 7 and 10 have not been clearly found in the literature study conducted. Suggestions like being able to customize breathing exercises

and targets for students to accomplish according the students ability, having calibration tests to test a student's breathing capabilities as shown in points 7 to 10 have not been clearly found in the literature study either. The game audio and music related suggestions from the participants are in line with those suggested in chapter 6.

As per inputs and suggestions from the participants, we have been pointed towards a basic idea of what singing teachers and students would like to have in the breathing exercise game. Using these ideas, we need to understand which ideas suggested by the participants of the co-design session could be feasible in a technical sense and in combination with each other, also keeping in mind the scope and time limitations of this project. This was done by personally brainstorming and creating game ideas, with the help of the outcomes from this chapter. These ideas would still however be premature and would have scope for further enhancements.

8 Game Idea Formulation

After the co-design session was conducted and analyzed as seen in chapter 7, we came up with 3 game ideas to discuss with the participants. These ideas were inspired from the co-design session ideas and concepts discussed in chapters 5 and 6 before this chapter. Hence, my thought process began with the idea that there needed to be a way to include timely breathing patterns in these games for breathing exercises can be performed while playing the game, which also have an influence on visuals and music. This could be done with the help of *Beat Saber*-like games, where there are blocks strategically spawned which are to be slashed at timely instants according to beats of the music being played. Tweaking this concept, such that breathing exercises can be performed formed the basis of my thinking process to formulate gameplay ideas. Therefore, the following ideas were formulated to later ask participants what they think about them. These ideas were still brief and subject to further changes and adjustments.

IDEA 1: ROAD TRIPPER: In this breathing exercise game, players would be on a virtual road trip while performing breathing exercises.

Visuals and Audio: In the game, there would be a first / third person view of the player driving the car on the street, with ongoing vehicles on all lanes of the road. The player's inhalations and exhalations would be able to make the car maneuver through the traffic on the road and progress in the game. The traffic will have to spawn / be present at instants when the player needs to inhale / exhale / hold their breath, such that a certain breathing exercise is fulfilled. Another guidance factor for the player would be the music that is playing in the car (in-game music), the beats of which will give the player cues as to when to breathe in/out. The audio would also include different types of beats specific to inhalations and exhalations that would be synced with the music, serving as tutorial sounds, in addition to background game sounds. Also, street signs will indicate immediate and continuous instructions and feedback.

If the player breathes erroneously, the car crashes / takes a wrong turn and starts from the previous 'checkpoint'. In order to better understand the breathing exercise, there will be red traffic signals from time to time, if the player needs to catch their breath and also to understand the breathing exercise better.

Progress, feedback and personalization: From the co-design session video, two participants were discussing the possibility of being able to see their teacher showing the way to do a certain breathing exercise and the muscle movements involved in it as it is one of the most helpful ways for students to understand the exercise correctly. This could be incorporated at the red traffic signal, where there could be a video pop-up with a video of the player's singing teacher or just an animation showing the correct way to perform the given breathing exercise to come next. After the red signal, the player can then drive again with their breaths as the game control and progress further in the game until the destination, i.e., their daily goal prescribed by the teacher is complete. Upon completion of the daily goal, the score from the game will be saved to a leaderboard, where the player can compare themselves with their peers. The players would also be compelled to play the game everyday, as there will be a 'streak' that they would need to maintain (similar to Duolingo), thereby performing their breathing exercises everyday.

To make sure that there is no discrepancy in the breath input values, there will be a calibration before each game session. This can also be used as a 'test' to measure the progress of the player over time. To personalize the game for both the player and their teacher, each can have an avatar, choose how much of the game they want to play, and even select the location and time of day of their drive. They will also be able to select the song they want to practice on and unlock new songs each day. The difficulty of the exercise would increase as the player progresses in the game, however, each song would have a fixed set of breathing exercises. The teacher's breathing instructional videos would add a more personal touch to the game. There could also be a doubts forum in the game where teachers and students can comment.

IDEA 1: RoadTripper

Breathing exercise game for singers where the player is on a virtual roadtrip while performing breathing exercises

1. Based on the Co-Design Session Activities, here's the explanation of the game:

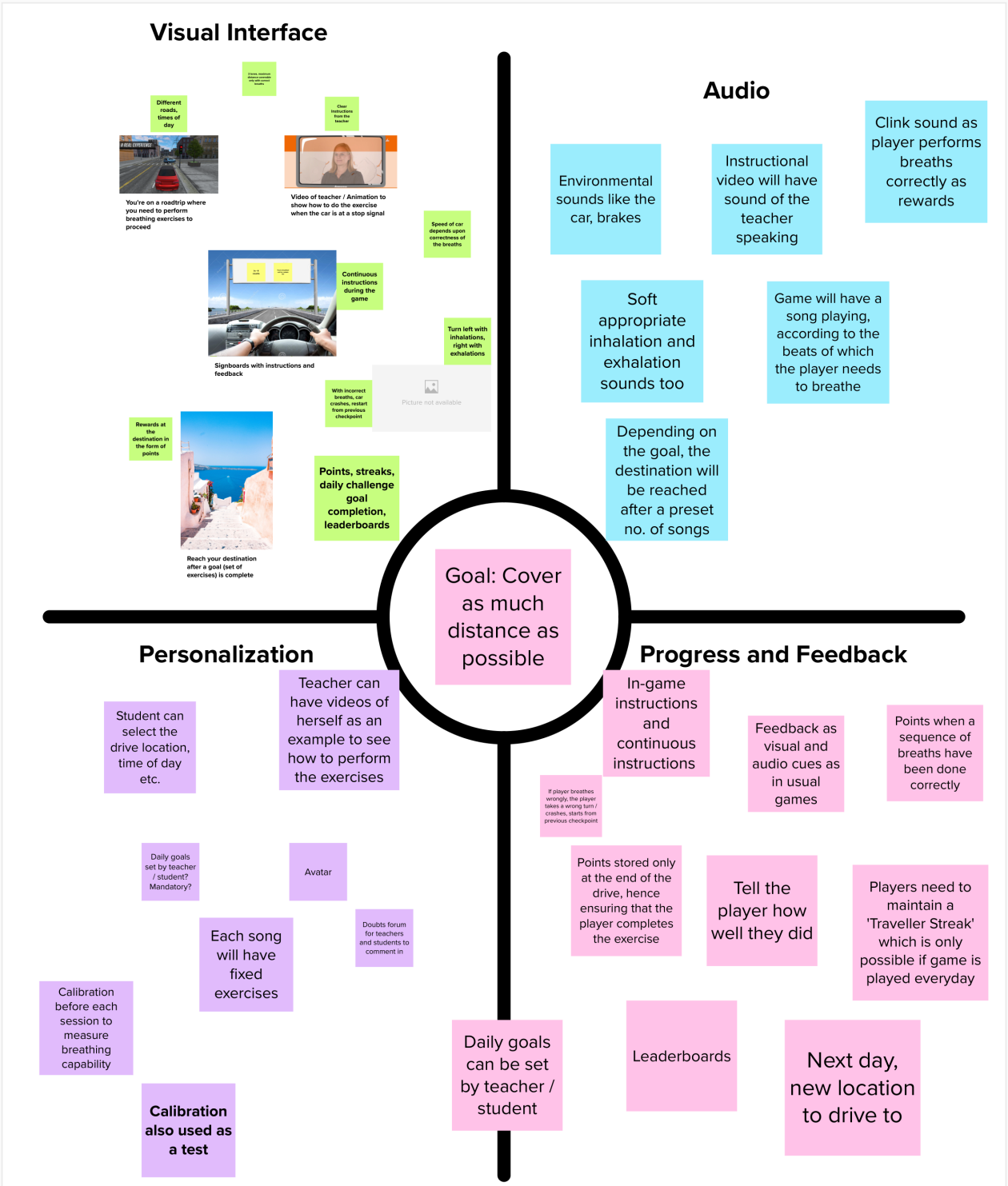


Figure 37: Mural with summary of idea 1

IDEA 2: BAND OF BREATHS: In this game, the player uses their breaths to make a band performance complete.

Visuals and Audio: Initially, the game will begin with the player choosing a song to practice breathing exercises on. A musical instrument (eg: piano) will be present on a stage in the game. As the player keeps performing the breathing exercises correctly, more instruments (guitar, drums, vocals, etc.) will be added to the first instrument, one by one, thereby making the song sound complete. Visual guidance could be given in the form of generic game guidance concepts like arrows or something similar to the Apple Watch breathing exercise interface. Audio guidance could be given in the form of soft, appropriately timed inhalation and exhalation sounds, in addition, of course, to the time signature that the song already provides. Rewards for correct breaths would be in the form of visuals and audio of the instruments being added to the song. There can also be more feedback in the form of musical notations to indicate that 'you have breathed out for one bar / quaver / crotchet'. If the breathing is done incorrectly, then the newly added instruments won't get unlocked or would get unlocked with a hazy, incorrect sound from the instrument. Depending on how 'full' the song sounds, the player will get an idea of how well they've performed their breathing exercises and also about the importance that each instrument has in the song, but that's just an extra bit of knowledge.

Progress, feedback and personalization: Most of the progress and feedback is similar to that of idea 1, except the fact that there will not be traffic signals and street signs to give instructions. Instructions like the teacher's video can be given pre-game or whenever the player wishes to see it. Calibration, daily goals, streaks, leaderboards, and avatars can be incorporated in the same way as idea 1. However, an added incentive to get players to play the game everyday would be that on the next day, a new song with new instruments would get unlocked.

IDEA 3: SONG BUBBLES: In this game, the player will be able to see what part of a song they are breathing out.

Visuals and Audio: Say for example, there is a karaoke version of a song being played. The breathing exercise is such, that the player needs to breathe out whenever the singer is supposed to sing. When the player breathes out, in the game there will be a bubble blown to the extent that the player breathes out. This bubble would have the words of the song that have been breathed out in that exhalation and would also be heard along with the song. Visual guidance would be in the form of an outline of bubble size that needs to be exhaled, so the player knows exactly how much they need to exhale. In addition, there would be audio guidance in terms of the time signatures of the song being played and an underlying inhalation and exhalation distinguishing beat, similar to that of idea 1. If the player does not breathe correctly, then the bubble bursts and that section of the song would be missing.

Progress, feedback and personalization: The player can choose / unlock different instruments to be breathed out instead of vocals, in which case, there would be sheet music present in the bubbles instead of lyrics being sung. Here, like in idea 2, the player would understand the importance of a missing instrument / vocal. The rest of the progress, feedback and personalization techniques would be similar to that in idea 2.

8.1 Follow-up with Co-Design Participants

After formulating these ideas, 3 participants (1 singing teacher, 2 singing student-teachers) from the co-design session participated again in an unstructured discussion to refine the 3 ideas and if possible, select the best game idea among them. This session was also conducted on Mural as the design and brainstorming tool and Discord as the video conferencing tool. The session was recorded with the participants' consent and it lasted for roughly 40 minutes. The participants came up with some interesting inputs:

1. Among all game ideas, the idea 1: Road Tripper was the best one as it was the most engaging and has most

IDEA 2: Band of Breath

Make a band performance complete by breathing correctly. Exmple song: Hey Jude

1 Based on the Co-Design Session Activities, here's the explanation of the game:

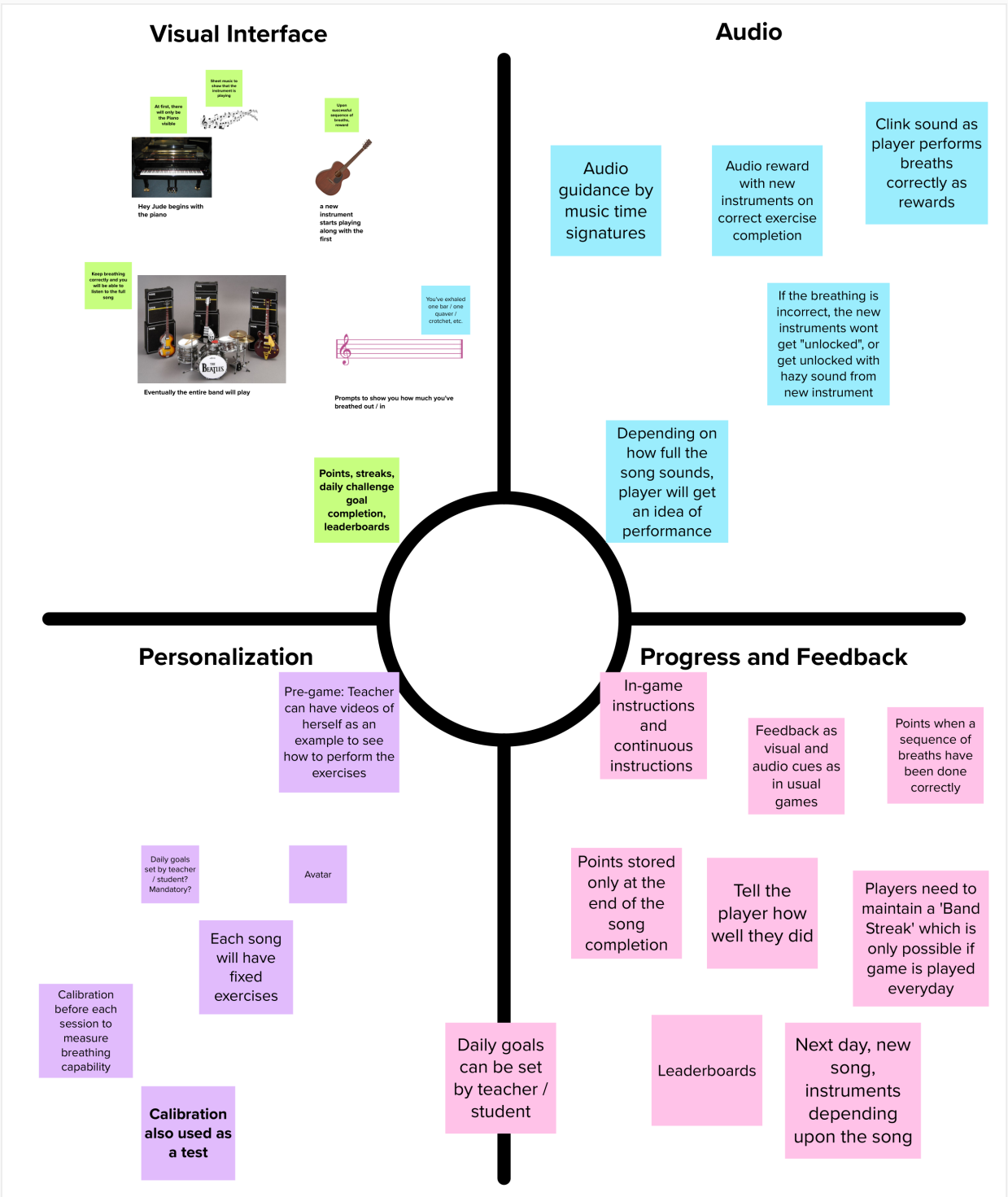


Figure 38: Mural with summary of idea 2

IDEA 3: Song Bubbles

Look at what part of the song you're breathing out

1

Based on the Co-Design Session Activities, here's the explanation of the game:

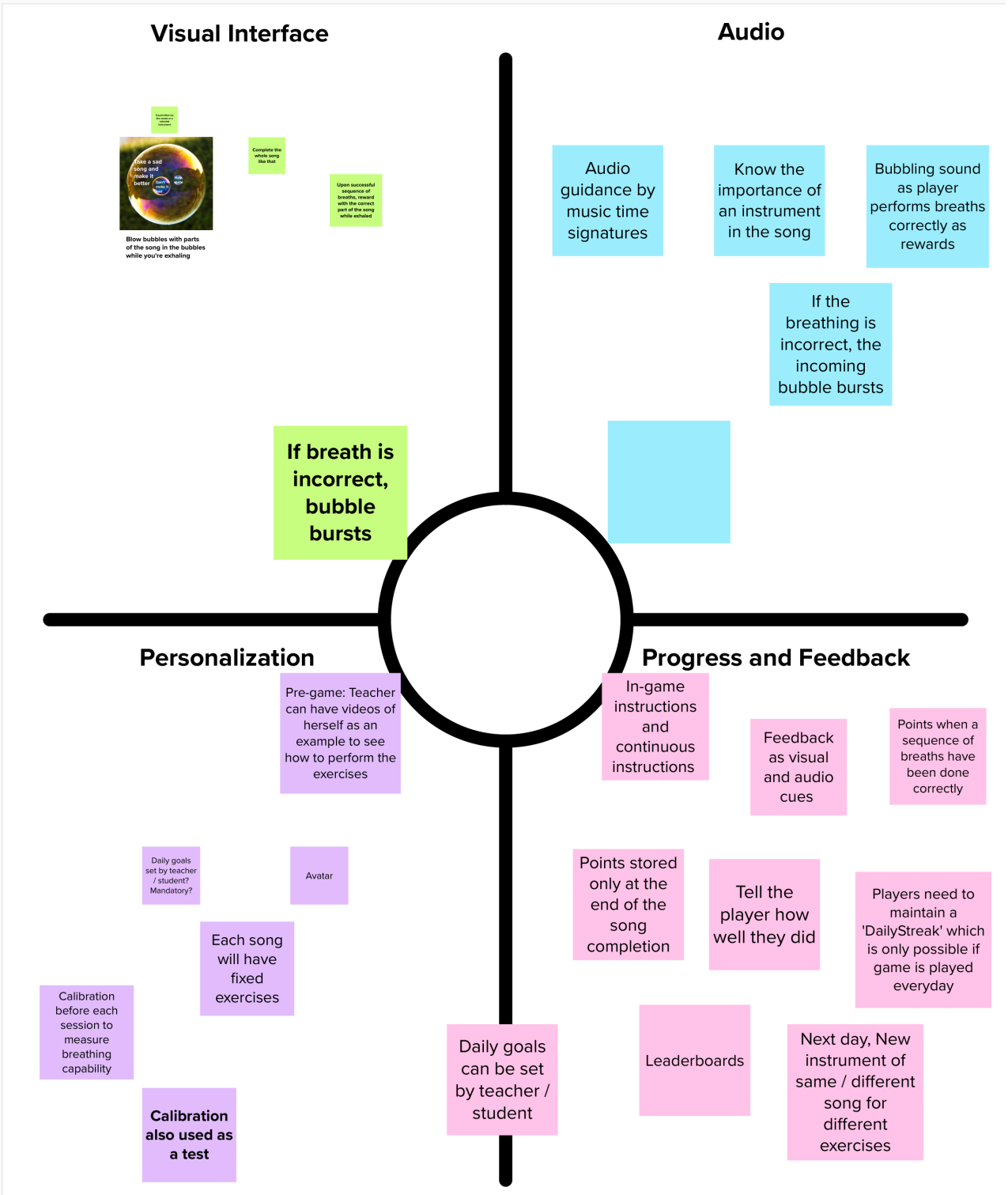


Figure 39: Mural with summary of idea 3

co-involvement of the teacher and the student.

2. The game can be homework based and it's nice if the daily / weekly goals for the student are set by the teacher. The teacher can do this goal setting task in the last few minutes of the class.

3. Every day that the streak is being maintained unlocks a new scenery to drive in. If on a given day the streak is broken, that particular scenery would not be unlocked

4. Ideas 2 and 3 are also interesting, but less challenging as compared to idea 1.

5. Ideas like idea 2 and idea 3 can be used as rewards / bonus levels at the destinations in idea 1. This would make the idea 1 game even more engaging as players would want to see what they get at the end of the drive. For eg: it would be like having a song to practice breathing while driving in idea 1 and then reaching a concert and seeing the band perform (like in idea 2).

6. Have a short tutorial before the game begins to show how inhalations and exhalations will affect the game.

With all of these inputs and ideas, we could now start building prototypes for breathing exercise games for singers. This would include creating audio and music for the prototypes via the *Reaper* DAW and creating a game prototype on the *Unity* game design engine. These are explained in the upcoming chapters.

9 Music and Audio for the Prototypes

It has already been established in the co-design session outcomes, research topics [12] as well as other breathing exercise game research [4, 24, 32], that music has a major role to play in breathing exercise games. We have already discussed in chapter 6 how audio and music can play different roles in music. Since music is such an integral part of this project, a song needed to be selected for the game prototype(s) to serve as an example of its usage. In the co-design session, it was put forth by all participants that the music selection in the game should be done by the player, as they might like it better. This is also suggested in section 6.1 of this report, where we talk about literature that supports this suggestion. The song selected for this purpose was *'Hey Jude'*[11] by *The Beatles*, since it has a simple beat pattern (4/4 time signature) that we could use to incorporate more than one exercise in and also because it is a song that I would choose if I were the user of this application. This song, therefore, fulfils the music-related requirements from section 7.2.1, about it being of the user's choice, providing guidance with a rhythm, while also being pleasant and not too flashy. As also suggested by [4], the sounds made by collectible items as well as other in-game sounds and visuals would be better understood by players if they made sense musically. This timely spawning of game-objects in the game depends upon the beats per minute (bpm) of the song. For ease of game sound design and coding, it was important that the song contains a constant bpm. However, in popular songs like *Hey Jude*, the bpm slightly shifts from a certain number as they are generally not recorded with a metronome. So, I attempted to recreate and record all parts of the song - lead vocals, background vocals, piano and guitar with a metronome (72 bpm) as reference, while making the drum beats via an online drum beat generator[12]. The song, at a constant 72 bpm, was put together on the *Reaper* Digital Audio Workstation. Since every part of the song was recorded separately each part, i.e.. parts of vocals, background vocals, guitar, drums, piano, metronome, are also separately available to use in the game, as seen in Figure 40.

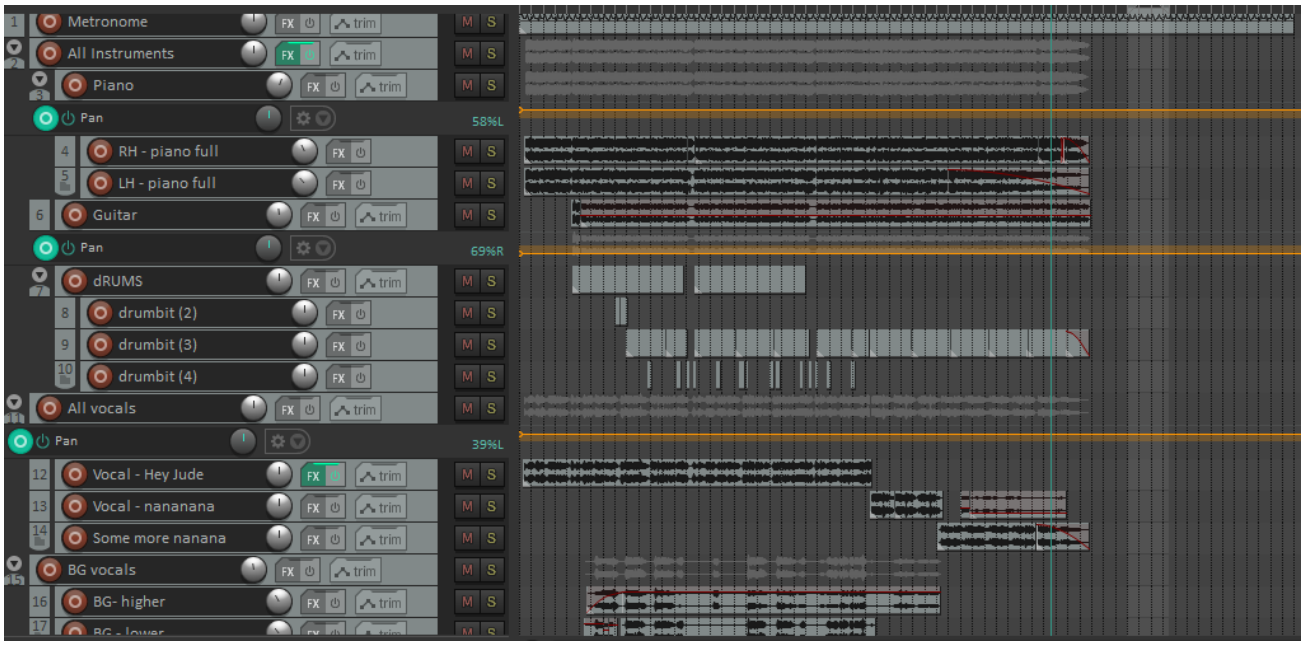


Figure 40: Hey Jude Reaper Project Screenshot

This recording of the song *Hey Jude* was used in the games created as background ambient music, to provide a rhythm and also as feedback. The metronome click track is used at times to help provide a rhythm along with the song and separately as a tutorial sound. In addition to these sounds, there are a few more sounds used in the games, that have either been recorded, created via an online beat generator or created on *Reaper* using their in-built MIDI keyboard. Inhalation and Exhalation sounds were recorded in order to provide timely tutorial sounds

[11] Beatles. (1970). Hey Jude. New York, N.Y. :Apple

[12] https://drumbit.app/

such that players can mimic these sounds with their breath. Drum sounds like bass drums, crash cymbals and reverse cymbals were generated online. These can provide positive and negative feedback to the player, when the sounds are played at the correct instants in the game, according to the song. In a similar way, MIDI chords generated on *Reaper* can also be used to provide feedback. An example of possible audio influence in the game is shown in Figure 41. Here, we see that the song *Hey Jude* is constantly being played along with a metronome. When the player is supposed to inhale or exhale, there are the respective breath-sounds being played, as tutorials, such that the player can mimic these sounds. As seen in the figure, these sounds are always at beat 1 according to the song, meaning that the player needs to inhale / exhale at those specific points, alternately. The topmost dotted block in the figure show the drum sounds in the game that are also at instants that musically make sense. The bass drum is at every 1st beat, while the crash cymbal is at every 3rd and 4th beat of a bar. If these drum sounds are made at the correct instants, that means that the player is performing their breathing exercise correctly. The red colored crash and bass sounds show badly timed sounds, which would indicate that the player is not breathing correctly.

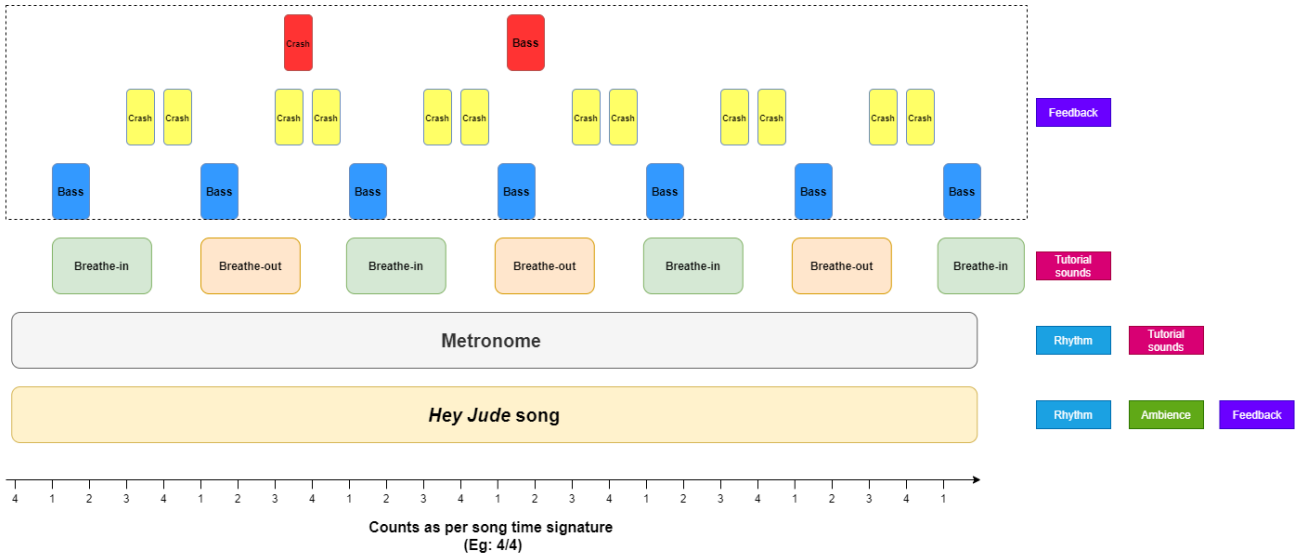


Figure 41: Example of possible sounds in a game and what roles they can play

With the help of these created sounds, it is possible to design breathing exercise games on Unity in synchronization with visuals. With appropriate timing and volume adjustments of sounds and music in the game, we can try to use audio as ambience, feedback, provide a rhythm and provide tutorial sounds, as explained previously in Chapter 6.

10 Creating Prototypes

In this chapter, we take a look at what prototypes for the breathing exercise games for singers were created, how they were made and the reasoning behind the choices made in the prototype creation. Due to time constraints in the Master thesis, these prototypes show bare minimum functionality such that we are able to understand how to create breathing exercise games using the *Breathline* breath sensor to control games, which have features like visuals and audio that can be added and modified according to chapters 5, 6 and outcomes from chapter 7. Further possible improvements to make it a minimum viable product can be done in the future, as discussed later in chapter 14. To create the interface for the game, *InVision Studio* was used as an application design prototyping software and to make the gameplay, *Unity* was used as the game design platform. These are explained as follows:

10.1 Game 1: Breath Slasher

In order to get used to the functionality of timely spawning of gameobjects, adding different sounds at appropriate instants according to the visuals & music in the game and to be able to achieve in-game sensor input, we first decided to make a simple game with primitive game objects. Hence, the game 'Breath Slasher' was created keeping the *Beat Saber* game in mind as a point of reference, to illustrate the possibility of having working breathing exercise games created. In this game, two breathing exercises were covered. These are 'panting', which is an inhalation followed by a series of exhalations and 'in-out' which is an inhalation and an exhalation for a specified number of counts. *Hey Jude* is the song that plays from the start of the game, immediately after a metronome cue or countdown of 3 counts. For the game-objects used in this scene, standard primitive shapes such as cubes were used while the lights were taken from the 'Standard Assets' Unity asset. To make the game aesthetics slightly more appealing, some shaders were used for special effects like those seen glowing around the cubes in figures 43 and 44, from the Unity asset called 'Special FX Shaders'. There are also musical notes used in the scene from the Unity asset, 'theNotes'. For the background in the scene, the material of a large cube was changed to a 2-sided material, to give the look of being inside a room, similar to *Beat Saber*.

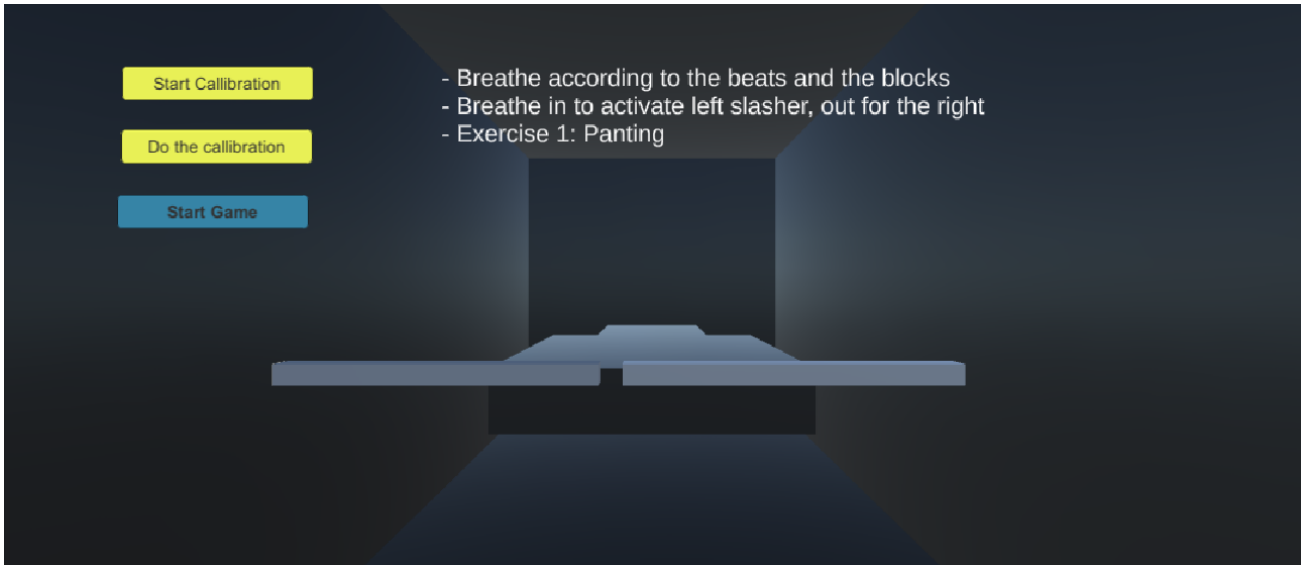


Figure 42: Breath Slasher initial screen

In Figure 42, we see the two horizontal 'slashers' in the scene. The left slasher is activated when the player inhales, while the right slasher is activated when the player exhales. This is noticeable in figures 43 and 44. As seen in these figures, there are pink 'inhalation blocks' and blue 'exhalation blocks' travelling towards the slashers on the left and right respectively. The gameplay is coded in such a way, that if the left or right slasher is activated

with inhalations or exhalations respectively, while the respective incoming blocks collide with them, they disappear and make a sound.

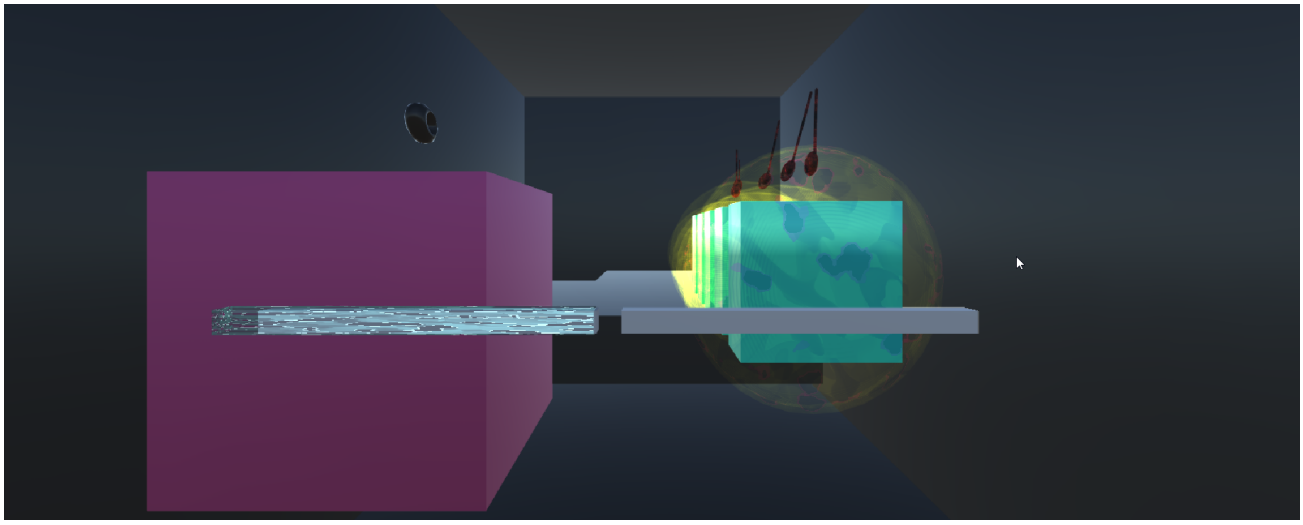


Figure 43: Upon inhalation, Left Slasher is activated

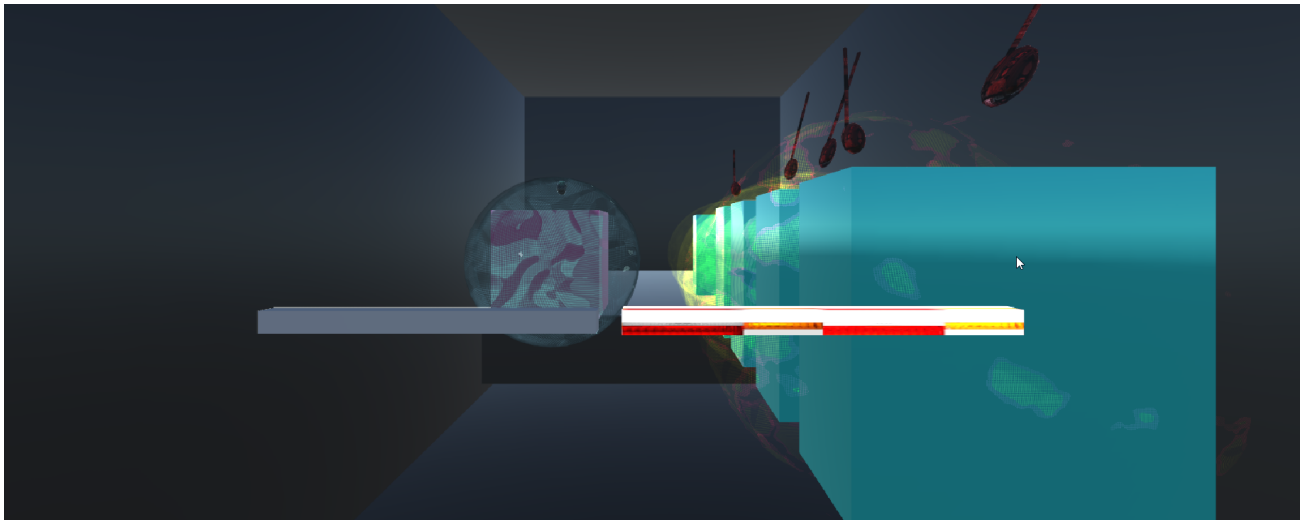


Figure 44: Upon exhalation, Right Slasher is activated

10.1.1 Block Spawning and timing

This section shows how the spawning and timing of gameobjects are used in this game and also how they can be used to make different breathing exercises, thereby enabling us to create different levels, as discussed in section 5.4. The lengths of the inhalation and exhalation blocks can be varied via adjustments made to the C# scripts used in the making of this game. These blocks spawn at instances that are on the correct beat position, as per the recording of the song *Hey Jude*. This is done by adjusting the spawn rate to (60/72) seconds as the song was recorded at a constant 72 bpm. This means that a cube is spawned at every 1/4 of the 4/4 bar. The spawn rate also depends on the size of the cubes being spawned. For example, if a cube of length 1 unit is spawned, the next cube is spawned (60/72) seconds after the first cube is spawned, while if a cube of length 8 units is spawned, the next cube is spawned 8 x (60/72) seconds after the 8 unit cube is spawned. Similarly, if an exercise requires a

certain beat to be skipped, this spawn rate can be multiplied by 2. This would make the next cube spawn after 2/4 of the 4/4 bar. This, however is not used currently in this game. Hence, the blocks always spawn at instants in the song that musically make sense for a popular song like *Hey Jude*. The spawn positions of these cubes are also such, that as they travel towards the Slashers, they collide with the slashers at instants that musically make sense. These positions were found by trial and error, by moving the spawn positions of the cubes and checking if it is at the right distance by running the game, until the right distance for timely collision was found. The movement of the cubes is done by constantly updating the transform of the cube in the forward direction, with respect to time (Time.deltaTime function in C#) and multiplying it by 2 units (speed). Therefore, the cubes travel at 2 m/s towards the slashers. This speed, found by trial and error, should work for all bpm rates, as the collision of the cubes with the slashers depends upon the spawn rate, size of object and position. Altering the speed is possible, but it would require alterations made to the sizes of the cubes as well as the appropriate objects to be spawned. For instance, if the speed is set to 1, the cubes travel only half the distance as it would if it were set to 2, and there would be too many cubes visible on screen which are very close (almost touching) to each other. Also, the cubes that collide with the slashers in one 4/4 bar would then require two 4/4 bars, thereby changing the exercise. Similarly, if the speed is set to a greater value, say 4, the cubes travel double the distance as it would if it were set to 2, and there would be too few cubes visible on screen which are far away from each other to each other. Hence, altering the speed is possible if different exercises and difficulties are required, but not performed here as these games are prototypes to show functionality.

In relation with Chapter 5, this game requires the player to inhale/exhale for different amounts of time. The inhalation/exhalation done by the player can be termed as a Single Action (SA) and since there are blocks arriving of different lengths, they require Amplitude control (A). Therefore, the GACE used in this game is SA/A.

10.1.2 Musical influence

The song *Hey Jude* is used as ambient music as well as to provide a constant rhythm according to which players can adjust their breaths, as discussed in section 6.2. Using the accurate spawning rates to our advantage, we could assign specific sounds to each cube, such that they are on the right beat, thereby possibly giving a feeling of 'reward' to the player due to the fact that they are adding to the music while performing their breathing exercise. This was achieved by playing the sound specified to each cube when the cube collides with the slasher. Since 'panting' is an exercise which has different lengths of inhalations and exhalations, this is translated to the game with different cube lengths and note types hovering over the cubes. Since the inhalation is supposed to be 1 count long, the length of the inhalation cube (left pink cube) is 1 unit, while the hovering musical note is a full note (lasts for 1/4 of a 4/4 bar). Since the exhalations are short bursts of breaths, the exhalation cubes (right blue cubes) are of lengths 0.5 units each (each lasts for 1/8 of a 4/4 bar). The notes hovering over these cubes are also shorter duration notes (quarter notes), indicating that these cubes need shorter bursts of exhalations. The inspiration behind adding these musical notes comes from the co-design session, where participants suggested adding musical notations to the game since the application is for singers. In addition to that, it could possibly also help players understand note types in music theory, if the correct note types are displayed.

We use concepts of musical expectancy and brain stem reflex discussed in section 6.4 to provide audio feedback to players. The inhalation block has a combined kick-drum + reverse cymbal sound attached to it, while the exhalation blocks have a crash drum sound attached to them. The cubes make this sound upon collision with the slasher and then disappear, indicating that the correct breath was done at that instant, thereby providing positive feedback to the player. These sounds also musically make sense, with a bass+reverse cymbal drum sound at every first beat of the 4-beat bar and crash drum sound at every half beat from beats 2 to 4 of the bar. These sounds also seem to replicate the breathing action, with the bass+reverse cymbal sound mimicking inhalations, while the crash drum sound mimicking short exhalation bursts. As negative feedback in the game, if the player doesn't inhale/exhale at the correct instants, they either will not hear the sound that the collision of the blocks and the slasher makes, thereby disrupting the pattern of sounds for that instant, or make the collision sound slightly late,

that does not make sense for a constant-beat pop song like *Hey Jude*. The problem of slight delay in sensing breaths discussed in section 4.1.2, was not addressed here, but would need to be addressed in future versions of the game.

10.1.3 More in-game features

The transition from the panting exercise to the in-out exercise is facilitated by a short video clip showing how the next exercise needs to be performed. This video could either be a recording of a teacher, or an animation, but for illustration of this possibility, I recorded a video of myself, as seen in figure 45. This would give the players a

Figure 45: Instruction video whenever required in the game

chance to understand what needs to be done in the next exercise, how they need to breathe technically, how they should feel about their body while breathing, etc. as per what the teacher wants to say. This feature was added, because of an idea that came up in the co-design session, where 2 participants suggested that they understand the breathing exercises best when the teacher shows how it is to be done and how the relevant parts of the body need to move. Also, it could be a way to have teachers more involved in the application, as also suggested in the co-design session outcomes. This break in the breathing exercise is often necessary, as suggested in initial Research Topics interviews and literature[12], where it has been suggested that doing breathing exercises for too long may cause dizziness in the players, depending on their level and breathing capacity.

After the video is playing, the game proceeds to the second exercise, which, as seen in figure 46, is an inhalation for 1 count, shown be a 1 unit long inhalation block, followed by an exhalation for 7 counts, shown by a longer 7 unit long exhalation block.

10.2 Game 2: Road Tripper

Building upon Game 1, another breath-controlled game was created. This game is something that resulted from the co-design session and feedback of the game ideas from participants, hence we stuck with the idea that the

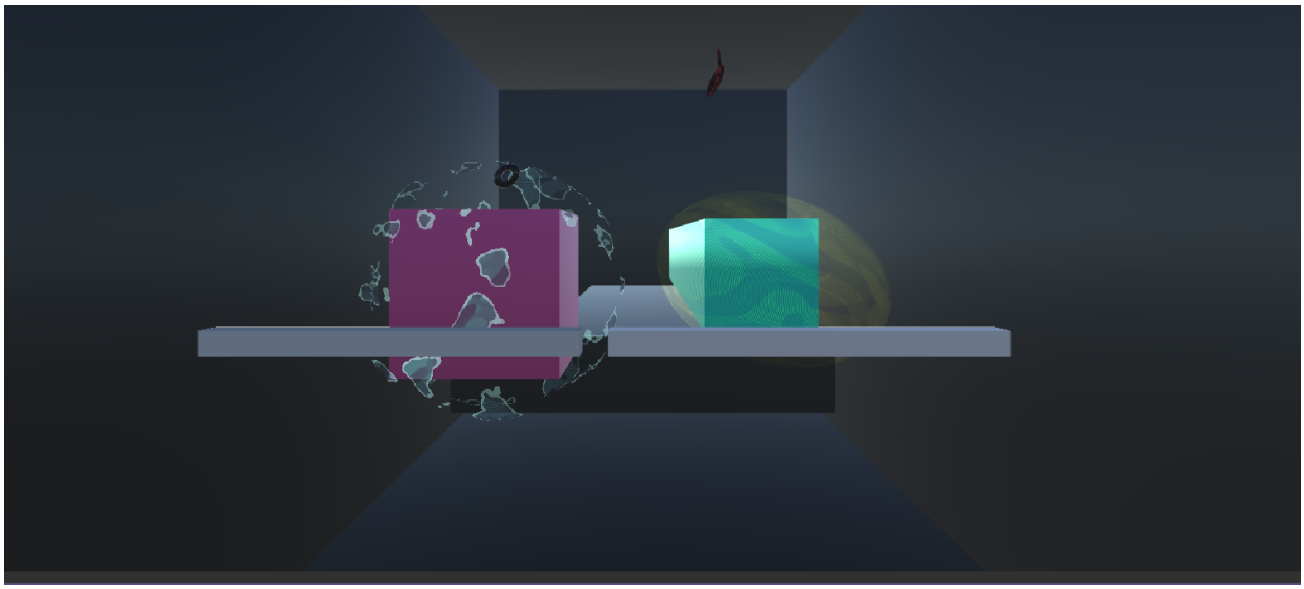


Figure 46: Second exercise after video - 'In-Out'

co-design participants liked the most. Another reason for building this prototype was the fact that we could take concepts and scripts (for example, scripts to spawn gameobjects at the right instants) from Game 1 and only slightly tweak it to make this game possible, thereby being able to build another game functional enough to illustrate the possibility of creating breathing exercise games. This would also illustrate the possibility of being able to make a different game by merely tweaking some characteristics of the game and replacing gameobjects of one game with other gameobjects, as discussed towards the end of section 5.4. In this game, the 'in-out' exercise where inhalations and exhalation counts can vary is illustrated. Similar to Game 1, there is *Hey Jude* playing from the start, with a metronome countdown of 3 counts. The scene comprises of a road, from the Unity 'Create with Code' course material, a terrain that was created on the sides of the road with the materials and textures like grass and trees used from the 'Standard Assets' Unity asset. The evening sky skybox is used from the 'AllSkyFree' Unity asset. There are also musical notes used in the scene from the Unity asset, 'theNotes'. The cars used in this project are used from 'Standard Assets', 'Vehicle Physics Pro', and the 'Create with Code' course material. There is also a traffic signal used from the 'Traffic Essentials Asset Pack' Unity asset, while UI elements like in-game instructions and score were created with the help of TextMeshPro.

In figure 47, we see a car on a road with an evening sky and a scenic terrain on either side of the road. The car is made to appear to be moving forward, by making the background and the road move backwards constantly. Hence the car is stationary along the forward axis and can only move horizontally. Upon inhalation, the car moves left and upon exhalation, the car moves right. The gameplay is such that there are obstacles in the form of other vehicles, and collectibles, in the form of fuel cans, that can spawn at specific instances on either side of the middle line on the road. Each obstacle and collectible item has a musical note hovering over it. With the help of the player's breath, the car needs to be guided through the scene, without touching obstacles and collecting all collectibles. The score in the game increases by 1 with every correct breath input on each count and reduces by 1 if incorrect. Also, if the collectible items are collected by colliding into them, the score increases by 2.

10.2.1 Spawning and Timing

Each obstacle and collectible in this game are of 1 unit length. Similar to game 1, they spawn at intervals of 60/72 seconds, thereby maintaining the timing according to the bpm of the song, with the same speed and distances concepts explained for game 1. The exercise initially is a basic 4-count inhalation followed by a 4-count exhalation. This means that there will be 4 obstacle vehicles spawning one on the right side of the road in the first 4 counts and 4 obstacle vehicles spawning on the left side of the road in the next 4 counts. Alongside that, there are

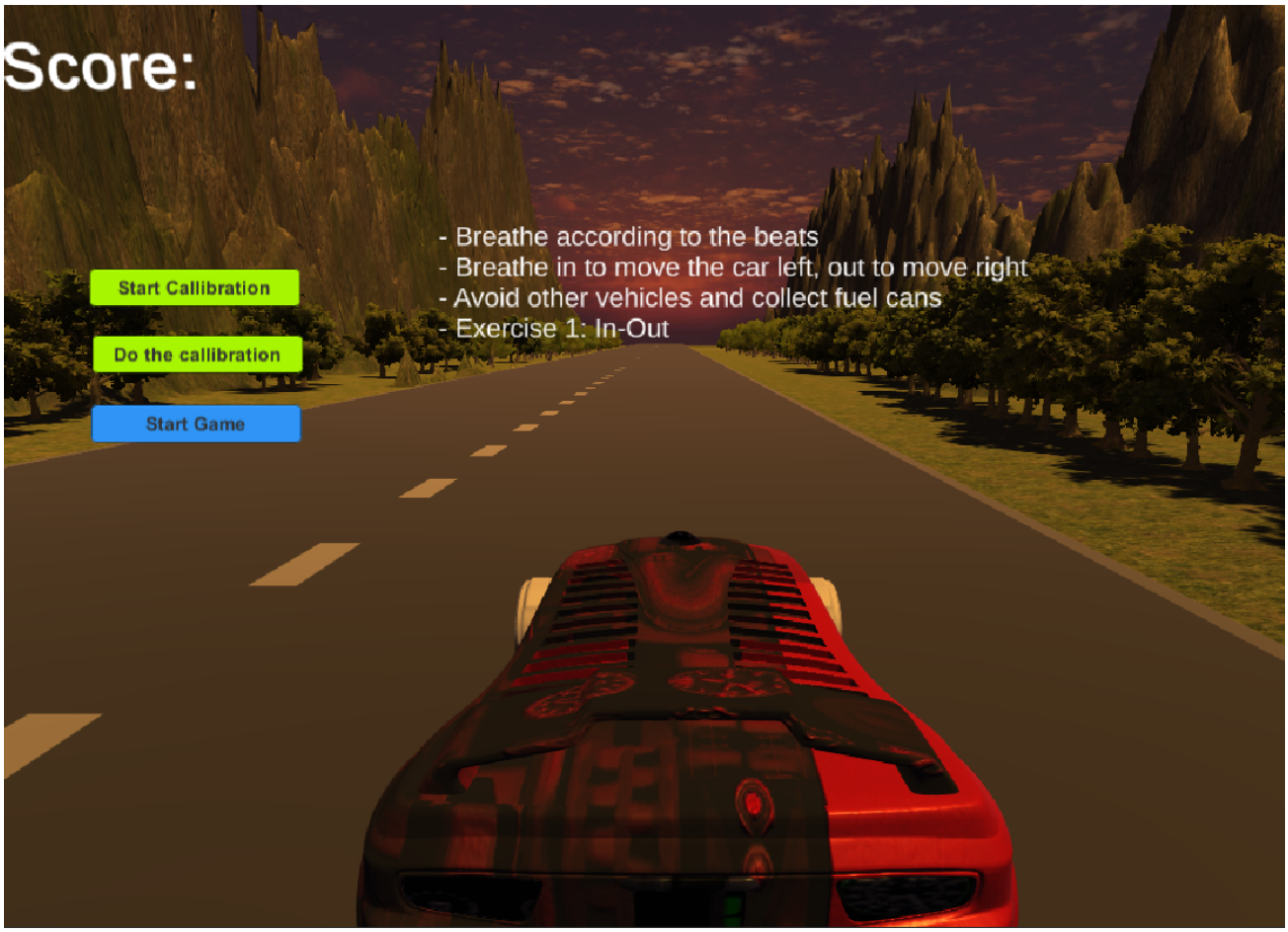


Figure 47: Road Tripper initial screen

collectible cubes spawning on the side of the road opposite to that of the obstacles on the third and fourth beat of each 4-beat bar. This is illustrated in figure 48. This spawn timing means that the player needs to breathe in for 4 counts in order to avoid the obstacles on the right and then needs to breathe out for 4 counts to avoid the obstacles on the left. If the player does so, the collectible items will also be successfully collected, thereby boosting the score.

In relation with Chapter 5, this game requires the player to inhale/exhale for different amounts of time, which controls the direction in which the player moves (left/right). Since the car needs to uniformly and continuously move from left to right or right to left, it depends on the inhalation/exhalation done by the player. Hence, it can be termed as a Continuous Action (CA) which requires Direction control (D). Therefore, the GACE used in this game is CA/D. As discussed in section 5.4, the forward movement of the car here is automated, to enable the incorporation of the directional aspect of moving the car left/right. Therefore, since game 1 had the SA/A GACE, here we see how changing the GACE can lead to a different exercise and also a different game.

Figure 48: Obstacle vehicles spawning on the right side of the road at beats 1,2,3 and 4 and collectible fuel cans spawning on the left at beats 3 and 4

In addition to the spawning of obstacles and collectibles, the instructions on the top of the screen also changes on every count. When the player is supposed to breathe in, on the top of the screen comes the text 'Breathe in' with the count number represented by the number of musical notes next to it, as seen in figure 48. Similarly, for exhalations, there is 'breathe out' on the top of the screen.

10.2.2 Musical influence

In addition to just providing guidance and ambience as in game 1, we thought that it could be possible to use music as a reward too. So, the game is designed in such a way, that the game begins with only a metronome and 'tutorial'

breath sounds, i.e. the sound of a person inhaling while the player needs to inhale and the sound of exhalation when the player needs to exhale. The song *Hey Jude* also plays along with it from the start, but starting at volume = 0. The intention behind this is that the metronome and breath sounds serve the purpose of first showing players what they need to do in the game and correlate how their breathing can affect elements in the game. Also, once the player understands this, i.e. as the score increases, they can be more independent and perform the correct breaths to move the car left/right without listening to the tutorial sounds and instead listening to the music that they want to listen to, which will still provide guidance with it's rhythm. As the player progresses and the player's score increases, the volume of the song increases more and more until a limit that is not too loud and the metronome and tutorial breaths' volume decreases to zero. If the player then performs badly, the metronome and tutorial breaths slowly creep in again, while the song volume reduces. This could possibly give the player a sense that if they perform their exercise correctly, they can hear their favorite song better. We also use concepts of musical expectancy and brain stem reflex discussed in section 6.4 to provide audio feedback to players.In addition to these audio features, the collectible objects are also placed in strategic places, such that if collected properly, they make a sound at the third and fourth beats of each bar. While inhaling, the player gets to hear bass drum sounds at the specified instants and while exhaling, crash drum sounds. These are also placed at instants that musically make sense, thereby possibly giving players a sense of adding to the music. As negative feedback in the game, there are some badly placed chord sounds attached to the obstacle vehicles, so if the player's car crashes into these obstacles, there is an odd chord that is played, indicating there is something wrong that's being done in the exercise.

10.2.3 Other features

To add to the visual cues for inhaling and exhaling, there is another textual visual cue that indicates when a player needs to breathe in/breathe out as seen at the top of figure 48. This is added, with the intention that players can get accustomed to the breath controls, helping them correlate between the physical breath and the movement it causes to the car in the game. Similar to Game 1, there is a possibility to have a video of a teacher or an animation giving instructions to the player at any point in the game. Here, this is done when the signal at the right side of the road turns red, which means that the car stops there and the player can breathe easy, listen to the teacher's instructions which appears on a traffic sign and then go on with the next exercise/breathing technique suggested in the video. This is illustrated in figure 49, where again, it is a video of me, instead of a teacher or an animation.

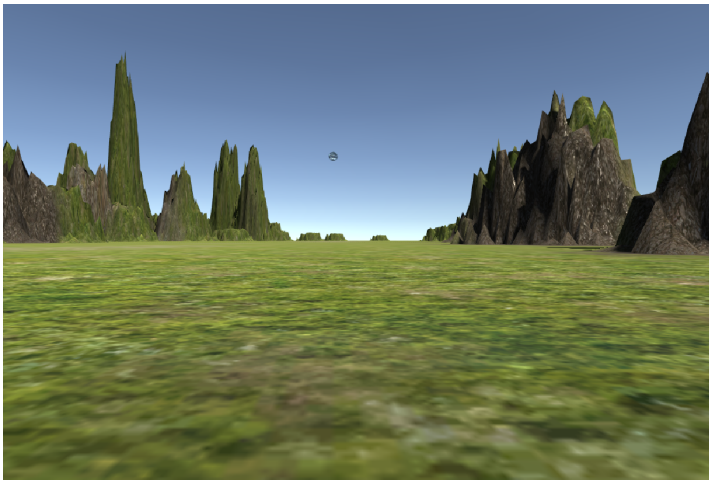
The next exercise translated to this game was in-out, but with 4-counts inhalation and 16 counts exhalation, which means that there will be 4 cars spawning on the right side of the road followed by 16 vehicles spawning on the left side.

10.3 More game possibilities

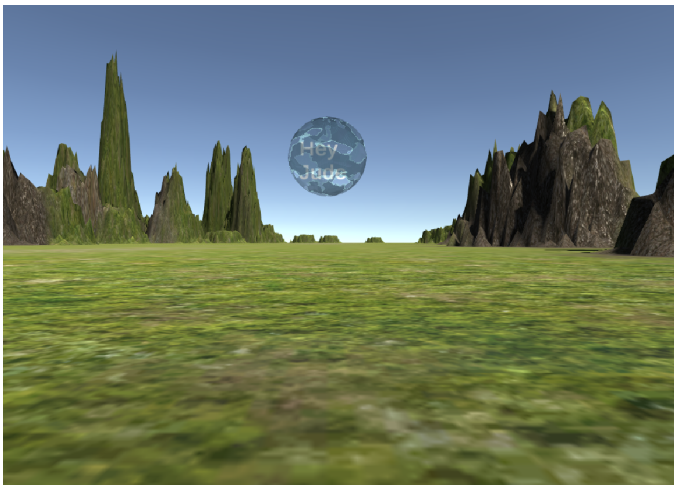
The games discussed above forms the basis of ideas like timely spawning of obstacles, making relevant sounds that sync with the song, using different forms of in-game instructions and using music to provide guidance, feedback, rewards in addition to an enjoyable ambience. However, more creative forms of games such as the 'Bubble game' discussed in the co-design follow-up session can also incorporate ideas like these in them, thereby still keeping it appealing to players. Games like the bubble game which use breathing metaphors could in fact, be better suited for breathing exercise games, as also suggested in [32, 36, 43, 45, 7]. The bubble game could work for singers as described in section 8, with spawning of bubbles, size of bubbles, having instruction bubbles and using music creatively to enhance the player's experience of playing a breathing exercise game. All of this, while having a potentially more calming visual interface of bubbles.

These several game possibilities lead to various possible settings for both teachers and students. This is possible with an application interface, which both, teachers as well as students need to interact with, to possibly get a better overall experience with breathing exercise games.

Figure 49: Red light stop signal with teacher being able to give instructions



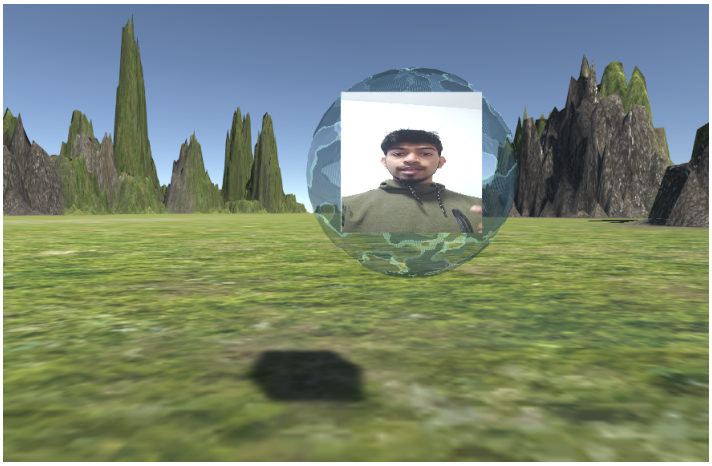
(a) Spawning of a small bubble



(b) The bubble expands

Figure 50: When the player exhales, the bubble expands, with appropriate part of lyrics

(a) Bubbles expand according to the phrase being sung and float away



(b) Possibility of having instructional video bubbles

Figure 51: Possibilities with bubbles

In the above three sections, we see how different breathing exercises in games can be incorporated in the ways discussed in Chapter 5. In transferring Game 1, which was for the 'panting' and 'in-diffOut' exercises to Game 2, which was for the 'in-out' exercise, we changed the GACE mappings and the game objects present in the game. Different levels and exercises can be set by modifying parameters in these games such as the speed, sizes of spawned objects, spawn rate etc. as well as by adding new/different functionality to the games, like blowing cubes away instead of destroying them, or affecting the forward movement of the car with breaths instead of the direction.

10.4 Application Interface

An application interface design prototype was created for singing teachers and students taking into account several requirements that were formulated in Chapter 7. This is an initial illustration that shows the possibility of having teacher-student interaction, where teachers can set exercises for their students, monitor their progress, etc., while students can also view exercises set by their teacher as further explained in this chapter. This section explains the making of this interface prototype, created on InVision Studio. The initial screens are the title screens, after which the user is asked if they are a singer, wind-instrumentalist, mindfulness seeker or any other breathing exercise domain. In this interface, only the 'Singer' button was made active as an example, as seen in figure 52. The user's profile would of course be saved and the user would not need to go through all of these interfaces every time they open the application. Note that the names of singing teachers and students are random and any personal resemblance to any reader of this report is completely unintentional.

The 'Singer' option would have possibilities for both singing teachers and students. To better understand the student's interfaces, we first take a look at what options the teacher has. Figure 53 shows the first screens that a teacher would look at. This includes a 'Hello' message, followed by a list of this particular teacher's students. There are also points that the student has scored while playing the breathing exercise game. Upon selecting a student's name ('Pol Mckenzie' in this case), the teacher can also see the level that the student is at. The teacher then has two options for this student - to view the past performance of this student and to set exercises as homework for this student in the next week. In figure 54, we see that the teacher can view what breathing exercises were done by the student in the previous week and also what difficulty level it was done at. The 'Performance Overview' card shows some statistical information about the student's performance. The image used to depict this is a random image of random statistics, but the criteria of improvement can include details like the student's improvement in inhalation capacity, exhalation duration, percentage correctness of exercise and other technical details.

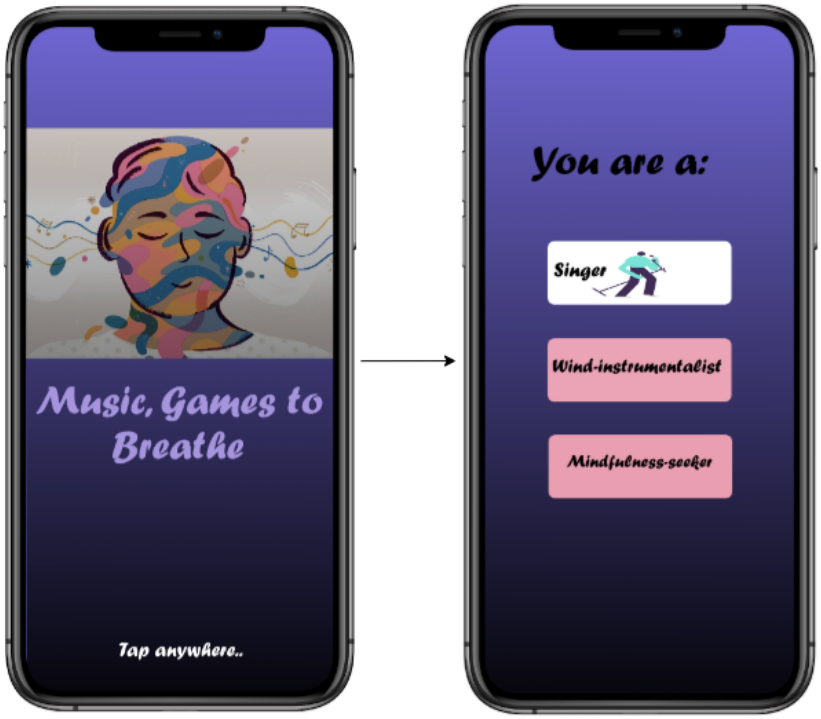


Figure 52: Initial screens

Figure 53: List of students under a teacher's supervision

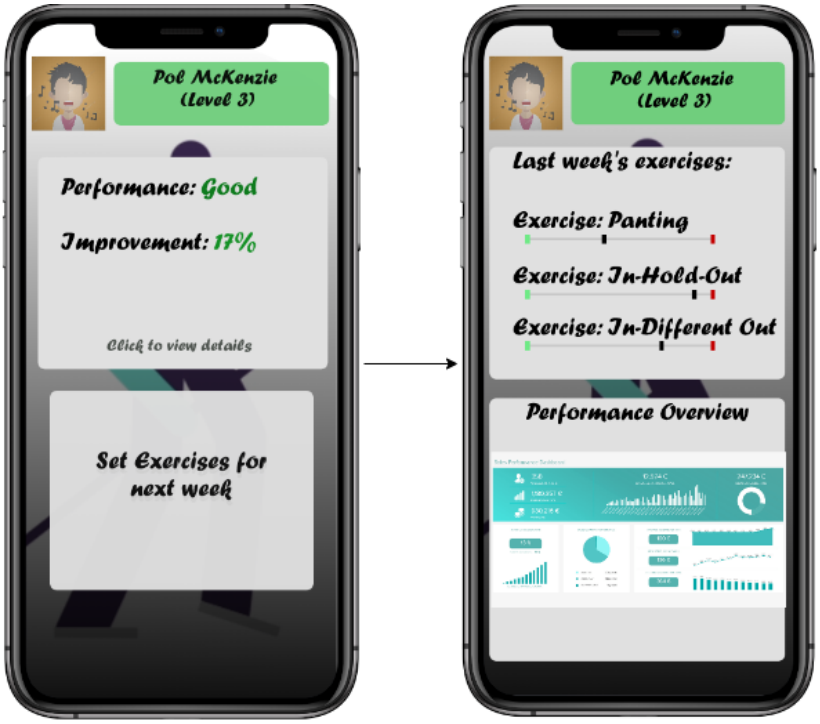


Figure 54: Teachers can see how their students have performed via the application

Figure 55 shows how teachers can set homework exercises for their students. Based on the students performance, the application suggests some exercises and difficulty levels to the teacher, which the teacher can change as per what she thinks is needed for the student. The teacher can even add or remove exercises here, with the help of the '+' and '-' signs at the bottom.

As a student, if the user is a first time user, thereby being a 'New Student', the user will be asked to make their profile, which would include general entries like their name, username, level, etc. The new student would also need to 'Look for teacher', where the student can either search for their own teacher via the search bar at the top, or find available teachers who would want to teach new students or use suggestions from the application itself, based on the student's performance and level. This can be seen in Figure 56.

A returning student's home screen would say hello to the student and show the avatar, name and level of the student. They would also be able to choose whether they want to practise breathing exercises, do the homework that has been set for them by their teacher, view score leaderboards among either their teacher's other students, class, city, country, etc. as per what the student wants to see, or view/edit their profile, as seen in figure 57. The 'Homework' button leads to the page where the student can see what breathing exercises have been set for them by their teacher and also the difficulty levels. As seen in figure 58, the student can change the exercises & difficulty levels and add/remove exercises from the list, but that is a subject of discussion and debate, if that should be made a possibility. Upon pressing the 'Go' button, the student is asked to pick a song for the game, and start the game. This leads to a 'Loading' screen which has a random trivia about the song that has been selected.

Figure 55: Teacher can set exercises for the student as 'homework' for the next week

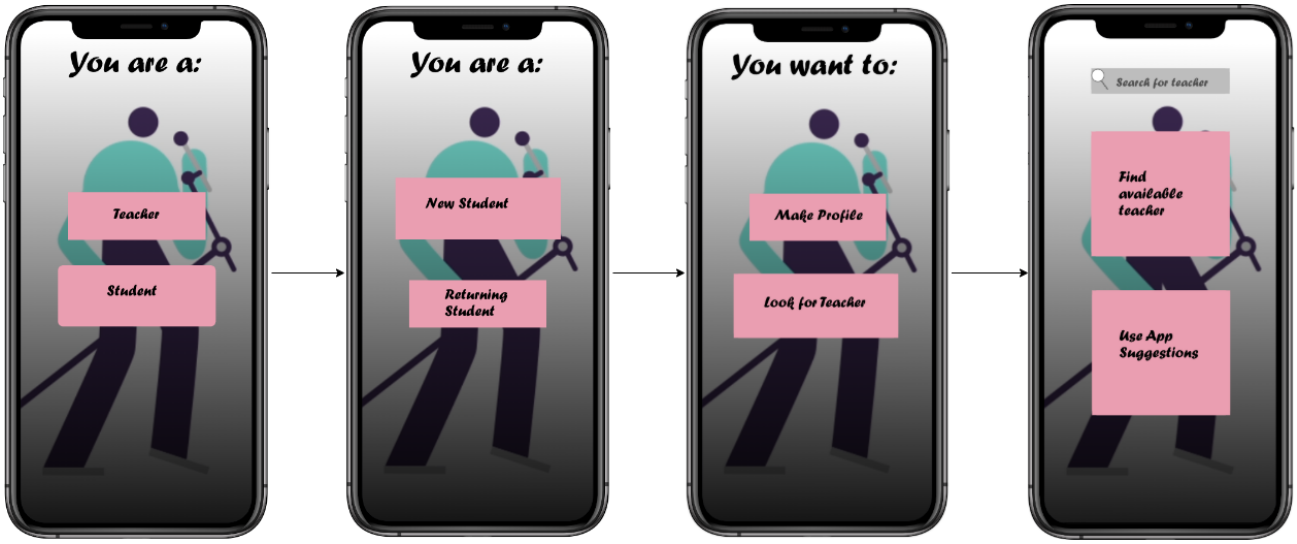


Figure 56: New students' options

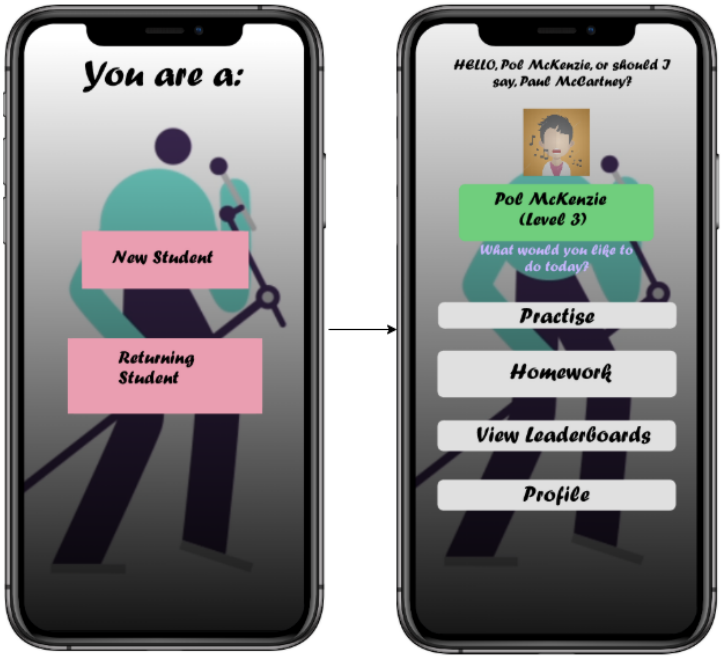


Figure 57: Returning students' options

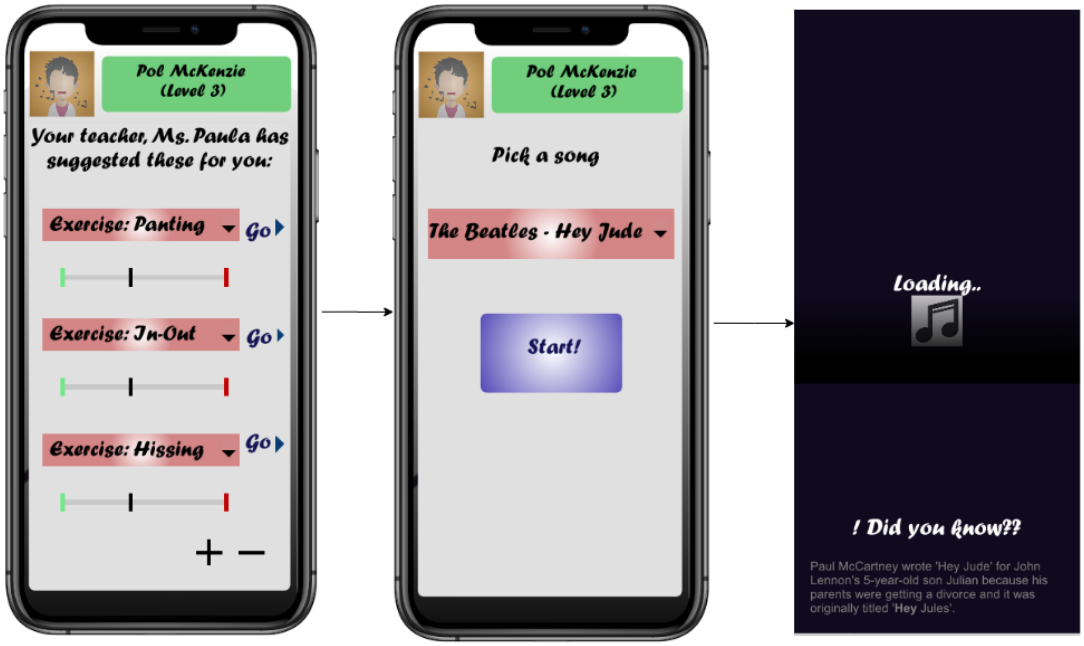


Figure 58: How a student sees their homework

This application interface simulation only consists of the core requirements before the game begins. Further embellishments and user motivation aspects such as daily goals, streaks, weekly goals, notifications, reminders, progress indicators, etc. can be developed in the next version of the prototype.

11 Requirements review of initial prototypes based on fulfilment of Co-Design session outcomes

Since the prototypes discussed in chapter 10 were built based on the co-design session requirements discussed in section 7.2.1, we reflect on how they comply with those requirements here.

Requrement 1 was for the game to be non-repetitive, have multiple/changing levels, scenes, tasks, such that players are involved and don't lose interest in the game. This is shown in the games discussed in this chapter in many ways. First, there are multiple games - Breath Slasher, Road Tripper and more possibilities as discussed in the previous sections, each of which fulfil different breathing exercises. This shows the possibility of having multiple/changing levels, scenes and tasks in the game. Moreover, as discussed in the 'Spawning and timing' sections in Breath Slasher and Road Tripper, we can also create different exercises and difficulty levels within each game too.

Requirement 2 was to have informative visuals that are relevant to the domain in question, i.e. singing. This is done in the games with the help of the hovering musical notes over the blocks in Breath Slasher and over the obstacle vehicles and collectibles in Road Tripper. These musical notes had different note-lengths as per musical theory, indicating how much a person needs to inhale/exhale in the game. However, in these prototypes there can be more detail and accuracy put into the design and usage of these musical elements.

Requirement 3 was to have audio that could guide (by providing a rhythm), provide feedback (by giving audio cues of correctness and faulty breathing patterns) and provide immersion (via sound effects, breathing sounds to mimic, etc.) in the game. This requirement is incorporated in the prototypes in several ways. The 'Musical Influence' sections under Breath Slasher and Road Tripper provide a detailed explanation of how music and audio plays a role in them, which also relates to chapter 6. The melodious nature and rising and falling sections in the song *Hey Jude* [39] give more possibilities to use the song in different ways to influence the game, but was not used to its maximum potential in the game. Breaths could be aligned to the music, for example, the 'walk down' sections of the song, (such as, 'And anytime you feel the pain, Hey Jude, refrain, don't carry the world upon your shoulders') could be designed in the breathing exercise as an inhalation before that section followed by a long exhalation that synchronizes with the melodic walkdown. Such detailed usage of music in the game can be done in future versions of it.

Requirement 4 was to not have music and visuals that are harsh, flashy or loud. The pop song *Hey Jude* was chosen here, which avoids the genres 'trance, EDM, hardstyle, heavy metal' which were discussed in the co-design session as ones to avoid. *Hey Jude* is widely known to be a "song of comfort", as quoted by it's writer Paul McCartney.

Requirement 5 suggests that the game / application should be a homework-based application and/or an online teaching application. This is fulfilled as shown in the interface design, where the teacher is able to set homework for the students, check their students performance, while the student is also able to perform breathing exercises based on what the teacher has suggested to them. Further details about how this can be used in future versions of the game can be found later in section 12.3.1.

Requirement 6 was about having creative ways of guidance and feedback. The prototypes discussed have guidance and feedback with both visuals and audio. The visuals in Breath Slasher and Road Tripper show how the blocks, obstacles and collectibles can guide players to take the right breaths for the right duration. The hovering musical notes are also intended to provide such guidance. In addition to that, in Road Tripper, there is also the text on the top of the screen indicative of whether a player should breathe in/out in the game. These visual elements a very basic illustration of how visual feedback can provide guidance and feedback. Similarly, audio also

plays a role in guidance and feedback, with the music providing a rhythm, additional collision sounds providing feedback, metronome and breath sounds providing in-game tutorials, and the volume adjustments of the song & tutorial sounds providing further feedback and guidance. More details about these aspects, showing how the guidance and feedback with visuals and audio can be improved is discussed in section 12.3.

Requirement 7 and 8 were based on having teachers involved in the game. As seen in the explanation of the interface, teachers can set homework exercises & difficulty levels for their students and also check their students' performance. Also, teachers can are enabled to give in-game feedback with the help of recorded videos as seen in the game prototypes. However, there can be more possible involvement of teachers, like solving students' doubts in the application and giving additional instructions and tips per exercise per student, as is discussed later in section 12.3.1.

Requirement 9 was about having a calibration "test" and a short form for the students to gauge their skill level. This is not incorporated in the prototypes created in a gamified way, however calibration of the device is done before starting the game in *Unity*, as seen in section 4.2. However, this can be implemented in a better way in the future by making another small game, like filling up a balloon to test lung capacity or creating a questionnaire for students to fill and using that as suggested by the co-design session participants.

Requirement 10 was about having social element, where the student can search for their teacher's profile / avatar and be able to view how they are performing as compared to the other students. This was shown in the interface, where students are able to find their teacher, or look for a teacher to teach them. Also, there is a leaderboards button shown in the screen of a 'Returning Student', however, there are no details illustrated about how those leaderboards would be and what they would be based on. An avatar is shown in the interface to give a personal touch to the student's profile, again without much detail. These features are however, not implemented in the games due to it's technical complexity, but in a future version of the game, these can be implemented and illustrated.

These game and interface prototypes gently illustrate some possibilities of incorporating various elements useful in breathing exercise games for singers, as per the co-design session outcomes. To get more details about how these elements can be further improved, we conducted another round of interviews, as discussed in the next chapter.

12 Participant feedback and evaluation

The goal of this evaluation was to get insight from potential users that could possibly provide more answers to Research Question 3, which was 'First considering one domain of work - singing, what do potential users of such a game want in it, such that the game is useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises? How can music play a role in such a game?' This evaluation could provide greater depth and detail to the requirements gained from the co-design session, thereby being helpful in future prototyping and research. For this, the game and interface ideas discussed in chapter 10 were qualitatively evaluated with 8 participants. These 8 participants included 3 singing teachers (ST), 2 singing student-teachers (SST), 1 singing student (SS), 1 wind-instrument teacher (WT) and 1 wind-instrument student (WS). The feedback was taken from each of them separately, in the form of a semi-structured interview, as this evaluation was to gain feedback and additional insights from participants, as opposed to brainstorming, which was done in the co-design sessions. All interviews were conducted online, due the ongoing COVID-19 pandemic, thereby it was safe to conduct them. All participants consented to having their interviews video and audio recorded. However, these interview recordings are only used for revisiting the user's thoughts and will not be published anywhere.

12.1 Preparation

Since the games created are still in its initial stages, videos of the gameplay for both game 1 and game 2 were recorded, along with a video me performing the breathing exercises required in the game, as seen in figure 59. This avoided the possibility of making users physically test out the games with the breath-sensor, thereby making it COVID-19 safe. Along with that, the working simulation of the interface was made and kept ready to explain to the participants. A link to the simulation was also sent to the participants before their interview, so that if they intend to, they could scroll through it and get a taste of what the application is about.

Figure 59: Snippet of video shown to participants

An information brochure summarizing in short what the project is about, what the interview would be about and how the participant's data would be used was also sent to the participants before the interview, along with a consent form, both of which can be found in the appendix.

12.2 Interview plan

The semi-structured interview was based around the following points:

1. Brief introduction of the project and what this meeting is about.
2. First explain the interface as it leads to the game. Show initial screens.
3. Show the 'Teacher' part of the interface as the 'Student' part would then be better understandable. Explain the 'Performance' and 'Set Exercise' possibilities. Come back to the 'Hello' screen for the teacher.
4. Is there something specific that the participant noticed in this screen? Any likes, dislikes, something to add or remove from it? Discuss.
5. Repeat step 4 for 'Performance' and 'Set Exercise' screens.
6. Repeat steps 3, 4 and 5 for the student screens. Show the possibilities for both a new student and a returning student and discuss details like 'should a student be able to change the homework exercises set by the teacher?' and anything else that comes up in the discussion.
7. After pressing 'Play' in the interface, go to the video of Game 1 - 'Breath Slasher'. Before starting the video, explain the basic gameplay in short, without talking much about the audio influence as rewards, musical correctness, etc. Start the video until before the in-game instruction video turns up.
8. Repeat step 4 for this part of the game.
9. Talk about how the additional sounds make sense musically. Also, about elements such as the hovering musical notes, negative feedback through audio cues. Discuss their thoughts. Explain the game elements they did not notice and understand their thoughts about that.
10. Continue with game video. Show the in-game instructional video. Discuss what they think about it.
11. Show the last part of the game, where the exercise changed according to the instructions from the in-game instruction video. Discuss thoughts, ideas.
12. Repeat steps 7-10 for Game 2 - 'Road Tripper'.
13. With the help of pictures, talk about the possibility of translating the possibilities of having audio and visual influence to games like the bubble game, which are relatively more calm as compared to the working games provided and also have metaphors related to breathing. Is there a specific breathing exercise game they would prefer? What would work for breathing exercises? What makes it better?
14. Final thoughts and closing comments.

Wind-instrumentalists were chosen for interviews because it is still the domain of music and is the most similar to singing, thereby possibly giving both similar and different views, with which we might also get an initial insight about transferability to another domain.

12.3 Outcomes

The outcomes of these interviews can be discussed in parts, by discussing different elements that participants had views about. A rough google sheet was created to organize the participants thoughts on various aspects of the game and interface. This sheet was categorized into 4 main sub-sheets - Interface, Breath Slasher, Road Tripper and the Bubble game. Each of those had columns specific to them, for example, the interface had columns about different relevant parts of the interface such as the 'Performance' screen that the teacher can see, the student's 'Homework' screen, etc., while the 'Road Tripper' game had columns about 'collectibles', 'song volume adjustment', etc. All participants' views were filled into these sheets per participant, after revisiting the recorded videos of the interviews, to ensure that no important detail from them is missed out. The link to view these sheets is available in the appendix. The segregated categorical information from these sheets helped me get the following outcomes from each part of the discussion with the participants. After discussing each point, i.e. each part of the games and interface, we will see some 'Notes', that would bring together the participants' views, to suggest what we found interesting among the thoughts and ideas of the participants that could be incorporated in a future version of them.

12.3.1 Interface Simulation

Here, we discuss various aspects from the basic interface created for the breathing exercise game for singers. This could provide more specific details about the inclusions/exclusions of what should and should not be there in these games, after initial pointers gained from the co-design session. The outcomes discussed here are indicative of the 'ensuring regularity' part of RQ3.

Teacher's options and possibilities

All participants were of the view that the interface for teacher is simple and easy to understand, the possibilities that it has are adequate, at first glance. One participant (1WS) suggested to have an additional button to be able to see what homework the teacher has set in the past, so that the teacher can set the same homework with/without minor changes again for the same person or for someone else. 4 participants (2ST, 1WT, 1SS) suggested that it would be nice to categorize students based on their class or level, instead of ranking them based on their score. This is because ranking students based on their score might not be an optimal way for a teacher to get the right knowledge of the student's situation. They suggest that for a teacher, it is important to see the progress of each student individually and not how they compare with one another. "I don't care so much about the rating of each student in comparison to the other ones. I wouldn't mind who is the best, just that there are my students and he has done his homework with so and so exercises. (Comparing scores) is more of a fun part of the game. I'm more curious about their individual progress" - 1WT. 1 participant (1SST) suggested that there should be some "teacher's notes" for each student, if they want to make a note about anything specific that a student needs to work on. Another participant suggested that it would be nice to see if the student has played against other students, just as an additional aspect to the game. 1 participant (SST) suggested that there should be some "teacher's notes" for each student, if they want to make a note about anything specific that a student needs to work on. Another participant (SST) suggested that it would be nice to see if the student has played against other students, just as an additional aspect to the game.

Notes for future version:

1. Teachers' involvement in the application should stick to checking performance of their students and setting homework exercises for the next week. This keeps the application simple, easy to use and adequate from a teacher's perspective.

2. Teachers want every student of theirs to practice and improve, without bias. Hence, providing a list of students to teachers based on scores, where students are compared against one another is not relevant to teachers. Instead, students can merely be segregated according to which class or level they are currently at.

Being able to see student's performance

6 participants (3ST, 1 each of SST, SS, WT) suggested that it would be helpful for teachers to see technical details about what has improved in the student, such as breathing capacity (informative and fun to know), exhalation duration, percentage of exercise done correctly, information about whether the student is adequately using their diaphragm, and regularity of performing exercises can be shown on the performance overview screen. This is because, based on this information, the teacher can set difficulty for next lesson as well as be able to understand what other exercises the student can do as homework for the next lesson that are appropriate given the improvements of the student. 1 of these participants (ST) said that it is not only useful to see these characteristics, but also "fun to know" about them. 2 participants were unsure about how useful this performance analysis would be and suggested that these statistics should be at a minimal. One of them (WS) said that it would be too much information to take in for the teacher, while the other (SS) said that the teacher would know about the improvement anyway in the next lesson, like in traditional teaching methods. 1 participant (ST) also suggested that there can be more details in the form of questions that a student has answered, such as: How natural does the breathing feel? There were more suggestions on how to view the performance. These include a comparative analysis in the form of graphs that show the performance of students in the game and translating the game levels into technical details.

Notes for future version:

1. Show statistics of player's performance to teachers. This could be not only be helpful for teachers to understand their students' capabilities better, thereby suggesting appropriate exercises for the following week, but also be just fun to know.

2. Some useful factors of students' performance are - breathing (inhalation) capacity, exhalation duration, percentage of exercises done correctly and how often the students are doing their exercises. Such details calculated and stored with the help of the *Breathline* sensor, analyzed and displayed in the application.

3. These statistics could be made even better with comparative analysis of how the students have been performing on a daily/weekly/monthly basis. Seeing their improvement over time could bring satisfaction to the teacher as well as provide motivation to students as "seeing improvement in oneself is a great motivation" - 1ST.

Setting homework exercises for the following week

5 participants (2SST, 1ST, 1SS, 1WT) suggested that in addition to having the exercises and difficulty levels, there should also be a way to type in specific notes for the students for each exercise, as teachers would like to give specific instructions and tips to students personally, based on what they know about the student in-person. 6 participants (3ST, 1SS, 1WT, 1WS) suggested that since teachers like to be creative and give personalized exercises for their students, there should be a 'create your own exercise' option for teachers, where they can specify details of the exercise in it like number of counts in/out, technique, etc. Teachers can make use of this feature in case a certain exercise that they want their student to perform is not present in the extensive list of exercises that the application would provide to the teacher to choose exercises from. One participant (SST) that instead of a 'make your own exercise feature', a teacher should just be able to describe their exercise in the application and the application (or its creators) can make it automatically. The 2 participants (2SST) who did not like the idea of creating their own exercises said that it would be too much work for teachers, especially considering the amount of workload that they have. About that, one other participant (SST)suggested that if almost all exercises are present in the drop down list and if they are editable with respect to difficulty, then there might not be a need for teachers to make their own exercises, but it is still a good option to have. 3 participants (1ST, 1SS, 1WT) pointed out the fact that they would like to see details about the exercise that they are setting as homework. A mere slider is not enough to understand the level and there should be a way to know what a given difficulty level indicates in terms of inhalation capacity, exhalation duration and any other technical details relevant to the

given exercise. Suggestions for this include having a 'Details' tab in which these details will be visible, setting the level that a student should reach in a given week - each level indicating what technical details it corresponds to.

Notes for future version:

1. Add a place for teachers to provide notes to the students, per student and/or per exercise. This could be helpful as teachers can give specific tips to each student as they know their students the best with their in-person interaction and understand their needs.

2. Make the list of exercises extensive enough for teachers to choose from and assign homework for their students. This would be even better if the list can be filtered according to the goal of exercises, such as 'Increasing exhalation capacity', 'phrasing', and so on.

3. Make it possible for teachers to 'Create their own exercise' as many participants suggested that they like to be creative and personalize exercises that they suggest to their students according to the student's capability. Although the list of exercises might be extensive enough, teachers might like the room and platform to express themselves. It could also be helpful if exercises suggested by teachers are available to view and select for other teachers as well.

4. There should be a way to know what a given difficulty level in an exercise indicates in terms of technical details like inhalation capacity, exhalation duration, etc. Some ways to make this possible could be in the form of a 'Details' tab, or by having the values pop out of the difficulty level slider when clicked.

New Student possibilities

2 participants (1ST, 1SST) suggested that there should be a 'test' for students so that teachers can know what level the student is at. 3 other participants (2ST, 1SST) suggested that there should be a possibility to check ones breathing capacity, exhalation duration, etc. but not in the form of a test, but only as a way to explore the application and keep a record of it for oneself and if necessary, for the teacher. 2 participants (1ST, 1WS) said that there should not be a test as students might not feel like the level of the test matches their level and that students should be able to enter their level themselves. All participants suggested that the 'find a teacher' button should lead to a page with a list of teachers or music schools nearby. This is because of two reasons. Firstly, it becomes a "win" for the teacher as the application advertises for the teacher as well and secondly, "finding a teacher is an art. Students really form a special kind of bond with their music teachers." For this, however, teachers would need to have the application and enter themselves as being open to having new students. 1 participant (WT) pointed out to the fact that it must be clear that the student will get a real person as a teacher while searching for a teacher.

Notes for future version:

1. There must be a way for students to measure their breathing capabilities in the game. The purpose of this could range from just initial exploration of the application, to record it over time for checking it or as a test for students and teachers to determine their level. However, since there are views in favour of all these purposes, this is still to be explored.

2. New students should be able to find their own teacher by searching for them, or be able to find a teacher/music school nearby who is also using the application. This could be an easy way for students to find teachers as well as be good publicity for teachers.

3. The application could also have the possibility to suggest exercises to the student based on how they have been performing. This, however, will need some more exploration and deliberation as it would reduce the student-teacher interaction.

Returning student possibilities

3 participants (2SST, 1ST) suggested that there must be a way for students to ask doubts to their teacher, in the application itself, as students can have doubts about their exercises during the week in between lessons with their teacher. These doubts should go to the teacher as messages and not be in the form of a forum. 1 participant (WS), however said that if a student has a doubt, they can contact their teacher externally if necessary and a doubts section is not required in this application. 7 participants (3ST, 2SST, 1WS, 1WT) suggested that there should be a possibility to compete and play games against other students at the same level, 5 of which suggested that it could be a nice motivation for students to practice breathing exercises and it is also fun. The other two (1ST and 1WS) were slightly skeptical about this, due to 2 separate reasons: firstly, it would take extra time using the application. Time, that students of music usually do not have and secondly, that the students would only be interested if they are friends in real life with other people using the application. Yet they suggested that it would be nice to have. 2 participants (1ST and 1WT) were fascinated by the avatar and said that it gives a nice personal feel to the application. The 'Practice' and 'Homework' options led to a number of different thoughts from the participants. While all participants agreed that students can practice any unlocked exercise that they want, 1 participant (SST) thought that practice should only be practise for the homework exercises, while homework should be like an "assignment" that absolutely needs to be done before the next lesson. 2 participants (1WT, 1SS) provided interesting arguments about not separating practice from homework. This is because, since 'Practice' also makes one perform the breathing exercises, this should also be counted as exercises done by the student in that week in the weekly report that the teacher gets. Quoting one of these participants (WT), "My view, as a teacher, is that practice and homework and fun is the same thing for me. I never tell my students that "this is your homework". I tell them that you can do this and this and this and this shows how you can have fun with your instrument". Hence, these 2 participants suggested having only one 'Play' mode, which has various games/levels that are unlocked, while having the 'Homework' set by the teacher also among these games/levels. This homework must however be highlighted in some way as the games/levels that "must be done" by the student during the week, so that it gives some minimum criteria and requirement for the students to practice their breathing exercises while also giving the teacher (partial) control over what the student is doing as their homework exercises.

Notes for future version:

1. The design and distinction between 'Practice' and 'Homework' should be carefully worked out. The arguments provided by some participants of not separating practice from homework seem strong. It could therefore be beneficial to have mandatory homework exercises in addition to other practice exercises that a student can do during the week, under the same 'Play' or 'Practice' mode. Under this mode, there could be levels or stars in each practice exercise (includes homework set by teacher) that players would need to attain to level up in the game.

2. Elements like avatars give a personalized touch to the game and could be likeable to players.

3. The possibility of students of the same level playing a game against one another is interesting, for motivation purposes.

4. If students have doubts about a certain exercise, it could be useful if they could ask these doubts to their teacher via this application itself, as the exercise/note to which the doubt pertains to is all at one place. This could be done by adding a 'Notes' or 'Comments' section to each exercise, where teachers can add their instructions/tips and students can ask their doubts.

Homework that the teacher has set for the student

Without taking into account the argument of combining practice and homework into one, the participants were shown a basic screen that displays homework exercises that the teacher has set for their student. 3 participants

(1ST, 1SST, 1WS) thought it would be beneficial if students can see how much of their homework they have completed, how much is remaining and also how much time is left to complete it before the next lesson. This also includes seeing which level they are at as compared to the level set by their teacher. The participants had different views about whether it is okay for a student to be able to have the difficulty levels from the homework altered, but with various considerations. 4 participants (2ST, 2SST) suggested that there must be a notification going to the teacher saying that the student has changed a certain exercise's difficulty level. 2 of these participants (2ST) said that this gives control to the teacher about what their students do as homework. The other 2 of these participants (2SST) suggested that teachers can constantly update the homework set for the student, depending on what the student changes in the game, for example, if a student completes a difficulty level set by their teacher, the teacher should be able to set new higher targets for the students during the week. The other 4 participants (1ST, 1WT, 1SS, 1WS) were of the view that neither should the homework be changeable by students, nor should teachers be bothered with lots of notifications during the week, but just at the end of the week (before the next lesson), after the student has completed the homework. This is because teachers have likely set the homework for the students after putting thought to it after considering the student's capabilities. These 4 participants say that while the teacher's set homework is left unchanged, the application should detect the level of the student automatically and allow the student to progress to the level suggested by the teacher. There must be a way for a teacher to see what exercise has been set and what has been done by the student. 2 participant (1WS and 1SST) said that it must only be possible to increase the difficulty level because some students are very enthusiastic about improving themselves.

Notes for future version:

1. A progress indicator for students would enable students to see what level they are at as compared to the targets set by the teacher as homework and also see the how much time the student has left to reach those targets set by their teacher.

2. The student being able to alter their homework would lead to complications in the usage of the application for both teachers and students. One solution to the difficulty level altering problem discussed is that the application should be able to detect the level of the student automatically, thereby enabling students to level up to the standards set by the teacher for the student as homework.

3. If a student is enthusiastic and wishes to go past the set level, they can play the game to level up further and this should also be reflected in the performance review that the teacher receives.

Other thoughts All participants were looking forward to seeing how this application shapes up and they all see potential and usefulness in it, which points towards the application being acceptable, likeable and useful. All participants liked the fact that the player can choose the song of their choice for the game, as has been discussed in previous chapters. Other than that, there were suggestions that the application should have more motivating elements such as streaks, reminders, goals, etc. that will make students want to practice daily, but with the suggestions in the above paragraphs, they believe that the application can be very useful, neat and simple to use for both singing and wind-instrument teachers and students.

12.3.2 Game 1: Breath Slasher

Gameplay visuals

Overall, all participants found the gameplay visuals interesting and fun. "Really like the game and games are the most fun way to do the breathing exercises. It makes something difficult fun!" - 1WT. "I really like the game and it can be played by anyone at any level." - 1ST. There were still some noteworthy thoughts, criticisms and suggestions that participants provided. 3 participants (1ST, 1SST, 1WT) suggested that the cube lengths that indicate the duration of the inhalation/exhalation should be more clearly visible. One suggestion (from WS) for

this involved changing the angle of the player's view to be tilted enough so that the lengths of the cubes are more visible. Another participant (SS) suggested that instead of the cubes arriving from the front, it could be clearer if they were to be arriving from the top. For this, a helpful feature included in the game were the musical notes hovering over the cubes. 2 participants (1ST, 1SST) liked this idea of having musical note-lengths indicating how much the player needs to breathe for each arriving block, but they also said that it would depend upon how much musical knowledge the player has. 3 participants suggested that these notes should be more visible to be more effective, i.e. they should be in front of the block and accurately indicate the length of breaths that the player needs to take at a given instruction. To make it clearer, 2 participants (SS and WT) suggested that there be more simple cues like textual cues indicating the duration of each oncoming block, such that the player is mentally prepared to perform the right breath for the right duration. All participants liked having these musical notes in the game, considering it is a music-based application. One participant thought that having these musical notes depict breath durations could be useful for students to understand aspects of music theory like note-lengths like a full-note, quarter-note, eight-note, etc. The wind-instrument student participant (WS) could not relate to the panting exercise as such short exhalation bursts are usually not done in wind-instrument breathing exercises. This participant also suggested that for their breathing exercises, they would prefer that inhalations would be in sync with the moments of inhalations that are actually required in the song. 2 participants (2ST) suggested that it would be helpful to have feedback about what aspect of the breathing exercise the student is doing wrong. They suggest having in-game instructions like "You are not using your abdomen" or "Breathe in deeper", etc. can be added to add more completeness to the instructions. 1 participant (ST) suggested that the difficulty of the exercise could automatically be set in-game, according to how the player is performing. 2 participants (1SS, 1SST) suggested to have more visual forms of feedback with colours, text and other ways like "something bad happens to the notes if you breathe wrongly".

Notes for future version:

1. Make the instructions regarding the duration of breaths visually clear. This could be done in the form of textual instructions that indicate how long the player needs to breathe for and/or shaping gameobjects, camera angles, etc. such that these durations are clearly understandable.

2. Adding musical notes to games for singers and wins-instrumentalists is likeable as it is related to their domain.

3. Add prompts/indicators to show what aspect (eg: depth of inhalation, abdominal activation, etc.) of one's breath is going wrong.

4. More visual forms of feedback involving colours, effects can be added to the game to improve the player's experience.

Role of audio

All participants liked the idea of timely collision sounds of cubes colliding with the slasher to make players feel like they are contributing to the music with the breathing exercise. 6 participants actually felt like it would be that way after watching the game video, although 2 participants (1ST, 1WS) were unsure and would only be able to comment on that if they tried playing the game themselves. 2 participants (1SST, 1WS) were of the view that there can be different patterns of sound instead of just the crash drum sound, that still make sense musically, to give some more variation in the game. 4 participants (2ST, 1SS, 1WT) liked the off-beat negative audio feedback, while 1 participant (WS) suggested that it might be off-putting. 1 other participant (ST) suggested that instead of having off-beat beats on wrongly timed breaths, it would be nice to also have a crackling sound that is an indicator of a wrongly done breath pattern.

Notes for future version:

1. Timely spawning and collision sounds gives good positive feedback, while ill-timed sounds gives players the feeling that something is wrong, i.e. negative feedback.

2. It is very important to ensure that the sounds that collisions make in the game make sense musically according to the song that is playing.

Video Instructions
7 participants (3ST, 1SST, 1SS, 1WT, 1WS) were of the view that an instructional video of the teacher would be a "fun, good and informative" (-SS) addition in the middle of the game. 1 of them (ST) felt, in fact, that it is the best part of the game. 2 of these participants (ST) stressed on the importance of having a break in between breathing exercises, so as to avoid dizziness, hence, the video would be an appropriate break as it provides feedback and instructions on what to do next. 5 participants (3ST, 1WT, 1SST) suggested that it should be a possibility, but optional, with animation-instructions present for each exercise nevertheless. 1 participant (SS), however, felt like a video of the teacher would be weird, both for the teacher to record as well as for the student to see. 1 other participant (WS) suggested that they would like to try this feature out in the game too, because their experience suggests that teachers do not tell students that how they need to breathe very often.

Notes for future version:

1. The video instruction feature got mostly positive views from participants, indicating that it can be useful in the game, to provide instructions as well as to give players a break from performing breathing exercises.

2. At different positions in the game, there must be default instructional animations, with teachers having an option to add a video of themselves instead of the animation.

Overall, the participants thought that functionally, it is a nice game to practice breathing, but minor details as discussed above can be improved. Also, the scene should be made prettier.

12.3.3 Game 2: Road Tripper

Collectibles & Obstacles
3 participants suggested that the collectible item collision sounds do add to the music and make the breathing exercise more fun. 2 participants (1ST, 1WS) were not sure if the collectible items are supposed to be collected or not. This means that it should be clearer that those items are indeed collectible. 3 participants (2ST, 1SST) would like the collectibles to be present at different moments that still fit the music, and not just the 3rd and 4th beats of the bar. 1 participant (WS) thought that the collectible sounds are unnecessary as it could be distracting, leaving the player wondering about what these sounds are or if these sounds are supposed to be there or not. 1 participant (WT) said that they would only be able to comment on the influence of having collectibles and it's sounds if they play the game. 1 participant (SS) thought that the late collectible sounds upon incorrectly performed breaths is a good form of negative feedback.

3 participants (2ST, 1SST) thought that the obstacles provided adequate as to what needs to be done and the negative feedback that they provided in the form of the misplaced chord sounds are sufficient. However, 3 other participants (1ST, 1SST, 1WT) thought that there must be more significance to these obstacles. 2 of these participants (1SST, 1WT) suggested that it is okay if the player car only slightly collides with the obstacle vehicles (giving the sound of a wrong chord as negative feedback), but a more serious collision, i.e. a worse error in breathing should lead to a collision and thereby 'game over', while also adding a car crash sound to it. One participant (ST) pointed out an interesting problem with the obstacles: While inhaling/exhaling, i.e. moving the player car from right to left/left to right, if the player sees that they are on collision course with an obstacle, they may stop their flow of breath and wait for the obstacle vehicles to pass before inhaling/exhaling again. This would

deviate from the main exercise, so either instruct players about that beforehand or code the gameplay to avoid such scenarios. Quoting that participant, "Make the game more about the exercise and not more about winning in the game."

1 participant (WS) felt that only one among the obstacles or the collectibles are necessary in the game as both provide the same visual instruction of moving the player from left to right or right to left. To counter that, one other participant (SST) said that both obstacles and collectibles are important because having just the cars would be less rewarding and having just fuel cans would mean you always win.

Notes for future version:

1. Contextual obstacles and collectibles provide engagement in the game. Their strategic usage could help to provide feedback, breath cues and entertainment, both in terms of visuals and audio
2. Timing of sounds at musically correct instants could add to the experience of the player, as it provides positive feedback. Conversely, incorrectly timed beats and wrong tonal features while playing the game could provide negative feedback to the player, thereby alerting them to perform the exercise better.
3. Depending on an exercise and difficulty, there could be a margin for error for players. If the player's breathing is within this margin for error, there could be smaller in-game consequences (such as the incorrect chord sound), while if the player is performing the exercise very badly, there could be larger in-game consequences (such as a car crash, game over).

Sounds - Increasing/ decreasing volumes

7 participants (3ST, 1SST, 1SS, 1WT, 1WS) were of the view that the song volume increasing and the tutorial sounds volume decreasing is a good feature, as the player can first focus on their breathing (with tutorial sounds) and then have the song to guide them after they understand the rhythm of the exercise. This feature subconsciously gives a rewarding feeling to the player that they are able to listen to the song of their choice having grown into the game. These 7 participants also thought that the inhalation/exhalation and metronome tutorial sounds are good to have in the beginning to understand what needs to be done in the exercise and them disappearing gives the player a sense of "independence" in the game. Also, the tutorial sounds reappearing upon incorrect breathing (timing) could be helpful to get the player to regain the correct breathing rhythm. 1 participant however, thought that having these tutorial sounds should be optional, while another participant (WS) found the breathing sounds annoying and would like it to be replaced by "metronome tiks for inhalation and toks for exhalation, or something like that". 1 participant (SS) however, felt that this feature would not make a difference in terms of the rewarding feeling. 2 participants (1ST, 1SS) suggested that there must be a meter in the corner of the screen to show the volumes of both the song and the tutorial sounds, which in turn is an indication of how they are performing.

Notes for future version:

1. Volume adjustments can serve as both feedback, as well as tutorials.
2. Tutorial sounds could be useful to get the player start at the correct rhythm, understand and correlate the inhalations/exhalations to its in-game function, as well as help players regain their breathing rhythm if they lose track of it.
3. Visual indications to the player about these volumes could provide additional continuous feedback about how they are performing their exercise at a given moment in time.

Instruction video

The thoughts about this were similar as in game 1, however, participants found it more appropriate in this game,

as the game came to a more natural pause with a stop signal. 2 participants (WS and SST) however said that the player must be allowed to skip this video like cut-scenes in video games, if it is not the first time that they are performing that particular section of the exercise.

More thoughts
2 participants (1ST, 1SST) thought that the additional textual "Breathe in: Breathe out" instructions at the top of the screen are unnecessary and that the cars provide enough guidance. However, the others thought that it is nice to have it as an extra guiding factor in case players lose their way and in the beginning to correlate which breath causes which movement in the car. "If you know what to do then it can still just be there, the player will just not focus on it." - 1WT. 4 participants (1WT, 3ST) thought that the notes hovering over the car are chaotic and unnecessary, while the others thought that since its a music-related game, it is nice to have. Other inputs from participants included having more visual negative feedback instead of just audio, possibility to change the speed of the car with breaths to incorporate different exercises, having motivating feedback that indicates something like, "Oh! level 3, you're doing great!" (-1ST) and having some feedback via stop signals. All participants liked the relation between breathing and driving in this game.

12.4 Bubble game and conclusive comments

All participants thought that the idea of having calming metaphors that are related to breathing, like bubbles, would be a good idea for breathing exercise games. 1 participant (SST) however suggested that, although such metaphoric games are more calming and relatable, they can be "less fun" as compared to the other games discussed. Despite talking fondly of the metaphors in games, participants said they would like to play all the games, suggesting that the differences in the games is one aspect of a breathing exercise game application that will keep it interesting and engaging. This also points reinforces the idea of configurability of game controls to create different exercises and games, as discussed in chapter 5, as participants see how different games can be made possible by tweaking different aspects of the game. The participants suggested that in the breathing exercise game application, the initial exercises that cover the basics of breathing could be games like game 1 and 2, while the bubble game could be closer to actual singing since they require the player to breathe at times that are required in the song. They suggest that the games should be driven by the goal (eg: increase inhalation capacity, phrasing, etc.) and the exercise. Having different games that have different ways of handling visuals and audio for different exercises is appealing to them, avoiding monotony of performing the same actions and playing the same game. Some participants suggested that the difficulty of the games would depend on the song chosen. For games like the bubble game, the teacher should be able to select the song for the student to practice on and not the student. Also, the application should suggest songs that fit certain breathing goals and exercises to the teacher and/or student. Teachers often find ways to incorporate breathing exercise into their student's daily lives like while cooking, etc. "but that might be less fun than in a game" (-1ST), as suggested by participants. "While working, when I decide to take a short break, I play candy crush. Instead I can play one of these games which will be fun but also helpful to me." - 1SS.

Overall, the participants liked the ideas for breathing exercise games and can see how it could be used in singing teaching. The two wind-instrument participants found the game to be very general and usable by people from their domain as well, pointing towards transferability between domains. However, this claim is not entirely conclusive, as singing and wind-instrument playing both are related to learning music, while breathing exercises in other domains like breath therapy and mindfulness are not.

13 Translation of breathing exercise games within a domain and across multiple domains

As suggested by singing and wind-instrument participants in chapter 12, the breathing exercise games created for them are very general, understandable and relatable to anybody. Hence, wind-instrumentalists, mindfulness-seekers, breath therapy patients, pregnant women, etc. can also use such games to fulfil their goals. However, there must be some changes made to them. Figure 60 gives an overview of how this can be achieved. Based on the work done in this report, we summarize and discuss this concept of transferability of breathing exercise games within a domain and across multiple domains in this chapter. We bring together concepts of altering the game controls, visuals and audio in games, so that this transferability can be made possible.

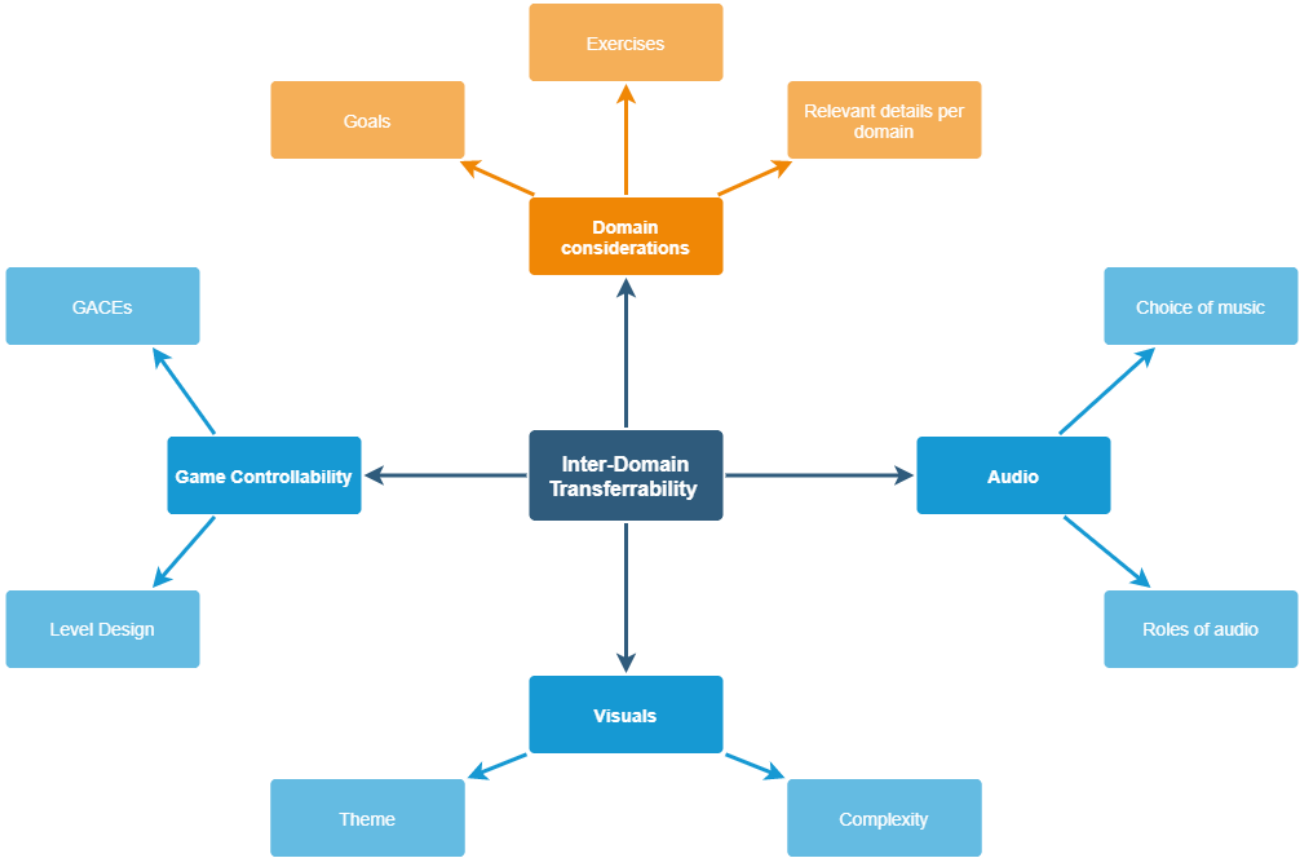


Figure 60: Overview of considerations and possibilities to make various breathing exercise games within and across domains

13.1 Domain considerations

As seen in the Research Topics [12], every explored domain that incorporates breathing exercises have both similar and unique goals and exercises. These goals and exercises are driven by details that are relevant to a given domain. For example, if breath therapy is required for a person with ADHD, that person requires breathing exercises that are simple and focused on calming the person down. On the other hand, breathing exercises for singers can be relatively complicated, to achieve several other goals like phrasing, increasing exhalation duration and so on. These details have been explored in depth for singers via co-design sessions and feedback, giving an overview of the requirements, possibilities and likeable features for a breathing exercise game for singers. In a similar manner, exploring other domains like mindfulness, pregnancy, disorders like ADHD, DMD, etc. can lead to understanding their requirements better. These domain-specific details, in addition to the specific goals and exercises present in various domains form the basis of creating breathing exercise games that can be altered to fit those domains. To

achieve configurability and transferability of breathing exercise games, domain-specific considerations need to be taken into account, after which, we have found several which can be used in combination with each other to be able to design breathing exercise games for every domain.

13.2 Game controllability

The ways in which the game can be controlled can be altered so as to design different breathing exercise games according to the requirements of the domain in question. Altering GACEs and level designs in games can lead to different controls, thereby different breathing exercises.

13.2.1 GACEs

The controls of a game depend upon the game controllers used in such games, as well as the GACEs, as discussed in chapter 5. The game controller defines how the real-world action of breathing translates to an in-game action. A breath sensor such as the *Breathline* sensor used in this project as a game controller can sense the expansion and contraction of the chest and belly while breathing, thereby giving various control possibilities by varying one's breath level. The different GACEs as mentioned in Chapter 5 can be changed in different ways, so as to create different exercises. Depending on the exercise, a game we see how a same game can accommodate multiple exercises with the example of a simple endless runner game, as explained in section 5.4. The same game action can be triggered by different GACEs, for example, a 'slow exhalation' (CA) can be used to continuously make an in-game character run, while alternatively, running can also be triggered by a 'quick inhalation' (SA), thereby enabling game designers to design different breathing exercises by changing the real-world player action that controls/triggers the same in-game action. Also, adding factors like amplitude and/or directional control can help form different in-game actions caused by breaths, for example, controlling the speed of a vehicle by varying the exhalation strength (CA/A), blowing lit candles, with the strength of the exhalation determining how many candles are extinguished (SA/A), controlling the direction of a moving car by inhaling/exhaling as seen in game 2: Road Tripper (CA/D), etc.

Thus, the controller used to develop breathing exercise games defines the possible real-world breath actions which can be used to affect in-game actions in different ways, by adjusting the GACEs in games as per the requirement of the goal, exercise and other considerations of a given domain.

13.2.2 Level design

By making changes to how a given level of a game is designed, different possibilities of breathing exercises and goals can be fulfilled. This is also explained in sections 5.4, where we see how different additions to the 'endless runner' game, can help embody different breathing exercises. By adding strategically placed obstacles, adding falling objects to avoid, adding collectible items, changing the goals and gameplay, etc. the possibilities of the levels and thus various breathing exercises can be accommodated. These level designs can lead to changing GACEs in the game as well. Taking the example of the prototype 'Road Tripper' game created in this project, we can see how different exercises can be formed by changing the level design. The game created consists of CA/D type GACEs where the direction of movement is controlled by continuous exhalation/inhalation of the player, such that the 'in-out' and 'in-diffOut' exercises can be performed. Here, the gameplay is such, that the player needs to avoid obstacles and collect collectible items by moving left/right by inhaling/exhaling. If the level is changed, such that instead of moving left/right, the car keeps moving along a straight path, while needing to jump over vehicles that appear in front of them, then that could accommodate different exercises if the oncoming vehicles are strategically timed. The forward motion of the player car can be controlled by breaths instead of the left/right motion, with the help of slow and controlled exhalations (CA with/without amplitude control (A) for acceleration), while the jumps can be triggered by a quick inhalations (SA), such that the 'in-diffOut' exercise can be embodied. Similarly and conversely, the forward motion of the player car can be controlled by slow and

controlled inhalations (CA with/without amplitude control (A) for acceleration), while the jumps can be triggered by a quick exhalations (SA), such that the 'panting' exercise can be embodied. In addition to changing the level designs, one can also change the difficulty of the exercise, by changing factors like player speed, spawn rates of obstacles and collectibles and so on.

Thus, different level designs, different GACEs and different combinations of them can lead to various breathing exercise games within and across domains.

13.3 Visuals

Visuals, being one of the major driving forces to trigger player action, has great scope of being altered, so as to accommodate same or different breathing exercises, within and across domains.

13.3.1 Theme

Depending on the domain, the theme of the game scene can be changed. The same game can be altered according to the domain in question. As an example, say, a game consists of obstacles and collectible items. If such a breathing exercise game is designed for singers, there can be music-related obstacle and collectible game objects, such as microphones, musical notes, etc. Also, on-screen indicators of breath levels can be in the form of 'how much of a given bar of (sheet) music has been completed'. On the other hand, the same obstacle and collectible game can be translated to the pregnancy domain, replacing those game objects by those related to pregnancy, such as diapers, baby clothes, etc. while breath levels can be indicated by 'how much of a milk bottle has been filled'. Altering such characteristics of the game can set the theme of the game to be more closely related to different domains, which could possibly be more relatable to the player. As per the co-design session outcomes and the prototype feedback from participants, we see that having musical notes (with better usage) can be likeable for singers, since they are relevant to their domain. Similarly, upon understanding the themes and requirements of people from other domains, by involving them in the game design process, it could be possible to design breathing exercise games for them, which could be more likeable and relatable.

13.3.2 Complexity

The complexity of the games is driven by the domain requirements. If a game scene involves various elements to take into account while playing, it may hamper the experience of players from one domain, while it would not matter much in another domain. For example, in the feedback from singing participants for the Road Tripper game, all but one participant suggested that there can be more elements (such as song and tutorial sound volume meters, textual cues and feedback, etc.) in the game that could aid in guidance and feedback. Since these participants were all from musical domains like singing and wind-instrument playing, they need to practice strict control of their breath, for which these guidance and feedback requirements could be added, if necessary. But, it is possible that these extra elements would be too chaotic and distracting for people from other domains. Thus, while the game should be simple enough to understand for all domains, the threshold for how complex the game can be, can be better understood by involving people from every domain in the design process.

13.4 Audio

We have seen with relevant literature and reasoning in the Research Topics [12] as well as chapter 6 how in-game audio/music is important to influence the emotions and motor-function of people, thereby enhancing the experience of playing the game. We have also seen in the co-design session and prototype feedback from participants that audio and music can truly aid breathing exercise games for various purposes. In this section we attempt to explain how audio/music can lead to transferability of breathing exercise games across domains.

13.4.1 Choice of music

The choice of music and other sounds that add to the music in breathing exercise games can differ according to the domain in question. As discussed in section 6.1, music such as drones, contemporary meditative music with smooth flowing rhythms are optimal for applications like mindfulness and therapy as it has a calming effect, while for breathing exercises in singing and wind-instrument playing, it is of greater importance to have a rhythm to the music, which the player can follow to perform relatively complex breathing exercises that can aid their development in their domain. We also see in the same section 6.1, the co-design session and prototype evaluation that the musical preference of the person playing the game can enhance the experience of performing breathing exercises in the game. Thus changing the music in the game according to the domain in question can make breathing exercise games more relevant and personal to the player. Limiting the player's choice of music to the genres and types of music that are most suitable to fulfil the goals and exercises of said domain could help in designing domain-specific breathing exercise games. As per the co-design session, while singers would like to have their musical preference playing in the game, it is not certain if this is the case for other domains. Again, by involving participants from other domains in the design process, it could be possible to tailor the musical needs of the game according to the domain.

13.4.2 Roles of in-game audio

Chapter 6 explains the various possible roles that in-game audio/music can play in breathing exercise games. These include ambience, providing a rhythm, tutorial/instructional audio and to provide in-game feedback to players. With such an arsenal of audio, game designers can add numerous audio elements to the game depending on the requirements of the goals and exercises of the domain in question.

All of these factors that are discussed in this chapter may or may not single-handedly change the exercise within or across domains. It is highly likely that a change in one factor may lead to a change in one or more other factors to be able to successfully translate breathing exercise games across multiple domains. For example, by changing the 'choice of music' from the rhythmic music required for singing breathing exercise games to drones for games in mindfulness, it would also most likely be necessary to change the other roles of in-game audio, visual complexity, and also game control elements. Therefore, all these factors need to be taken into account, while understanding potential users to eventually create breathing exercise games for them.

14 Discussion

This project is an attempt to provide a starting point in several areas of research and game design, in relation to developing breathing exercise games for various domains. In this discussion, we first take a look at how this project provides answers to each research question presented in the introduction. For each research question, we will summarize the work done and its contributions to the field and limitations & possible future work that could help answer each research question in greater depth.

14.1 Research Question 1

Given a breath sensor, how can we use the obtained data to develop an efficient game controller, using breath as the game input?

14.1.1 Work Done and contributions

In the Research Topics phase [12], we performed initial explorations with the *Breathline* breath sensor (made by Ben Bulsink), which consists of two belts, one each to be worn on the chest and abdomen. This plug-and-play sensor could acquire real time information about both chest and abdominal breath levels separately in the *Breathe.exe* file developed by Ben Bulsink. In chapter 4 of this report, we see how this breath sensor could be used as a game controller with statistical analysis done in Python. To make the sensor usable as a game controller, the input data needed to first be cleaned by removing outliers and checked for stability across various conditions as seen in section 4.1.1. After that, by using a moving average filter, the data was smoothed to get rid of unwanted local irregularities Then, the large breath values obtained from the sensor was normalized between 0 and 1, to make the data more understandable.

After performing these operations on Python, we see how such operations were performed on the Unity game design engine, in section 4.2. We could thus detect the cleaned, smoothed and normalized breath values from the breath sensor on Unity. With that, we could also detect whether the person wearing the sensor is inhaling, exhaling, or holding their breath, if they are breathing in/out slowly, quickly or holding their breath and also extra functions like detecting whether the person has crossed a certain low or high breath threshold value. Detecting these values in breath sensors can enable game designers to use breath sensors as a game controller successfully. With this, it is also possible to detect and analyze various aspects of a person's breath, such as inhalation capacity, exhalation duration, breathing rhythm, etc. that are important to the person, depending on the requirements of the domain that person is from.

14.1.2 Limitations and future work

1. **Available game control possibilities from sensor:** Although several aspects of breaths were detected from the *Breathline* sensor, not all of them were used in building the game prototypes. Only the detection of whether a person is inhaling or exhaling were used. Using breath values between 0 and 1, threshold crossings, speed of inhalation/exhalation, etc. can be used to give more feedback to users, by getting a greater understanding of how the user is breathing. All these features would need to be tested while building games in the future.

2. **Accelerometer readings from *Breathline* sensor:** The accelerometer readings available from the sensor were not fetched and used here. These values could be used to detect the posture of users, which is an important aspect of breathing exercises. This would also need to be tried and tested in the future.

3. **Smoothing filters:** Global outlier elimination was done by detecting and discarding breath values which are greater than a set number of standard deviations away from the mean value from a list of values used to calibrate the sensor. After that, moving average smoothing was used to eliminate local outliers and

smoothen the incoming data. Although this works satisfactorily in this project, a moving median filter could possibly deal with both global and local outliers which will need to be tried in the future.

4. **Handling game input delay:** There is a delay of roughly 0.6 seconds in detection of input breath values caused by the smoothing (moving average or median) windows as explained in section 4.1.2. Different ways of handling delay could be looked into in future versions. One possible way could be to use the player calibration to get some typical breath values to fill up the smoothing window up until the first incoming value from the breath sensor arrives upon starting the game. That means, that if the smoothing window is of size M, fill up the window with (M-1) values of typical breath values of the player and then perform smoothing once the first true input of the game begins. Alternatively, the moving smoothing could begin after the first (M-1) values arrive in the game, thereby reducing the delay. For this alternative, the countdown to the game can be used to adjust the smoothing filter to the immediate input value.

5. **Involving users for sensor (controller) analysis:** The sensor analysis was done only with readings of my own, without involving participants breathing data. Involving users could bring greater validity to this analysis.

6. **Different breath sensors:** Different types of breath sensors can be explored to use as a game controller, since this project only covers the *Breathline* breath sensor.

14.2 Research Question 2

Since we know that there are several breathing exercises used in different domains, what elements of gaming(controls, level design, visuals, in-game audio/music, etc.) could be altered such that these exercises can be performed with the help of games?

14.2.1 Work Done and contributions

In chapter 5, we discussed the relation between the real-world player controller action that is coupled to an in-game action and formed the theory of GACEs (Game Action Control Events). We also saw how standard game control input using devices like keyboard, mouse, touchscreen, joystick, etc. can be converted to breath control inputs by using the GACE mappings, with the help of several examples of existing games. We then saw examples of how existing breathing exercise games are also in line with this theory of GACE mappings. After that, taking the example of the generic endless runner game created, the different ways in which GACE mappings and level design can be used to embody different breathing exercise in a game were illustrated in section 5.4.

The Research Topics [12] highlighted the importance of music in games and provided initial ideas of how we can use music in game audio to influence the player's emotions and motor functions. Chapter 6 talks about the various roles that music can play in breathing exercise games, viz. ambience, to provide a rhythm, as tutorial/instructional audio and to provide in-game feedback. These roles and ideas were supported with relevant literature. These roles of audio, in combination with appropriate GACE mappings and level design can form a thinking base for game designers to create different breathing exercise games for different domains.

14.2.2 Limitations and future work

1. **Examples of how different breathing exercises can be embodied in games:** The fact that different breathing exercises can be embodied in games, with GACE mapping possibilities and level design, were only illustrated with the Endless runner initial prototype. More examples, with working implementations could strengthen that argument.

2. **Possibilities of in-game audio:** The possible roles of audio/music discussed in chapter 6 could possibly require more validation and research. Each role discussed can have a research conducted of its own, on how it affects players playing breathing exercise games.

3. **Volume adjustments of elements of in-game audio:** The concept of adjusting music and tutorial sound volumes to provide feedback to players about their breathing needs greater validation. Fish [13] explains that while adapting game audio to the game enhances the gaming experience, it is important to understand that player-game interactivity is achieved by having the audio adapt to changes in the gaming environment, i.e. interaction between the audio and the state of the game. However, participants providing feedback in this project suggested that they liked the volume adjustments as feedback. This conflicting thought needs to be resolved by more in-depth literature study about game audio as well as testing with participants.

4. **Player's preferred music:** Since we have seen in section 6.1 that the choice of music matters in games, using any available music of player's preference in games can be a tricky matter, especially if used to provide a rhythm and timely feedback. This is because not every song is recorded with a metronome as reference and many songs have changing tempos within songs. The song chosen in this project, *Hey Jude*, also was not recorded with a metronome originally by *The Beatles*, hence all parts were recorded myself, with a metronome set at 72 bpm as reference. However, it is not possible to do that to accommodate all possible songs of every user's preference. Algorithms that can detect the tempo, time signatures, etc. of songs need to be explored and implemented to solve this issue. To add to that, exploring the appropriateness of songs in each domain also requires more work. Using popular songs like *Hey Jude* in domains like mindfulness might not be as appropriate as compared to the relaxing tones of oceans, drones, etc. as was suggested in [15], and discussed in section 6.1.

5. **Audio games:** This project consisted of both audio and visuals to create breathing exercise games. However, with the roles that audio play, audio games can be explored in the future for breathing exercises. Audio games were briefly talked about in the Research Topics, with reference to [30, 49, 14], but its usage in breathing exercise games seems to be fairly unexplored.

14.3 Research Question 3

First considering one domain of work - singing, what do potential users of such a game want in it, such that the game is useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises? How can music play a role in such a game?

14.3.1 Work Done and contributions

A co-design session was conducted as discussed in chapter 7, through which we gained insights and ideas from singing teachers and students about how they would like breathing exercises to be. This session covered insights about game visuals, audio, feedback and personalization of the game. Section 7.2 provides a list of requirements that resulted from this co-design session that can make breathing exercise games for singers be useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises.

With ideas gained from co-design session participants, we came up with 3 game ideas, which were again discussed with the participants, as seen in chapters 8 and 8.1. Based on these co-design session requirements and then participant feedback on game ideas, game and interface prototypes were created, as seen in chapter 10, which were then evaluated as per those requirements in chapter 11. With further participant interviews, we got more detailed thoughts about how several elements in the prototype games and interface created should be and we discussed each of these with notes for future versions of it. Therefore, by involving participants from the singing domain in the design process, we got in-depth insights about the how potential users from the singing domain

would want breathing exercise games to be, such that the game is useful, interactive and fun, thereby ensuring regularity and correctness of students performing their breathing exercises.

14.3.2 Limitations and future work

1. **More participants, more ideas:** The co-design session was conducted with a limited number of participants. It is possible that with a larger set, there can be more insights and ideas that could lead to different requirements for breathing exercise games for singers.

2. **Platform for development:** The breathing exercise games suggested in this project require a breath sensor, and a visual and audio interface. It is not clear whether the game should be built as a mobile, computer, console-based or VR application. Further research needs to be done exploring each platform, hence creating a breathing exercise-gaming experience in the most optimal platform or combination of platforms.

3. **Prototype development:** Due to time restrictions, the prototypes created were only basic functional versions that were just capable of depicting the outcomes of the co-design sessions. Greater depth and detailing of these ideas can be achieved, by putting more time into it. The calibration of the device as per the user was only done by simple button presses as discussed in section 4.1.4. This can be improved by making the calibration of the device as part of a small game that embodies full inhalations and exhalations so as to record necessary values required to calibrate and normalize incoming data. In the game prototypes created in this project, we only made use of the breath sensor to detect whether the player is inhaling or exhaling. The other features of the sensor, such as using breath values alone (for eg: to control speeds of objects by using breath values as multipliers), detecting the speed of exhalation/inhalation, detecting posture of players by making use of accelerometer readings, etc. can be used in the game as control elements and also to analyze player performance to give in-game and post-game feedback. As discussed in chapter 4, it is possible to detect the breath levels of both chest and abdominal belt values separately. This could help give players feedback of not just timing, but also of the technique of breathing, so as to avoid mistakes such as shallow breathing (chest breathing) in the game. Also, handling the player's breathing exercise performance in terms of game elements like scores, rewards, etc. needs more work. Other details like the use of domain specific elements in the game (like musical notes, sheet music references, musical instruments, etc.) also need more attention to detail so that it is made more relevant in the breathing exercise game per domain.

4. **Audio input for singing-related games:** As seen in tables 1 and 2, breathing exercises used in singing often require vocalizing their breaths. Also, as per participant interaction, singing teachers and students are curious to be able to use such applications for their teaching in the future, to enhance the experience of teaching and learning, not only for breathing exercises but also as an all in one singing application. For such an application, voice input control to games would also need to be explored.

5. **Online feedback:** The feedback taken from participants for the game prototypes was done with the help of a video of the gameplay, shown to them over an online interview, on account of the COVID-19 restrictions. With these videos being shown to participants during the interviews, the lag between video and audio transmission did not let them get a desirable experience of the games. Instead, the prototypes could have been better evaluated with participants online, if instead of videos, game prototypes with alternate keyboard control were given to participants to try out themselves. That would give participants a better understanding about the details of the game like how the game audio and video work together in embodying breathing exercises in the prototypes.

6. **In-person feedback:** To add to the previous point, if participants are allowed to test the game fully, with the breath sensor visuals and audio all working together in person, that would add to their experience, enabling them to discuss their thoughts about the games in greater detail. This can be done in the future with better developed prototypes, with the help of ideas gained in this project, to get better feedback from participants.

7. **Validating game elements used and to the game as a whole:** The prototype evaluation done here was qualitative, with a small number of participants. This evaluation added to the ideas we already found in the co-design sessions. However, validating these ideas with the help of well-grounded acceptance scales such as the Van der Laan acceptance scale [51] would strengthen the outcomes of this project. These scales can be used to evaluate the prototypes as a whole as well as individual elements of the games, for example, the song/tutorial sound volume adjustments, instructional video, feedback via collectible sounds, visual feedback, etc. in the game - Road Tripper can be evaluated individually in addition to the evaluation of the whole game.

8. **Developing full version of games, to provide better experience to participants for more detailed insights:** Since the interface prototype was not connected to the game, it was not possible to detect and analyze player perfomances pre and post-game. By analyzing data from the games, reflecting the information relevant to teachers and students in the interface and realizing the various functionalities discussed (such as viewing player performance, setting homework exercises and difficulty levels, etc.) work, the entire product could enable participants to get a fuller experience of its usage. Once this is done, a more thorough evaluation of the game as a whole can be made possible, after letting teachers and students both use the application for a longer period of time by adding it to their usual teaching and learning process. This would give a greater insight about the usability, acceptance and likeability of the game.

9. **Games with breathing metaphors:** Different types of games with breathing metaphors (as used in [7, 32]), such as the bubble game discussed in section 8, can be developed and tested.

14.4 Research Question 4

How can such a breathing exercise game be translated to other domains of work?

14.4.1 Work Done and contributions

Chapters 4 and 6 provide an insight on how different elements of visuals, audio and game control can be used to create games to embody a number of breathing exercises, fulfilling various goals within and across domains. Chapter 13 brings together all these different elements to give an overview of all factors that can be altered to achieve the transferability of breathing exercises in breathing exercise games.

14.4.2 Limitations and future work

1. **Involving participants from each domain in design process:** To be able to design breathing exercise games for any domain, it is important to understand its users in as much depth as possible. This can be done by involving participants from each domain that the game needs to be built for in the design process, as was done in this project with singers and as suggested in the future work of Research Question 3.

2. **Single game with multiple levels or suite of games?:** Participants in the singing breathing exercise game prototype feedback suggested that they liked the bubble game, but also the other games and suggested that there could be multiple games to embody different breathing exercises. However, having one game and adjusting the various factors discussed in chapter 13 could also possibly lead to good usability, acceptance and likeability. This can also be explored in the future.

14.5 Conclusions

To conclude, this report provides an exploration of different possibilities in interactive technology to create breathing exercise. We see how the data input received from breath sensors can be used to make an effective game controller. We provide a breakdown of various aspects of games - game controls (with the help of GACE concept),

level design, visuals and audio that can help create various breathing exercise games keeping the domain that requires these exercises in mind. We also provide an overview of what aspects of breathing exercise games can be tweaked in order to embody different breathing exercises, both within and across different domains. By understanding the viewpoint of singers by involving them in the prototype design process, we provide requirements and details that could make such games usable, acceptable and likeable for the singing teachers and students. With such an understanding of other domains, with the overview of translation of breathing exercises within & across domains and with the help of the limitations & future possibilities discussed in the final discussion section, we believe that researchers and game designers can do further work to create and design breathing exercise games for the eventual benefit of individuals who require to perform regular and correct breathing exercises.

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Appendices

Relevant links

- Spreadsheets with participant feedback from Chapter 12, game inventory used for developing GACE theory in Chapter 5: link
- Document with co-design session planning, and outcomes from co-design session mural: link
- Application interface simulation: link

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Ptcpt No.

INFORMED CONSENT STATEMENT

Concerns
The University of Twente and ArtEZ Academy of Music are researching the use of music and interactive media to aid in attaining various breathing goals, as explained in the information brochure given with this form.

Lead researchers:
Dennis Reidsma[1], Brolin Fernandes[1]
[1]University of Twente [2]ArtEZ Academy of Music

Contact information
If you have any questions about this investigation, please-contact Dennis Reidsma – d.reidsma@utwente.nl, an investigator on the spot or at the Secretary of the Ethics Committee(ethics-comm-ewi@utwente.nl). The Ethics Committee consists of independent experts from the university and is available for any questions and complaints surrounding the investigation.

Research: Music, Media to Breathe
I hereby declare the following for the 2020-2021 season:

☐ I hereby declare that I am fully informed of the investigation. The purpose of the research and the methods have been explained to me, where I have had the space to ask questions.

☐ I understand that I can terminate my participation at any time, without giving a reason, without any consequences (also later in the season).

☐ I hereby give prior permission for my participation in research during season 2020-2021 and for the collection and use of anonymous data as described in the information folder.

☐ I give permission to make video recordings for research purposes
(and/or)
☐ I give permission to make audio recordings for research purposes

This material is only examined by concerned researchers and will never be made public and/or shown to third parties for demonstration or reporting. All research material will be processed and stored in accordance with GDPR rules and guidelines.

Date: Place:

Name: Signature participant:
Age:

.....
.....
The extra copy of this consent form is for you to keep.

Information Brochure

Background

Technology plays an increasingly important role in our lives, helping us to perform better and live healthier lives. Technological innovations are increasingly being used in almost every domain, ranging from health & well-being, to sports, to music and so on.

At the University of Twente, in collaboration with ArtEZ Academy of Music, Enschede, an ongoing research is being conducted on whether music can influence people to breathe better, for various specific and general purposes. The gist of this research is: to develop a multipurpose interactive media application; with music as its major component; that can aid singers, musicians, breathing-difficulty patients, mindfulness seekers and as many more people as possible, to breathe better, thereby, possibly better fulfilling their goals. Currently, we possess two breathing devices which may aid in our research.

We, at the University of Twente and ArtEZ believe and hypothesize that creating such a game/media interface can have serious research potential, thereby aiding society. With the help of a few interviews in the past, we have established the breathing goals and exercises involved in various domains. Now, for the design phase, we would like to know more about what the users of a breathing exercise game would like to have in the game.

This is how we, together with you, will help people breathe!

UNIVERSITY OF TWENTE.

Human Media Interaction.

ArtEZ

ArtEZ muziek therapie

Ben Bulsink
Innovatie met elektronica

INFORMATION LEAFLET

PROJECT: MUSIC, MEDIA TO BREATHE:

INTERACTION TECHNOLOGY TO HELP PEOPLE BREATHE

This brochure contains information about the research project: *Music, Media to Breathe.* The brochure helps you decide if you want to cooperate with the research.

Dennis Reidsma – d.reidsma@utwente.nl

Investigation procedure

Through the co-design session, observations and video recordings, information will be collected about the various domains to be explored in our research. These include, but are not limited to: Singing, wind-instrument playing, mindfulness, therapy as required in DMD and COPD.

In this leaflet we explain what it means for you to participate in the research. You decide whether you want to participate in the research. For questions, please contact Dennis Reidsma, contact details on the front.

Participation

Participation is entirely voluntary. You can indicate at any time, without giving a reason, that you no longer want to participate in the research. The vote for participation needs to be granted once and is then valid for the rest of the research period (5-6 months). After that, you will be asked again to grant permission.

What happens during the session?

The **virtual** session will be to get ideas about how the users, i.e., singing teachers and students would want their breathing exercise game to be. The session will be conducted on 'Discord' for Video and Audio connectivity and on Mural for creative thinking and ideation. Using the ideas that are formed in this session, the researcher(s) will create a prototype for a breathing exercise game. After that, the researchers will also try to incorporate ideas learned from the singing domain into other domains where breathing is used.

What data is collected?

During the study, audio/video recordings are made, questionnaires may also be taken later and possibly another session if there is a requirement of ideas / clarification / evaluation.

Is the data stored?

The data and video will be kept securely and processed anonymously according to AVG guidelines. According to VSNU guidelines, research data is kept for at least 10 years.

Who has access to the data?

The video recordings and questionnaires are only accessible to people involved in this research. A list of names of people who have access to the material is available and can be requested from Dennis Reidsma. The creative design session on Mural can however still be accessed by all participants. You also have the right to know more about how the research is progressing. If you wish to know about how the research is progressing, the researcher can share non-sensitive information with you.

How is the data used?

The data are analysed for scientific research. This is published in scientific articles and in the 'ordinary' media, where completely *anonymous* results are presented on the basis of the data. The data may also be used by the researchers of this project for follow-up research, appropriate within the framework of this brochure. Furthermore, the results are used as inspiration for developing new forms of breath training with smart technology.

Will I be made public?

Research material by which you can be recognized are never shown publicly, even for demonstration, promotional purposes, or media.

We do want to make some of the anonymous data (e.g. information about breathing and exercises) publicly available for further research by others. We ask for permission for this separately via the consent form.

Can I have my data deleted?

If you decide during or immediately after an activity that you do not want to participate (anymore), all your data from that session will be deleted. Once the research materials are made anonymous, they can no longer be linked to you and therefore can no longer be removed.

More information and independent advice.

Would you like to provide independent advice on participating in this investigation, or to make a complaint? Then you can contact the Ethics Committee(ethics-comm-ewi@utwente.nl). It consists of independent experts from the university and is available for questions and complaints surrounding the investigation. For questions, please contact the researchers, contact details on the front of this leaflet.

Instruction manual of breath sensing belt available on request. Unity scripts, game files & videos and InVision interface also available on request.