# TONGUE INTERACTIONS

Designing motivation strategies for snoring rehabilitation

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**Jennifer Duarte**

To my son Mathias,

So many times, during these last 3 years,
I was asked how I managed this BA with you
by my side.

The truth is, I don't know how I would
have done it without you.

# Abstract

Snoring is a condition that affects around 2 billion people worldwide.
To solve this problem, Myofunctional therapy has been used as an effective treatment in this rehabilitation. However, long term therapy on a daily basis is a great motivation challenge.

With this Thesis and practice project, I aim to propose different motivation techniques and strategies which can be used in rehabilitation. Through different experiments, design methods and extensive research I explore different propositions to enhance patient's motivation during their snoring therapy.
With the use of different games concepts, I intent to offer more options and personalized game affordances to motivate individuals on a daily basis and over a long term.
Through a novel technology tongue interface connected to an app, the user can perform myofunctional therapy while driving playful and relaxing exercises.
This gamified interaction aims to increase motivation for daily use and helps to get self-perception of the movements.

# Acknowledgments

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# BACKGROUND

## Sleep and our health

Sleep plays a vital role for our health and well-being. Getting the right amount and quality of sleep during the night protects our mental and physical health. However, every second person worldwide is affected by sleep-breathing related disorders and more than 30% is correlated to lack of tongue muscle control with the result of disruptive snoring and sleep apnea.

If, on the one hand, it has a direct impact on the lives of patients affected by this condition, snoring or sleep apnea also interferes with the family members who sleep next to them.

## Snoring and sleep apnea

Snoring is caused by slack tissue in the airway increasing resistance for the air to pass through. (Dilkes M. and Adams A., 2017). In addition, our tongue and muscles in the throat and soft palate also naturally relax when we sleep. The combination of these two factors plus the loss of strength of some muscles leads to the vibration or flapping of the tissues or the falling back of the tongue obstructing the airflow. The prevalence of snoring in the general population varies widely (from 15% to 54%), mainly because most studies rely on subjective reports. Self-perception of snoring is imprecise and is largely dependent on subjective reports from bed partners. (Parish et al., 2003) As well, snoring demographics are difficult to track because it is not objectively measured during polysomnography tests. (Ieto et al., 2015) The muscles tone diminishing with age, weight gain or oral misalignment are some of the causes that explain why some people are more likely to snore.

Beyond being annoying for the sleeping neighbor, snoring may also be an indicator of sleep apnea.

Sleep apnea is a sleep disorder characterized by repetitive episodes of upper airway occlusion during sleep, as well repetitive episodes of complete (apnea) or partial (hypopnea) upper airway obstruction occurring during sleep. This occurs when the muscles that support the soft tissues in the throat, such as the tongue and soft palate, temporarily relax. When these muscles relax, the airway is narrowed or closed, and breathing is momentarily cut off. This sleep disordered breathing affects at least 4% of men and 2% of women (Young et al., 1993).
This condition is accompanied with excessive daytime sleepiness, a higher risk of traffic accidents, decreased quality of life (Hui Chen et al., 2008), and has been linked through many studies, to cardiovascular diseases, chronic heart failure ischemia, hypertension, stroke, obesity, and impaired glucose tolerance (Young et al., 2009).

Snoring is one of the most common symptoms associated with OSA. (Liistro et al., 1991; Ng et al., 2008) Among patients with OSA, snoring is common (70%-95%), and there is an association between snoring intensity and OSA. (Ibrahim et al., 2007; Maimon et al., 2007) On the other hand, subjects who suffer from snoring do not necessarily have OSA.

**Current treatments**

Snoring is commonly avoided through the change of habits and lifestyle, as for example changing sleep position, losing weight or avoiding alcohol. As well, oral appliances or nasal dilators can help reduce snoring, however these devices instead of solving the problem, only avoid it when used.
The current treatments of obstructive sleep apnea often include lifestyle changes as for

snoring, such as weight loss and the use of a breathing assistance device at night, such as a continuous positive airway pressure (CPAP) machine, oral appliances as mandibular advancement devices (MAD) or more invasive treatments, such as soft-tissue surgery, like uvulopalatopharyngoplasty (UPPP) and maxillomandibular surgery.

Continuous positive airway pressure (CPAP) is currently the most used treatment and prevents upper airway obstruction, resulting in improved sleep pattern and daytime symptoms (Levy et al., 2010). Despite proven efficacy, adherence to CPAP treatment is still not efficient. Barriers to adherence include mask discomfort, nasal congestion, local irritation, and claustrophobia (Baltzan et al., 2009). Oral appliances such as mandibular advancement device (MAD), used to protrude the mandible in a forward position during sleep and thus enlarge the upper airway, are less efficacious than CPAP therapy and are recommended for use in patients with mild or moderate OSA.

However, the lack of tongue muscle control responsible for snoring or sleep apnea, can be treated through so-called myofunctional muscle training. This therapy exercises target soft palate elevation that recruits several upper airway muscles such as the tensor and levator palati, as well as muscle fibers of the palatopharyngeal and palatoglossus muscles, tongue repositioning, and training of mandibular elevation to avoid mouth opening, and consists in muscle strengthening. (Felicio et al. 2018)
This non-invasive treatment is proved to be effective when performed every day and in a long-term management plan. To be the most

effective, myofunctional therapy should be performed every day for around 30 min or during a shorter amount of time but more often during the day. However, different studies have proved that either the 30 minutes or often in the day is unlikely to be followed on a long-term basis. Nevertheless, researches have found that using exercises for only eight minutes per day helps decrease the snoring volume of patients by 60%, improves their sleep quality and makes their partners feel less disturbed. (Ieto et al., 2015)

## Medical issues related to snoring

Sleep loss can have many adverse effects on the human body. A chronic sleep-restricted state can cause fatigue, daytime sleepiness, clumsiness and weight loss or weight gain. It can also adversely affect the brain and cognitive function. There are several adverse effects of sleep deprivation on the human body. However only few people are aware of the risks that sleep deprivation or snoring can have in their everyday life and health.

### Obstructive sleep apnea

Snoring, which is produced by vibrations of the soft tissues, is a good marker for OSA (Netzer, et al., 2003), a medical condition in which a person's airway becomes partially or completely obstructed during sleep, which causes a temporary pause in breathing. These sleep interruptions may have many repercussions as for example:

### Hypertension

Different studies have shown that sleep apnea is an independent risk factor for hypertension. (Peppard et al. 2000), supported by the evi-

dence of a relation between the apnea-hypopnea index and levels of blood pressure. The use of continuous positive airway pressure (CPAP) also showed to reduce the blood pressure levels.

**Stroke**

Over the last decade, some research suggests that heavy snoring itself may be a direct cause of cardiovascular complications, particularly a condition known as carotid artery atherosclerosis. (Lee et al. 2008)
The carotid artery is the main vessel supplying blood to the brain. When affected by atherosclerosis, fatty deposits known as plaque, form in the wall of the artery. Over time these can cause the blood vessel to narrow and limit blood flow. One study has shown that snoring vibrations are transmitted to the carotid artery, which can damage its wall and lead to the development of atherosclerosis. Subsequently, snoring may rupture a formed plaque, resulting in pieces of the plaque moving through the bloodstream and blocking small vessels in the brain, provoking stroke.

**Dementia**

Snoring has been associated with arterial hypertension, coronary heart disease, and also with stroke among middle-aged men.
As multi-infarct dementia (MID), in contrast to Alzheimer's disease (AD), is caused by multiple cerebral infarcts and is associated with a history of arterial hypertension and ischaemic heart disease, its relationship to snoring is of interest. (Erkinjuntti et al. 1987)

### Diabetes

Sleep loss may adversely affect glucose tolerance and involve an increased risk of type-2 diabetes with one study showing higher levels of blood glucose in the state of sleep debt despite normal or even slightly elevated insulin responses, causing significant impairment of glucose tolerance. (Mandell et al., 2015)

### Caries

Snoring has implications in our health that many times we don't even suspect. For example, when snoring, there is also a high chance of mouth breathing, drying out the mouth. The lack of saliva coating then increases the risk of caries. The important factor is that saliva plays a crucial role in the remineralization process that helps the teeth to continually rebuild and to heal existing cavities naturally.

## The negative impact of snoring on partners and relationships

The majority of adults sleep with a partner, and for a significant proportion of couples, sleep problems and relationship problems co-occur (Troxel et al. 2007). Despite the scarce scientific proofs about the relation between sleep and relationships, many studies have been done about this topic. The impact of sleep disturbance or sleep disorders has a direct impact on the person suffering from sleep-breathing related disorders, interfering on his life and health. However, the lives of their family members, more especially those who share their bed with them, as well as their relationship, shouldn't be neglected.

Complaints of bed partner disturbance from snoring are common in the general population, nevertheless snoring can be loud, with intensities varying around 40 dB to 80 dB or

louder. The World Health Organization (WHO) reports that noise above 30 dB can disturb sleep, therefore snoring noise can have a real impact on someone's sleep, having in consideration that 80 dB correspond approximately to milling or washing machines and almost as loud as a food blender.
Now imagine sleeping 60cm apart or less, from one of those machines all night, every day, during years.
For this reason, loud snoring, based on the evidence of sound disturbances and the high prevalence of snoring in the general population (Beninati et al. 1999), may have significant health consequences for the snorer's bed partner, causing significant deterioration of their sleep quality with resulting daytime consequences. In fact, women living with heavy snorers were more frequently affected by symptoms of insomnia, morning headache, daytime sleepiness and fatigue than women living with non-snorers. (Ulfberg et al. 1997) Not to mention that insomnia is associated with reduced well-being, health and psychological problems and diminished productivity.
Furthermore, the impact of sleep disturbance is associated with higher morbidity and mortality as well as occupational and motor vehicle accidents. (Colten & Altevogt. 2006; Horstmann et al. 2000; Ulfberg et al. 2000).

In a study conducted by the Sleep Disorders Center at Mayo Clinic Rochester, married couples in which one member had sleep-breathing disturbances (mostly sleep apnea) were recruited. The couples underwent simultaneous nocturnal polysomnography while sleeping. As a result, from the 10 spouses of the patient, 8 reported that they were awakened at least nightly by their partner's snoring and 7 report-

ed nightly difficulty returning to sleep. However significant improvements in sleep quality in spouses were experienced when the patients were treated with nasal CPAP (Beninati et al. 1999).
Other studies, like the one of Miljeteig et al, measuring the subjective and objective effects of uvulopalatopharyngoplasty in the treatment of snoring, involved 69 snorers, and 68 of their bed partners complaining about sleep interference. After surgery, only 26% of the bed partners no longer complained due to the fact that the snorers did not show significant improvements in AHI, snoring frequency, or intensity following surgery (Miljeteig et al, 1994).

Comparatively, Kiely and McNicholas reported questionnaire results obtained from 55 bed partners of patients with OSA successfully treated with nasal CPAP. These bed partners reported improvements in their own sleep, mood, daytime alertness, quality of life, and personal relationship with the patient. (Kiely and McNicholas. 1997)
Beside health issues for the spouses of persons suffering from loud snoring or sleep apnea, disturbed sleep and the accompanying effects may contribute to marital dissatisfaction and higher divorce rates, with couples ending up regularly sleeping in separated rooms. (Cartwright & Knight, 1987; Kiely & Mc Nicholas. 1997)

The impact that sleep disturbance might have in someone's life don't resume only on health issues but as well, in the cases of couples sharing the same bed, this can have repercussions on their relationship, affecting their marital happiness as well as quality of life.
Snoring disturbs not only sleeping hours but as well in the hours awake, because snoring

enhances agitation and tension among couples, leading them to dispute more often and over minor issues. Some snorers argued that their sleep partners often became cranky and angry, lashing out at them and blaming them for depriving them of an essential need – sleep. (Zarhin 2016) Most sleep partners after deprivation of sleep next to a snorer feel involuntary negative emotions such as resentment and rage which has an influence on the way they treat their partner during the rest of the time. In her interviews, Dana Zarhin collected interesting interviews from both, snorers and sleep partners, about their relationship:

*"Listen, when you sleep next to someone and you don't sleep because of him... you wake up feeling so angry. I couldn't talk to him. I couldn't look at him. Whenever I looked at him, all I saw was my sleep problems. I was nervous all the time. Of course, it is disruptive. It disrupts the whole household."*

Likewise, life events such as the transition to parenthood are known to cause sleep impairments and precipitous declines in marital quality, suggesting that sleep quality may play a critical role in the trajectory of marital functioning. However, a newborn parent's situation differs due to the fact that the expectation is that the situation is only temporary and is relatively better accepted to be woken up from a child than from a spouse. Beyond that, parents do not normally take severity from these poorly slept nights, whilst spouses wake up with some rancour and resentment.

Furthermore, studies found gender differences in the social perception of snoring, arguing that "the public" perceived snoring as an un-

feminine phenomenon which is more natural and acceptable for men. Some snoring women in the study felt embarrassed when talking about it. (Venn S. 2007) Men's snoring, however, is not discreditable, because it is discussed openly and without reference to embarrassment or awkwardness in the society.
While most of the women who snored felt guilty for disrupting their husbands' sleep by their snoring, this was not the case for the men which was seen as acceptable and even 'normal'. (Venn S. 2007)

While spousal snoring will always continue to be seen as a topic of humor for the society, the long exposure of this situation might lead to some serious health issues as well as they might have an impact in matrimonial relationships. For this reason, the effective treatment of snoring might be expected to have a positive impact on the lives of many people.

## Myofunctional therapy with a tongue interface

Using a tongue interface is an innovative solution for snoring and sleep apnea therapies. It consists in a tongue-device, fitted with sensors, sensitive to the tongue's position and force. This interface due to its possibility in interaction during rehabilitation exercises, enables the patient to drive a gamified training plan with the tongue.

The technology behind this tongue-based interface contains a unique polymer nanotechnology developed and patented by the company Bottmedical, which enables ultra-thin pressure sensors and stretchable electronics to be activated by the tongue as a tactile interface. The oral equipment is able to send data directly to a connected device for monitoring

and reviewing. The data is used to steer the therapy session to obtain the best results.

As said before, myofunctional therapy by itself is something that already exists as a treatment for snoring or sleep apnea, however at this time to my knowledge, it appears always as a passive way of rehabilitation. The user gets a plan of myofunctional exercises prescribed by a therapist and performs them at home in front of a mirror or alone. The burden of doing the same exercises every day during a very long period of time without interaction leads most of the time patients to abandon therapy after some time.

The idea of this innovative interface is to give the patient the possibility to visualize their movements in a playful way. The subjects can, by applying pressure or simply by touching the oral device with their tongue, activate the sensors which give a direct feedback visible through an app connected into a mobile phone or tablet. Not only this brings a notion of entertainment into the therapy, as it helps the patient to get track of his training and gain a sense of awareness of his own health. With this interaction, this project aims to develop motivation strategies through user centered design methods
The gamification and entertaining aspects are important factors which can help the patient to keep his motivation high to continue and complete the myofunctional therapy, ensuring the successful execution and attendance of the therapy. Motivation in the context of rehabilitation plays a critical role within the therapy and has been more and more studied in the last years.

## Motivation in rehabilitation

Motivation is an important factor in rehabilitation and frequently used as a determinant of rehabilitation outcome. Several factors can influence patient motivation and so improve exercise adherence.

It is proven that the myofunctional exercises increase the strength and subconscious control of the tongue at night through daily training. Such practices result in prevention, alleviation, or full treatment of chronic snoring and sleep-apnea. However, the repetition of the exercises as well as the fact that this treatment has to be performed on a regular daily basis, makes that patients lose their motivation in the long-term.

## Related work

Mobile and wearable interfaces are being more and more common in health, either for simple monitorization or as rehabilitation interfaces. However, tongue-based interfaces are still scarce and related works about this topic are therefore quite limited. Mostly, existing tongue-based interfaces exist in the context of assistive devices for individuals with severe paralysis such as tetraplegia. In fact, most of the time, the tongue generally escapes severe damage in spinal cord injuries (SCI) and most neuromuscular diseases. As a result, even patients with high levels of SCIs still maintain intact tongue control capabilities.

Tongue-Touch-Keypad (TTK) is a tongue activated communication controller with nine keys that require tongue pressure which enables persons of limited mobility to operate various devices reliably. (Fortune et al. 1994)

TonguePoint is a modified joystick to be used with tongue that provide an alternative computer input. (Salem & Zhai. 1997)

The dual-mode Tongue Drive System (dTDS) is a set of devices that allow people with severe disabilities to use computers by navigating a mouse cursor and typing through two modalities: voluntary tongue motion and speech. This device uses a small magnetic tracer attached to the tongue and an array of magnetic sensors that measure the variations of the magnetic field inside the mouth to track the tongue motion in the 3D oral space. (Huo et al. 2012)
The Smart mouth technology hearing uses microphones outside the ear to detect sounds

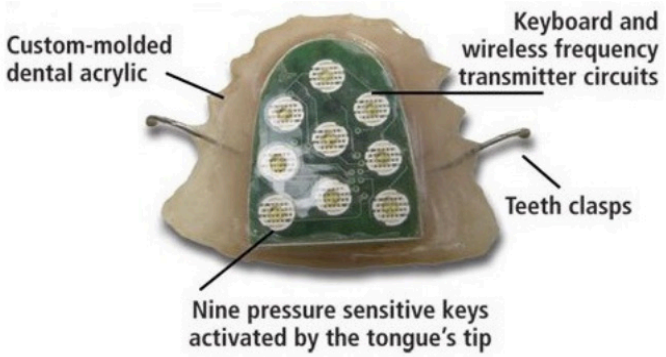



Figure 1 – TongueTouch Keypad (1994)

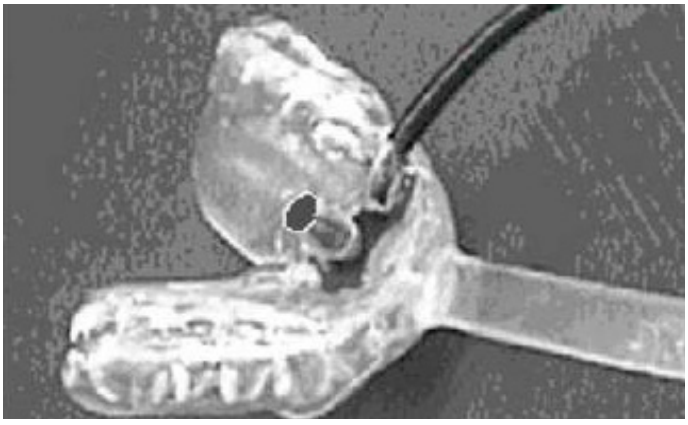


Figure 2 – TonguePoint (1997)

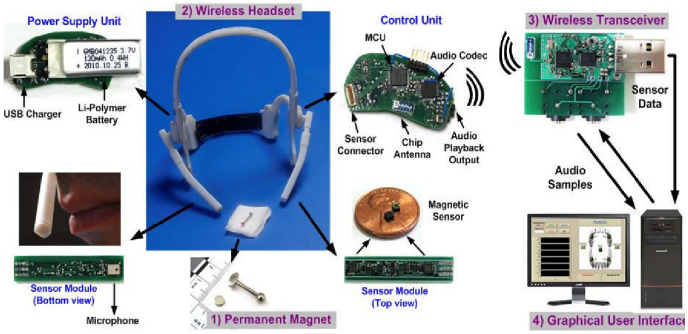



Figure 3 – Dual-mode Tongue Drive System (2012)

and words and send them to a speech processor which analyses the information and transmits it to a receiver where it is converted into electric impulses. Those impulses are sent to the electrode retainer fitted to the roof of the mouth and allow the wearer to feel a distinct pattern by pressing the device with his tongue. With training the brain is able to interpret those patterns and understand the sounds and words being spoken, the same way a blind person learns to read braille instead of written words.

Pallette is an open-source tongue-computer interface which enables the mobility of impaired, to control computers, tablets and phones as a Bluetooth mouse, using the tongue. It uses infrared sensors to track tongue motion and a microphone to detect tongue taps. The fact that it is open source allows anyone to make his own controller at home.

The BrainPort Vision device, uses an external camera placed on a headset which captures visual data and translates it in gentle electrical stimulation patterns on the surface of the tongue. Some users have described it as being able to “see with the tongue”.

Play-a-grill is a design project which consists in a music tongue controller used as a grill, popular in the hip-hop culture. Motors situated from each side of the molars, transduce the frequency of the sound through bone conduction which conducts the sound to the ear.

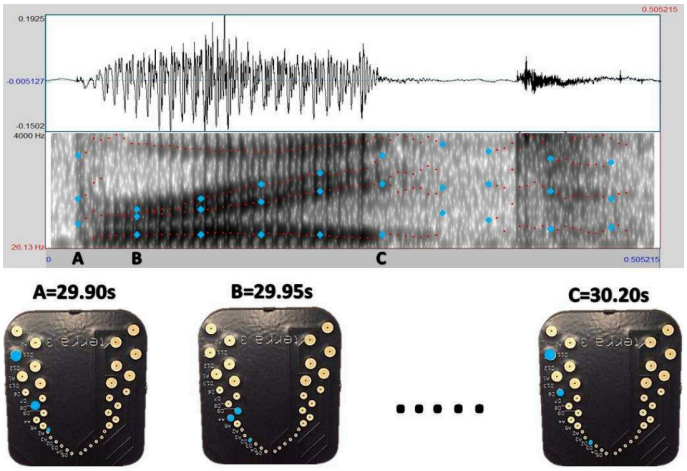



Figure 4 – Smart mouth technology hearing (2016)

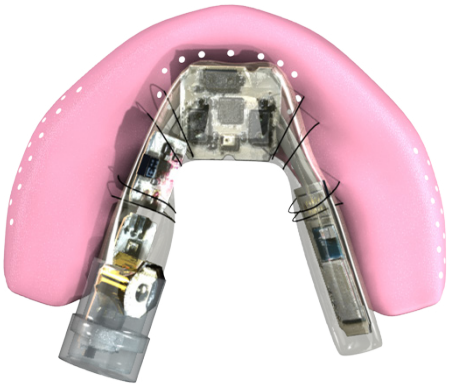


Figure 5 – Pallette (2016)

Figure 6 – BrainPort Vision (2005)

These related projects are just a few examples from many on the topic of tongue interfaces. However, there have been no published investigations of tongue interfaces for snoring prevention and no investigations into tongue interfaces from a design prospect (to my knowledge) to date.


Figure 7 – Play-a-Grill (2011)

# PROJECT QUESTIONS/ AIMS/ METHODOLOGY

## Research questions - hypothesis

In this thesis and BA project, I aimed to answer different questions and explore the topic of motivation in rehabilitation, more precisely oral rehabilitation in the context of snoring, through myofunctional therapy.

- How might design methods help to improve motivation in a daily basis therapy?
- How might I find design strategies to make oral home-rehabilitation playful and enter taining?
- How might I trigger long-term motivation for patients doing myofunctional exercises using a tongue-based interface?
- How might design methods empower people to be in charge of their own health throughout their rehabilitation?
- What are the tongue affordances and what potential can be further explored in a design project?

## Methodology

During this project I realized an extensive field research about myofunctional therapy. I talked with therapists and read a considerable amount of literature related with this topic. I also interviewed people to understand their understanding about snoring condition and to gather more information about the possible users of this project interface.

I did a lot of self-experiments, as well, whether to experience the dental splint feeling in my mouth or to try the accuracy of pressure sensors. User-tests would have been favorable for this project too, but because of the conditions

due to the Covid-19 situation it was impossible to meet possible users to proceed to dental scans and to later let them try this interface. Furthermore, user-tests for so called medical devices need ethics approvals which are not easy to get accepted.

## Research

It was important for me to understand the problematic of snoring, the existing therapies to solve this problem (as myofunctional therapy) and the technological possibilities around the tongue interface. By researching these topics, I gained more knowledge to work on this project which is about a health-related problem and needed a good understanding in order to propose real solutions.

## Interviews

During my research phase, I talked with experts in the field of oral rehabilitation in the context of snoring and sleep apnea. In a first moment, it was important for me to understand what consists of myofunctional therapy that rehabilitates the tongue and strengthens and reinforces the oral musculature in order to minimize snoring or sleep apnea symptoms.

Within this project, which started under the start-up Bottmedical based in Basel in collaboration with the University of Basel, the EMPA institute and the department of Interaction Design from the ZHdK, I had the chance to be in contact with different experts (as for example a maxillofacial surgeon) supporting this project, in order to answer questions and give more insights about the rehabilitation exercises and process. Furthermore, I interviewed subjects with snoring symptoms or sleep apnea to understand their conditions and the

therapies they have already tried and talked about their motivation.

## Concept

For this project I defined possible rehabilitation concepts using a tongue interface connected to an app. As the motivation during therapy is one of the main topics of this project, I investigated different approaches that can trigger this factor and keep patients exercising on a daily basis over a long term.
My focus in this phase was to understand how different users' personalities can perceive motivational strategies as well as feedback in different ways. I searched for solutions to trigger intrinsic motivation in order to encourage patients to continue and complete the treatment and what are the myofunctional exercises that can better be used in combination with the tongue interface.

## Prototype / user-tests and iterations

After researching in depth about the topic I started working on different ideas. For this I used prototyping methods.
Before the lockdown, I got a digital scan of my teeth which was automatically converted into a model and was later printed with 3D printers. A plastic foil is then thermoformed on top of the 3D model to get the dental splint. I could test the dental splint on my mouth and feel the textures, but it was not possible to test it with the original sensors from the Bottmedical company once the Basel University was closed and the sensors could not be fabricated. Because the tongue has so much sensibility potential, I found important to implement textures on the interface. These textures serve as reference points and give affordance to the movement to be performed. For example, the

stripes encourage sliding movements with the tongue on the palate and grid structures indicate pressure movements.

## Co-creation

Something that I found really valuable in this project was the interdisciplinarity of the persons involved, from the different cooperation partners. It was the first time I worked in a design project together with experts form different fields and I think this project really benefits from the co-creation between the different parts throughout the process.

## Motivation and intended contribution

When I first heard about the possibility to work on an innovative tongue interface project, I got very excited and curious about it. The novel aspect of the whole project was something that, I have to admit, immediately caught my attention and motivation. I saw it as a chance to work on something original and uncommon.
Many times, in design projects, we strive to produce something innovative or to reinvent existing solution. In this case, although tongue interfaces have been used before, the context of a tongue rehabilitation device for snoring is something that has never been seen before.

Furthermore, motivation in itself is a critical aspect in health rehabilitation in general and this BA project searched ways to increase and enhance patient's motivation, more specifically in the context of oral rehabilitation through myofunctional home-therapy.

Improving patient compliance and long-term motivation, increases exercise adherence as well, resulting in a reduction of snoring and sleep apnea.

With my bachelor project, I searched ways to investigate how Interaction Design can, through user-centered methods, influence patient's behavior to improve their health. The thematic of motivation as a broad psychological aspect is something that has been vastly and scientifically investigated to understand what can trigger or diminish it. However, it is not a scientific factor that can easily be manipulated because it is as complex and individual as the human behavior is.

With this project I dived into the problematic of snoring and understood myofunctional therapy as a way to solve or diminish this condition, as well as investigating ways of motivation especially in the context of rehabilitation and the creation of daily habits in the long term. This way, I hope to be able to propose solutions that fit both rehabilitation aspects, which serve the purpose of improving someone's snoring condition and motivational aspects, which are an important factor in this context of daily therapy in a long-term basis.
By ensuring an entertaining therapy, patients are more likely to follow their treatment at home, which results in a way of empowering people to take charge of their own health, improving health literacy and patient engagement.

# FIELD RESEARCH

## Concept and angle

Snoring is extremely common in the general population and may indicate OSA (obstructive sleep apnea). (Ieto et al., 2015) Snoring and other sleep disorders can cause sleep loss, which is among the most common health problem in the adult population.  Sleep deprivation is a serious issue that can be just as harmful to the human body as starvation or dehydration. Sleep is necessary for survival and functionality and have a big impact on our overall health system. One of the most significant barriers to treatment of snoring or sleep apnea, is the patients disregar of symptoms and their failure to report them to primary care physicians or underestimation of the impact in their health and quality of life.
Furthermore, as mentioned before, although myofunctional therapy is used as an effective treatment against snoring, the monotony associated to the repetitive exercises performed daily and in a long-term basis leads most of the time to the abandon of the therapy.
Therefore, the challenge is to find motivation strategies to be integrated into an interactive snoring rehabilitation.

## Expert Interviews

**Dr. med. Dent. Jeannette von Jackowski**

**How is myofunctional therapy plan for patients established?**

«These therapies are practiced differently in every part of the world. Similar to the exercises with a physiotherapist. Each physiotherapy has, so to speak, its own exercise plan and individual exercises.
The idea was that we develop the exercises in a team together with a myofunctional therapist, a speech therapist and a computer scientist/ programmer. »

**How much therapy is needed?**

«From the therapy plan for the patients it is known from literature that daily practice is necessary.
The daily therapy brings the fastest possible success. At the beginning the exercises are short - quality before quantity. So it is better to do the exercise correctly instead of doing it almost correctly 20 times.
At the beginning 1-2 minutes per session is intended. In the course of 6 weeks it increases to 20 min. Then you stay with 15-20 min. until the 12th week and always add new exercises. Then you recite and see if the exercises are still “effective” and change exercises. The ones that are then quite well mastered are taken as a warm up, so to speak, and then exercises that do not go well at all are taken out. So that the patient does not continue frustrated with an exercise that he has not mastered. This only increases the frustration and is demoralizing. It then always goes to a “higher level”.»

**Is there a most effective time of the day for the exercises?**

«The question is to be answered in the same way as you go jogging. There are people who love jogging in the morning and there are those who prefer jogging in the evening. It is proven that it must be right for the patient, then the success of the exercises is highest.
It does not help him to force a pattern. It has been shown that short intensive exercise sessions (e.g. 7 times a day) will give a minute more than 1x 7 minutes. Ideally, after the 12 weeks, the patient should practice 7x 7 min daily - that would be the ideal case. Only a few patients can do this, but this is the ideal case.»

## Snorers interviews

During the concept process it was important to better understand snoring patterns and its influence in people's lives. The questions I elaborated aim to understand if the persons interviewed are aware of their snoring, if there are possible repercussions in their health and life and if solving their snoring problems are for them a priority or not.

To date, I received 15 answers:
66.7% are males;
33.3% are females;

Ages are between 22 years old and 57 years old.

In the question **"How long do you consider snoring?"**, I could collect many different questions. Some interviewed reported snoring since always, others since childhood or their teenage times. Others reported that their snoring is more related to changes like weight gain, aging or hormonal changes. With this question I could conclude that snoring is for all interviewed a condition that lasts for at least some years.

To the question **"How loud is your snoring?"**, 20% responded that their snoring is light (like a deep breath), 60% said their snoring is loud (as loud as their voice tone when they speak) and 20% answered their snoring is very loud (louder than their voice tone). From those who answered "very loud", some confessed they were already diagnosed with sleep apnea and are sleeping with a CPAP mask.

In the question **"Has your snoring affected you in any way?"**, 5 of the 15 interviewed reported that it hasn't, 3 persons confessed they try to avoid sleeping next to others (friends or

strangers) because they feel ashamed of their snoring problem, some said their partner and themselves sleep in different rooms or they complain about their snoring.

At the question **“How do the person living with you deal with your snoring?”**, some reported their partner got used to it or that they share the same snoring problem. Other interviewed confessed they try different solutions like waiting until the partner falls asleep first, sleeping in different rooms or using earplugs. Others answered that they don’t do anything at all.

To the question **“How are you managing your snoring?”,** 4 persons reported using devices to reduce their snoring problem like CPAP masks, palate braces or nasal devices. One person said to be trying to lose weight to solve his snoring problem and 5 try to change sleep positions.

At the question **“How important is it for you to solve your snoring problem?”** (0= not important at all; 5= very important), two persons answered that it was not important at all, one person answered 2, 2 persons responded 3, three persons answered 4 and five persons answered 5, meaning very important.

At the question **“Would you do home therapy to solve your snoring problem?”**, 11 persons said yes, while 5 persons said no.

Finally, at the last question **“What would be for you the best moment of the day to do these exercises?”**, only one person answered early in the morning and one during lunchtime, 3 said at the end of the day and the majority of eleven said in the evening (before going to bed).

With this questionnaire I could conclude that persons with louder snoring are more susceptible to find important to solve their condition than persons with lighter snoring.
As well, persons with loud to very loud snoring who found out to suffer from sleep apnea, are as well more aware of the health risks that their snoring/ sleep apnea trigger and are already using devices to reduce this problem.
Some of the louder snorers reported it has an impact on their relationship, with their partners complaining or going to sleep in separate rooms.
Snoring acceptance and behavior regarding others also differs whether snorers are male or female. While persons snoring, regardless of their gender, admitted that they feel bad for disturbing others with their snoring and try to avoid as much as possible to sleep in shared spaces or next to strangers, only women questioned confessed feeling ashamed of it.

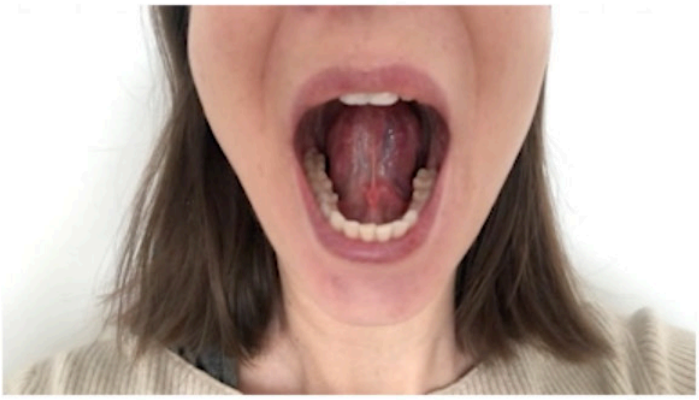
This questionnaire was important for me in the context of this project and in a still early stage of field investigation, because it helped me to know what other people's perception of snoring is. This seemed to be an important topic to research about, once the importance someone gives to this condition might affect his motivation to search for solving solutions and keeping the focus during therapy. As we know it, snoring is often an underestimated condition, which is most of the time associated with sleep quality/ comfort than health related problems.

## Myofunctional therapy research

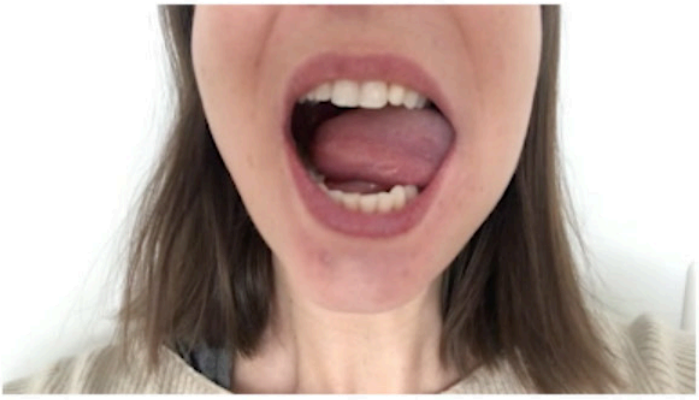
Within this project, I had the chance to get in touch with different experts which are also the founders of this cooperation partner company and are a very multidisciplinary team.

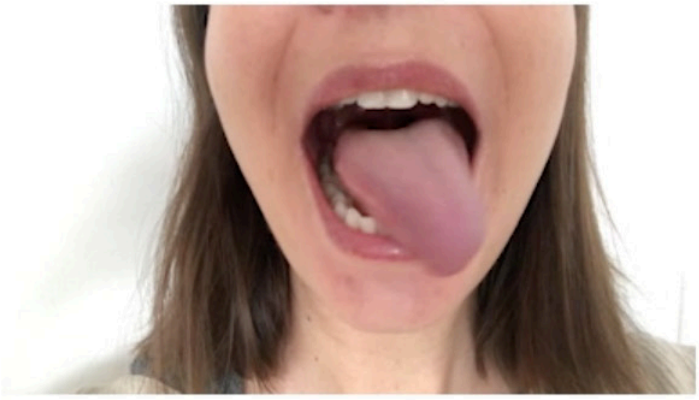
I learned about Myofunctional therapy to be an effective treatment against snoring and sleep apnea and moreover for mouth misalignment, speech and swallowing disfunctions.
Under advice from Dr. von Jackowski I started to research the myofunctional exercises used specifically for snoring therapy. As Dr. von Jackowski already told during our different interviews, there is no specific universal myofunctional therapy plan used to solve snoring but instead, there is a very wide range of exercises that are combined differently by each therapist. This information from one side did not reassure me in my research but on the other hand it gave me freedom to explore all the possibilities of therapy exercises.
I decided to create a matrix of the exercises that I found to be effective and explored other movements (basically I tried to get an overview of all possible movements someone can do with his tongue).

Figure 8 – Myofunctional exercises







I gathered 16 tongue movements that could be used during snoring therapy.
Some using the intermittent pronunciation of oral vowels like “A-A-A” are called isotonic exercises, while other continuous pronunciations like “AAAA” are called isometric exercises. These exercises require a tension on different muscles of the soft palate and throat which makes them good exercises for therapy. Other exercises, such as the tongue positioned on the floor of the mouth, tongue sucking upward against the palate and tongue sliding back and forth, as well as tongue going in and out of the mouth, moving left and right or up and down and tongue folding are good exercises to reinforce the tongue muscle.
I concluded that almost all possible movements of the tongue are effective for strengthening the muscle and for therapy, but not all movements were suitable to be tracked by pressure and touch sensors.
From these 16 exercises, together with a technology specialist, I selected only 5 of the exercises which could work with the tongue device we are designing for this project.
After establishing these possible exercises, I started investigating how they could be integrated with the tongue interface and more importantly with the sensors.

## Tongue affordances

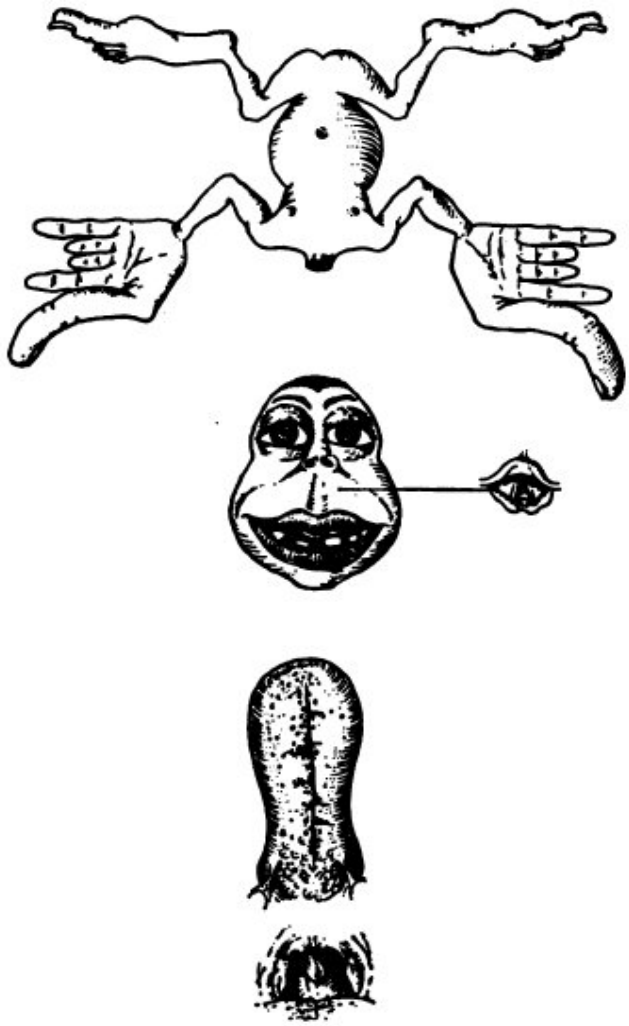


Figure 9 – Homunculus, 1937

Tongue and mouth occupy a significant amount of sensory and motor cortex in the human brain, rivalling with the fingers and the hands for example.

The homunculus shows a distorted human-like figure indicating the amount of cortical area dedicated to motor or somatosensory functions of each body part. The amount of sensory receptors on the tongue's surface is comparable to the number of sensory receptors on the hands' surface. Similarly, the number of brain cells that are dedicated to control tongue and mouth movement are approximately the same as the number of cells for controlling our hands. (Coren et al. 2004)

The tongue is an epithelial sac filled with muscles and connective tissue; these muscles can be controlled willfully and are generally referred to as skeletal muscles or voluntary striated muscles, which are divided into intrinsic and extrinsic muscles (Brand and Isselhard, 2003). In addition, the tongue has various functions: preservation of the position of the teeth and expression of feelings, speech, swallowing, and mastication.

As the tongue is a very flexible muscle, it can move rapidly and accurately within the oral cavity, which indicates its high capacity for communicating with the brain. Its motion is intuitive and does not require over-thinking or concentration.
From an interaction design perspective these seem to be great conditions to develop a concept of a tongue interface in which the tongue not only is the mediator between the user and the interface but as well is the main subject to rehabilitate to reduce snoring. As said before,

the tongue has an extraordinary capacity for sensing as well as a “memory”. Due to its high sensibility, the tongue can feel very small textures on the surface of the teeth.

Tongue somatosensory function, as said before, rivals with fingertips accuracy to feel surfaces and to identify textures.
While fingers can touch a very wide amount of superficies due to their location on our body extremities and are used to interact with many different devices in the everyday life, the tongue contrariwise, for being located inside the oral cavity, is more limited in access for interactions with external textures.
Therefore, it is true to affirm that tongue does not use its full sensorial capabilities in everyday life and that its capacities have been underexplored and have much more potential to offer. Tongue interfaces and controllers is something that only started appearing around 20 years ago. Now imagine all we can achieve in a couple of years more...

For this reason, I found it fundamental to introduce textures in the dental splint in order to explore and create more interaction for the tongue while using the interface.

## Textures and shape of the dental splint

As said before, the sensations of the tongue during the use of the interface were something that interested me to explore. In order to get some tongue position reference on the interface and to increase interaction, I designed texture and defined their position into the device to be placed in the mouth. Like this, I expected the texture to help the patient to get some sensitive affordance on the movements and tongue placement during the exercises.

I started with 3 types of textures: stripes, points (also called nipples) and grids formed by nipples aligned vertical and horizontally. The idea behind each of these 3 types of textures was to reinforce certain types of movements to be performed in certain places inside the mouth.

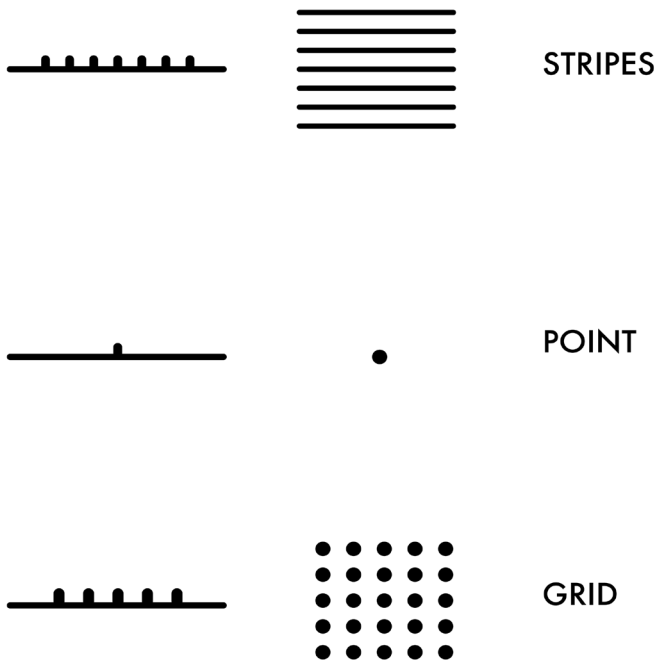



Figure 10 – Splint textures

For example, I imagined some stripe texture on the palate, perpendicular to it, which encourages a sliding movement with the tip of the tongue from the front to the back, which is one of the movements to be integrated in the rehabilitation plan.

As well, a grid setting texture located on the palate could indicate a movement of pressure applied with the tongue surface on the palate.

Additionally, 3 points positioned on the outside part of the upper jaw teeth, respectively on the second molar left, in the middle of the front incisor teeth and on the second molar right, could help to give the patient guidance while performing exercises with accuracy.

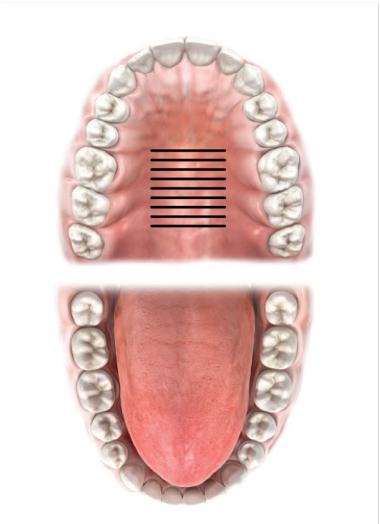


Figure 11 – Stripes texture

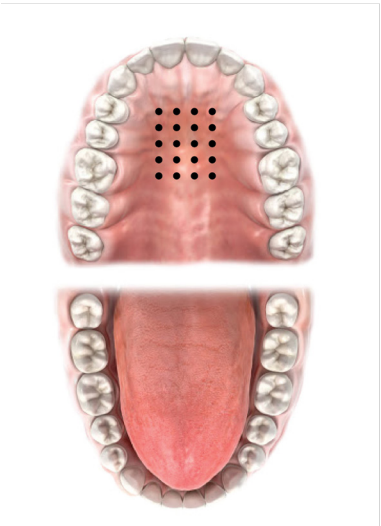


Figure 12 – Grid texture

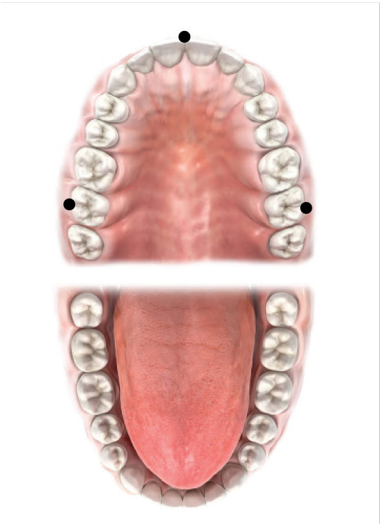


Figure 13 – Points texture

# EXPERIMENTS

## Games

### What is motivation?

Understanding what motivates people and designing systems to support motivation is of increasing interest to the HCI community. This is evident in areas including learning, game play, sustainability and the promotion of healthy lifestyles. (Balaam et al. 2011) Motivation is also a key element in every rehabilitation. It is as individual as human behaviour, and is for this reason, difficult to define.

Many different papers and articles have been written about the topic of motivation and behaviour change, with examples including expectancy/ value theory, attribution theory, social-cognitive theory, goal orientation theory and self-determination theory (Cook et al. 2016), to only name a few. Concepts defined by these theories have been used to develop motivation design strategies to engage users in different contexts.

In expectancy-value theory, motivation is a function of the expectation of success and perceived value. Attribution theory focuses on the causal attributions learners create to explain the results of an activity, and classifies these in terms of their locus, stability and controllability. Social-cognitive theory emphasises self-efficacy as the primary driver of motivated action, and also identifies cues that influence future self-efficacy and support self-regulated learning.

Goal orientation theory suggests that learners tend to engage in tasks with concerns about mastering the content (mastery goal, arising from a 'growth' mindset regarding intelligence and learning) or about doing better than others or avoiding failure (performance goals, aris-

ing from a ‘fixed’ mindset).

Finally, self-determination theory proposes that optimal performance results from actions motivated by intrinsic interests or by extrinsic values that have become integrated and internalized. Satisfying basic psychosocial needs of autonomy, competence and relatedness promotes such motivation. (cook et al. 2016)

Motivation is a process which is focused on a goal and it deals with both the initiation and the continuation of activity directed at achieving that goal (Cook et al. 2016), but as said before this process might vary from person to person, as well as over time.
To find adequate rehabilitation design strategies, it is therefore important to understand better what motivation is, in order to propose solutions.

## Intrinsic vs extrinsic motivation

There are two types of motivation:
First, intrinsic motivation, which refers to performing an activity for its own sake and the pleasure and satisfaction derived from participation. This type of motivation has been recognized as a critical factor in motivating continuous exercise.

Second, extrinsic motivation, which refers to the tendency to perform activities for known external rewards, whether tangible (e.g., winning medals, rewards) or psychological (e.g., praise)

In regard to rehabilitation, intrinsic motivation is the most important to achieve, especially when it comes to long term rehabilitation on a daily basis like it is the case for myofunction-

al therapy. Intrinsic motivation, as said before, is based on an internal genuine enjoyment of performing a task without being influenced by external pressure or reward. This is comparable to the act of running for example. People who like genuinely to run are more likely to keep doing it as a regular activity over a long period of time. They might always find time for this activity and they keep performing it because it makes them feel well. Other persons who do not enjoy running and do it for other reasons than the simple fact of enjoying this activity for themselves, are more likely to abandon it after a certain amount of time, because they force themselves to perform an activity they do not really like. Our highest, healthiest and most creative and productive achievements typically occur when we are motivated by an intrinsic interest in the task. The self-determination theory from Deci and Ryan, explains that intrinsic motivation can be triggered by the autonomy of controlling an action, the competence felt while performing the action and the relatedness and feeling of affiliation with it.

On the other hand, extrinsic motivation is triggered by external influences present in our society and social context. These influences come in the form of rewards, career goals, societal values, deadlines as well as penalties, sanctions and punishments. According to Deci and Ryan, these external influences might not be necessarily bad but subvert intrinsic motivation. Other theories though contradict this opinion and affirm that external pressures can, until a certain level, trigger the motivation to execute a certain task to raise the interest of performing it for himself. (Mekler et al. 2013) This can be compared to a situation of parents

applying pressure on their kids to learn to play a music instrument or new language. If the child has no interest to perform this activity, it can happen that he does it against his wish and quit after some time. But it can also happen that the child needs a first push to start an activity that initially does not seems appealing and that later in time he gains enjoyment in performing.

## Users personalities

While motivational affordances are widely used to enhance user engagement in HCI, they are often employed en masse. However, individuals with different dispositions may react positively or negatively to specific affordances.

Personality traits play an important role on the way some persons feel more motivated than others when confronted with certain types of motivation strategies. Many research papers and articles, especially in the field of game design, have been written about this topic, enhancing mostly two different personalities: introverts and extroverts. In generality, these theories of personality point out that extrovert individuals tend to be motivated by external rewards and would tend to perceive more enjoyable experiences than introverts regarding badges, points and levels. (Jia et al. 2016)

During my research about motivation affordances and users' personalities, I realized that these studies tend to categorize individuals in a very scientific way. However, even if it might be true to say that extroverts prefer some kind of incentives than introverts regarding games for example, the way an individual is categorized as extrovert or introvert seems to be very subjective.

When designing a gamified interface personalized for a certain type of user, if the categorization fails, this means that individuals might be using an interface that doesn't fit their personality or preferences. This error invalidates a whole motivation strategy and might lead the user to drop his rehabilitation after a short time.

## Perception of feedback

As well as personality, feedback perception also has an influence on intrinsic motivation. According to Deci, Koestner and Ryan, the effects of feedback are contingent. Feedback can either help people feel more competent or be perceived as controlling. If feedback from others is perceived as controlling, then it is damaging to intrinsic motivation; if feedback from others is understood as a source of information, then it increases intrinsic motivation.

This debate suggests that the characteristics and interpretation of feedback matters for motivation and raises a special attention when looking into a rehabilitation context, in which feedback occupies such an important place.
A playful interface associated to the feedback by the use of games can allow individuals to have fun while carrying out the training.

## Motivation strategies in games

Games can be powerful experiences, leveraging both motivation and engagement. The recent trend toward "gamifying" applications, however, often reduces the complexity of a well-designed and balanced game to its simplest components, such as badges, levels, points and leaderboards. (Deterding. 2012)

Health rehabilitation application and interfaces often use gamification as a tool to enhance the patient motivation and interest.
In fact, games have a broad appeal across audiences and have a great accessibility through mobile technology. However, the act of giving rewards might have different consequences regarding the context in which this is applied. What is appropriate in a context of sport training application, may not be in the context of health-rehabilitation
When using these strategies, we might think about the behavior we want to reward and encourage and strengthen the user's sense of competence and progress. The achievement should serve as a catalyst, but it is the activity and the attendance of the therapy in themselves, not the achievement, that are the real rewards for the patient.

## Game concepts

After choosing the exercises which could work well for both the interface and the tongue rehabilitation, I started investigating ways in which they could be applied and how to conjugate them together in a way to create a playful interaction.
In a first brainstorming I gathered different ideas of easy and well-known games with clear goals and with only few accessible commands.

These games objective is to be played by a wide range of users and to have a very clear and accessible goal in order to create an internal wish of playing them. Games that are too complex, need too much effort to be understood and which the goal is not clear or accessible, are less likely to be performed.
Taking into account the previous research about motivation, I found important to create

3 different types of games with different affordances and goals. This way I aim to create more opportunities for the users to find a game that correspond them and therefore to keep their motivation over long time.

The first game concept is a relaxing and meditative game;

The second is a challenging game:

And the third one is a concept of a companion game.

Each of these games have different motivational strategies and affordances which can match with different personalities.

The patient carries out myofunctional exercises which are recorded by the sensors of the tongue interface and reflected in real time in the app through different visuals/games. This allows to arise the patient interest and promotes an active participation in the rehabilitation. Moreover, through the data provided by the dental splint, the application allows the individuals to get an impression and a record of their training versus their snoring every everyday over each month since the beginning of the therapy. Overtime, the users can quantify the progress of their training in correlation to the amount of snoring which is necessary to give an informational feedback and helps maintaining the motivation.

## Relaxing concept

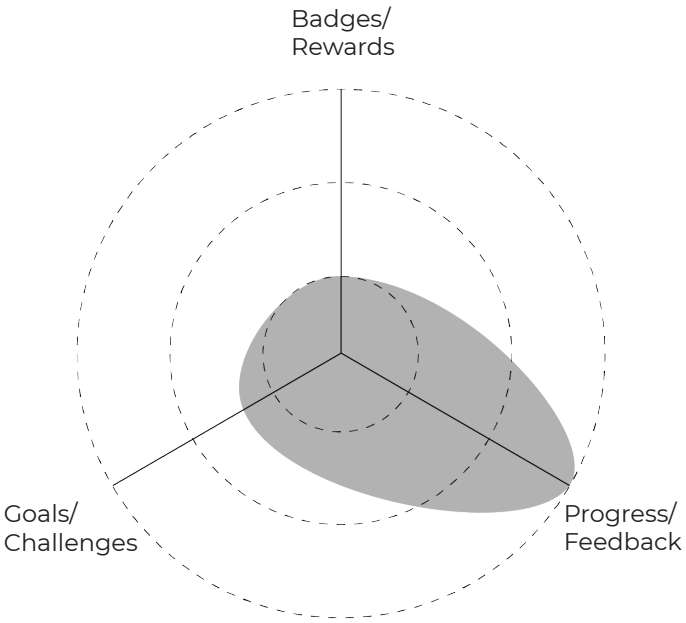



Figure 14 – Relaxing concept strategies

The first relaxation concept is not based on points and rewards and does not have an implicit perception of win or lose. This game would be adequate for a person who wants to perform his daily exercises but do not necessarily like to play or be too challenged. The inherent idea behind this concept is too focus on the movements while receiving a visual feedback of them. The visuals are based on basic or geometrical shapes with simple background, so that the focus remains in what matters. By playing this game, the user goes with the flow of his own movements.
The idea is to create a moment of relaxation and meditation during the performance of myofunctional exercises, which creates a moment of ritual every day. The goal of the game is very simple and straight forward, which makes it a suitable game to start exercising and get use to the tongue interface but also later on therapy.
Here, the challenge is nothing more than performing the movements in the right way and at a right pace. By doing so, the user gets a perception of the performed movements and can explore the possibilities of those.

In a first instance, a perfect circle appears on the screen and by moving the tongue over the sensors points the circle starts deforming and stretching. At the moment, 2 different kinds of exercises are thought for this game concept:

- Sliding with the tip of the tongue on the palate to the front and back.

- Swiping with the tongue on the exterior part of the upper jaw teeth from the left molar to the front teeth until the right mo lar and back.

More exercises can be added posteriorly. When sliding with the tongue on the palate the bubble placed on the screen starts deforming and is stretched vertically, like a bubble gum. Furthermore, when swiping with the tongue on the upper teeth this bubble expands horizontally. By repeating each exercise a couple of times, the bubble starts growing at the same time as it expands. If the user stops doing the movements, the bubble goes slowly back to its original position.

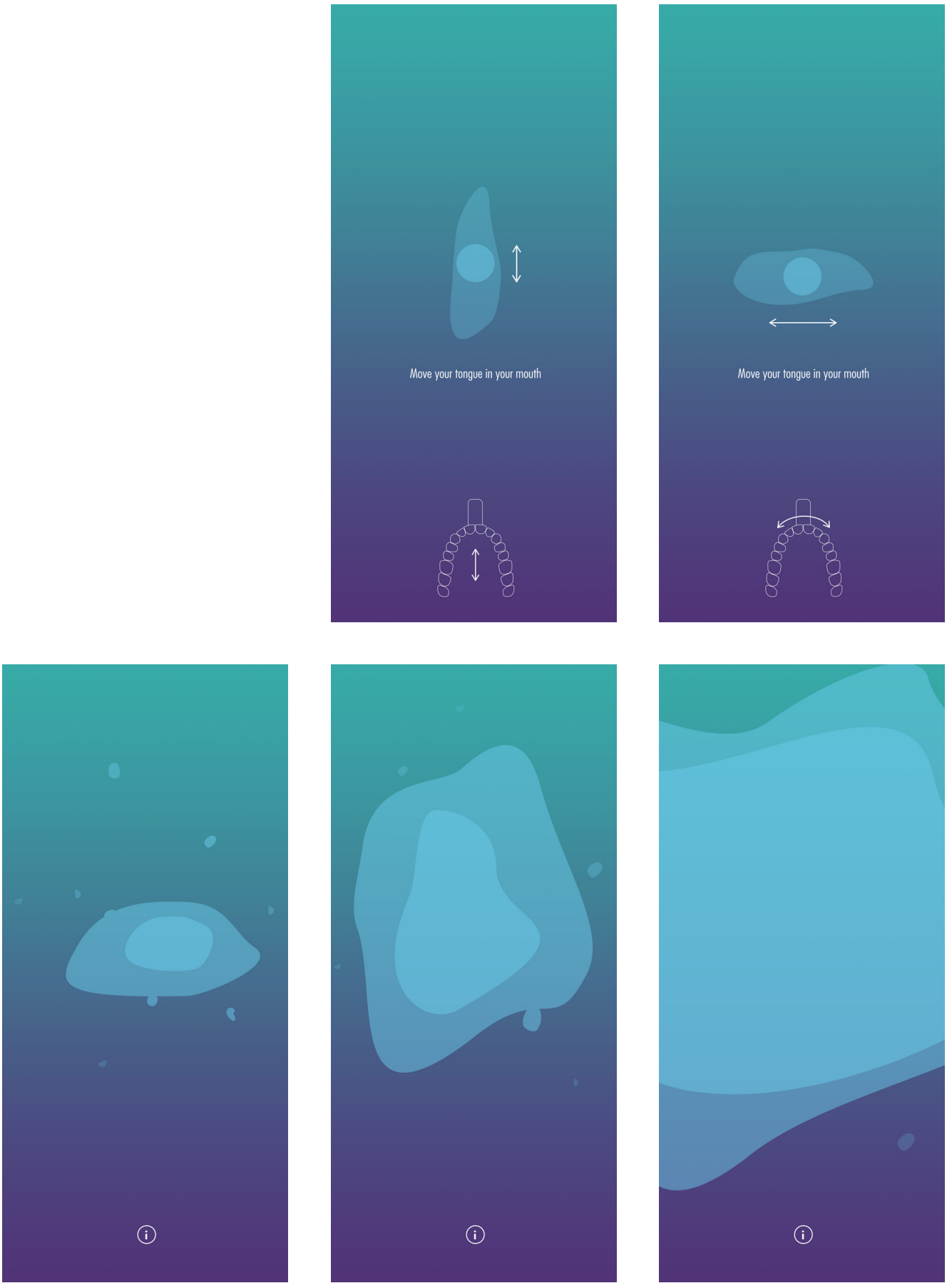



Figure 15 – Relaxing concept screens

## Challenging concept

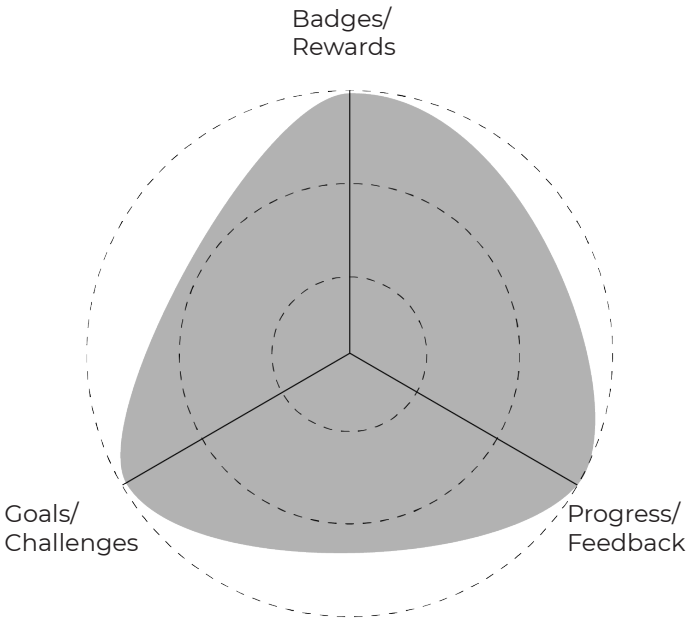



Figure 16 – Challenging concept strategies

This second game concept is based on an idea of challenging the user ability. It demands more coordination of the movements together with a specific rhythm. This game suits more persons who like challenges and seek to get better results overtime.

At the beginning of the game, balls of different colors start falling slowly from the top of the screen to the bottom. Each ball color means a point on the interface that have to be touched by the tongue at the moment the ball reaches the bottom line. This way, when 3 green balls appear on the screen, this means the user has to touch with his tongue 3 times on the palate and this in the right rhythm. After some time, the difficulty of the game increases and the movement have to alternate between different exercises. The pace of the movement should not increase in speed which would be counterproductive in terms of myofunctional therapy (doing the exercises quicker does not mean they are more efficient, on the contrary they would be ineffective). This way, this game serves not only to entertain during the therapy but as well to train individuals to do the exercises in the right pace.

In this game, a system of badges can be implemented, rewarding the user when for example e gets 3 right balls in a row and so on.

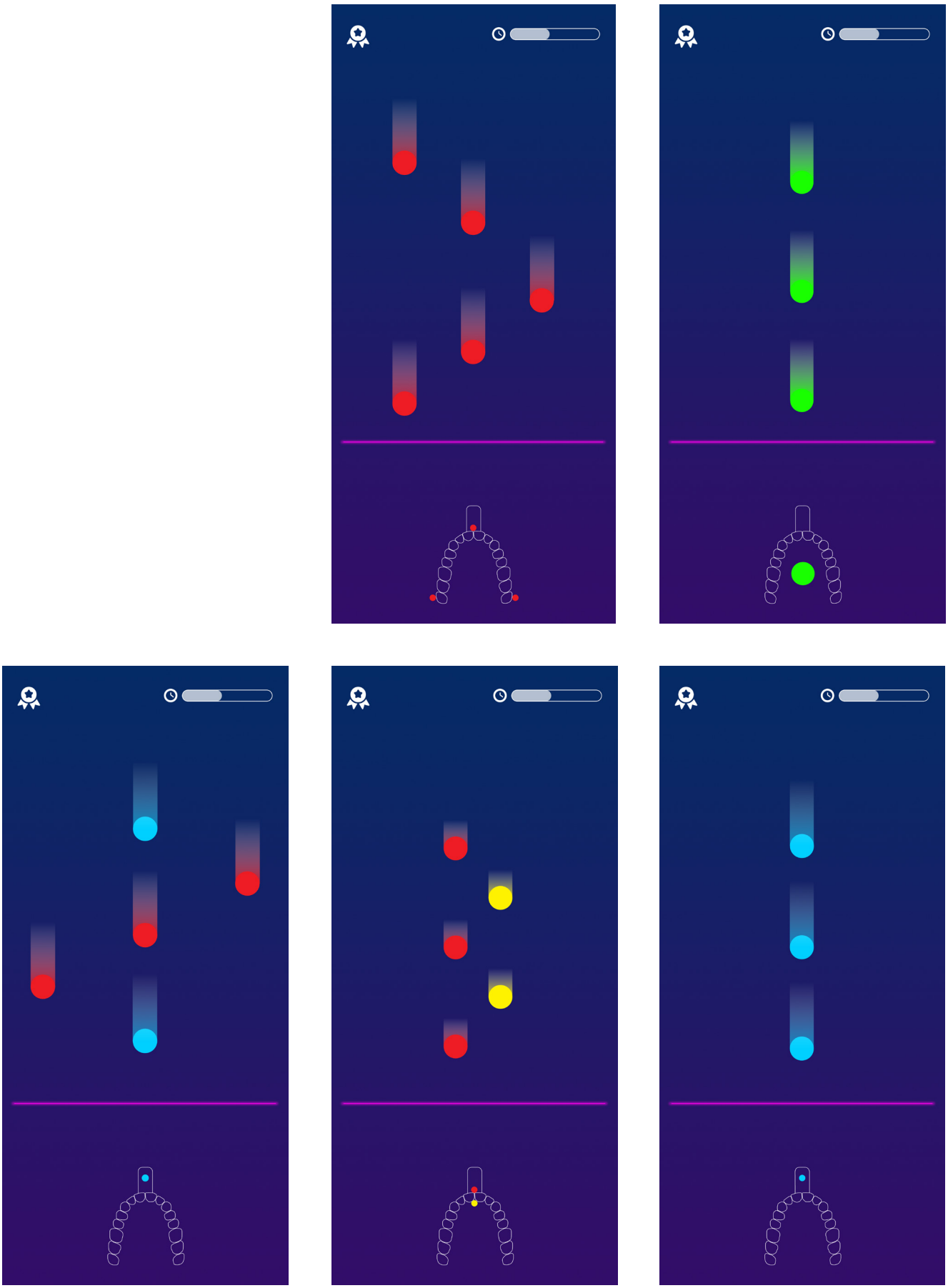


Figure 17 – Challenging concept screens

## Companion concept

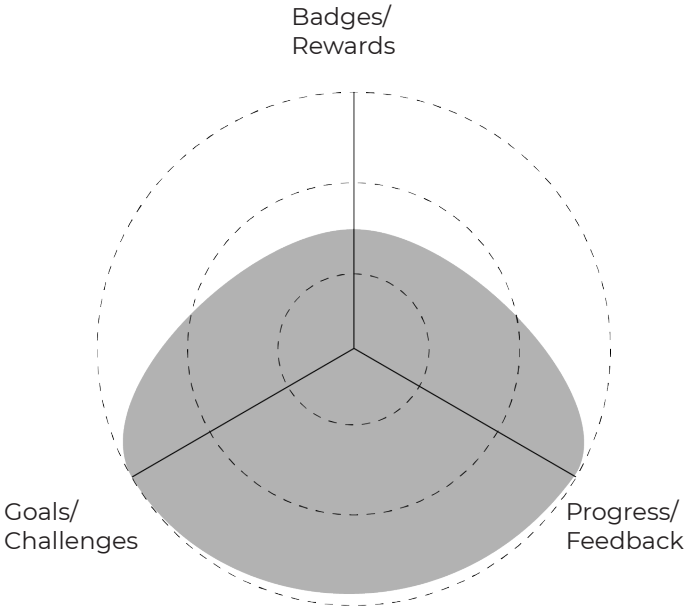



Figure 18 – Companion concept strategies

Finally, the third and last game concept is based on an idea of having a companion to interact with, using the tongue interface. Similarly to the idea of having a Tamagotchi, the patient has to perform different types of myofunctional movements to interact with his companion. This concept would suit better persons who prefer easy and simple tasks to be performed every day to nourish the relationship with this playmate.

At the beginning of the game, the companion starts little. To make it grow and evolve, the user has to feed, play and share affection with him. Each one of these actions is linked to a couple of exercises. This way, to feed the game buddy for example, the patient has to touch with his tongue on palate (which is the movement to feed) a couple of times until the companion get fed. The more these actions are performed, the more the companion evolves. In the case the user forgets to perform these actions, the companion state will change as well, showing feelings like hunger or missing the user.

This concept works as a reflection of oneself in which the user needs to take care of the virtual character as a metaphor to take care of himself. Similar studies have been developed using avatars or virtual characters in serious games related to health. In the words of Ferweda, “caring for a Tamagotchi stimulates the creation of an emotional attachment and awareness of how to take proper care of a pet.” The game taps into our basic psychological need of relatedness, which includes taking on responsibility through nurturing, caring, and the enjoyment of interacting with a pet. (Ferweda et al. 2019)

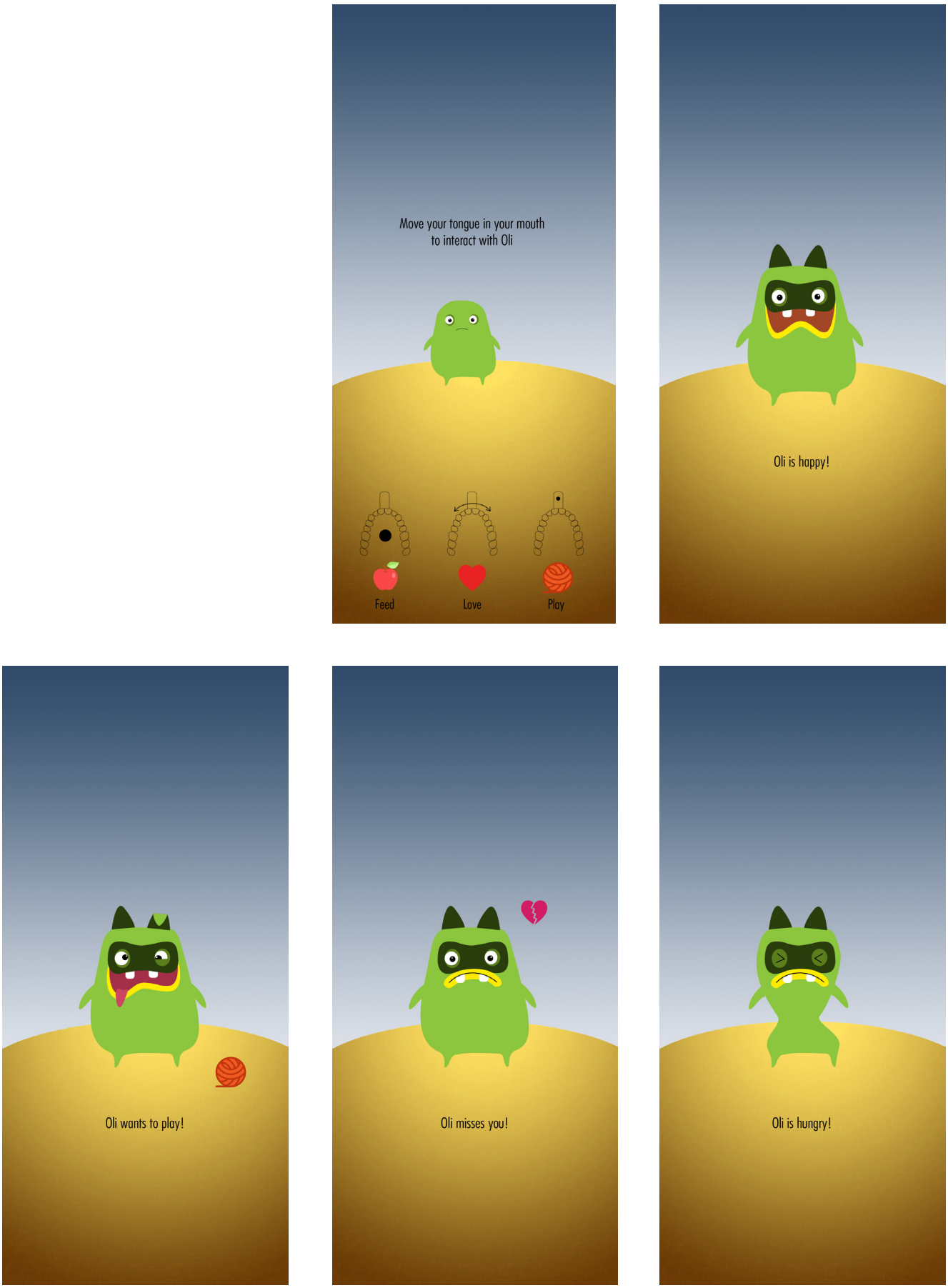
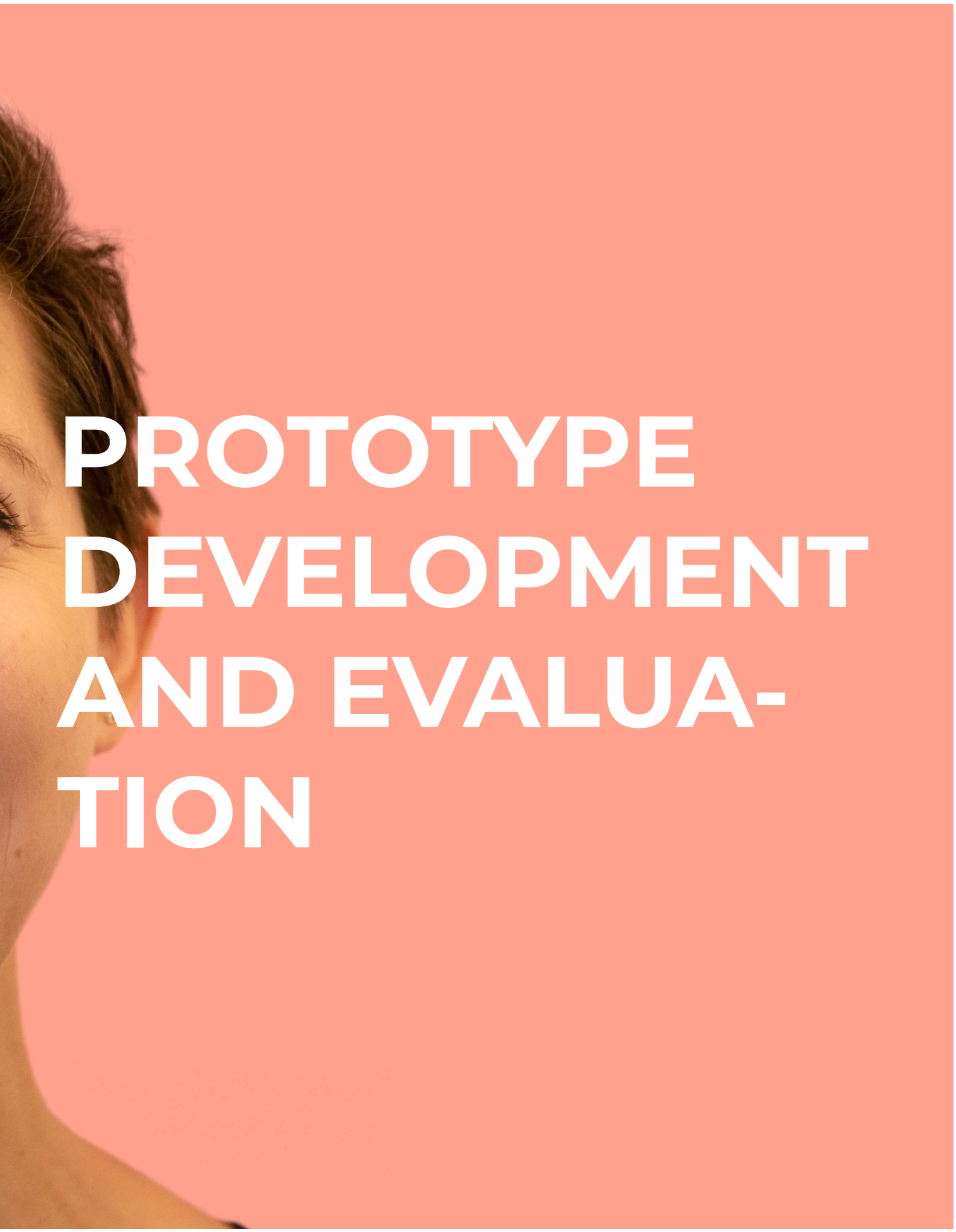



Figure 19 – Companion concept screens



# PROTOTYPE DEVELOPMENT AND EVALUA-TION

## Splints textures

During the project phase, different prototypes have been tested but with some limitations. Indeed, a week before the Covid-19 lockdown, I was able to go to Bottmedical to get a scan of my teeth. This scan consists on a digital 3D model of the inside of the mouth which is then transferred to a computer. From this 3D, a model of the upper jaw teeth and palate is done with a 3D printer. Then, a plastic foil is thermoformed on top of it which creates something very similar to a dental splint.

During the lockdown as all the facilities were closed, it was very difficult to be able to do this splint prototype. Only one person per day twice per week could access the facilities, therefore this took more time than otherwise expected. As well, due to this problematic and because of social distancing concerns, it was impossible to gather more users to do dental scans and later on to try the dental splints.

However, I was able to get different dental splints of my teeth with the textures that I designed in an earlier phase of the project. With this prototype I could test how the different textures feel like when touching them with the tongue.
The textures seemed to be well positioned, however due to material thickness the textures on the splints lost definition and were not protruding enough. Apart from that, the different splint thicknesses I tried worked both very well and I could feel that it was not intrusive to wear the splint.

The prototype though had an open palate because of a technical issue regarding the 3D data from the digital file. In furthers iterations, the splints should have a closed palate, how-

ever the acceptance of the splint is something to be tested on different users, once some persons may feel uncomfortable if an object goes too far back on their mouth.

**Sensors**

A prototype with integrated sensors on the fabricated splints was planned, but again, the production of these had to be postponed. However, it was possible to do similar tests with FlexiForce sensors. The constraint was however that each sensor being connected separately, made it very difficult to do any movement with the tongue.
A more final prototype should gather all technical content inside of a small handle positioned on the outside of the mouth.

**Games**

To test the relaxation games concept interaction with sensors, a quick prototype with an early stage of the games visuals was programmed. Despite the difficulties with the sensors mentioned above, it was possible to test the interaction with the visuals. The experience of the input/ output of this game concept was very interesting to try.

**App**

The design of a mobile application was an important step in this project. It gathers all the elements that have been researched and defined in the last months of work. As well, this application is the visual part of this interaction design project and makes the bridge between the interface and the games.

Before starting the wireframes, a workshop was organized with some of the experts included in this project. It helped to gather more

Figure 20 – Dental scan

Figure 21 – Splint textures prototypes

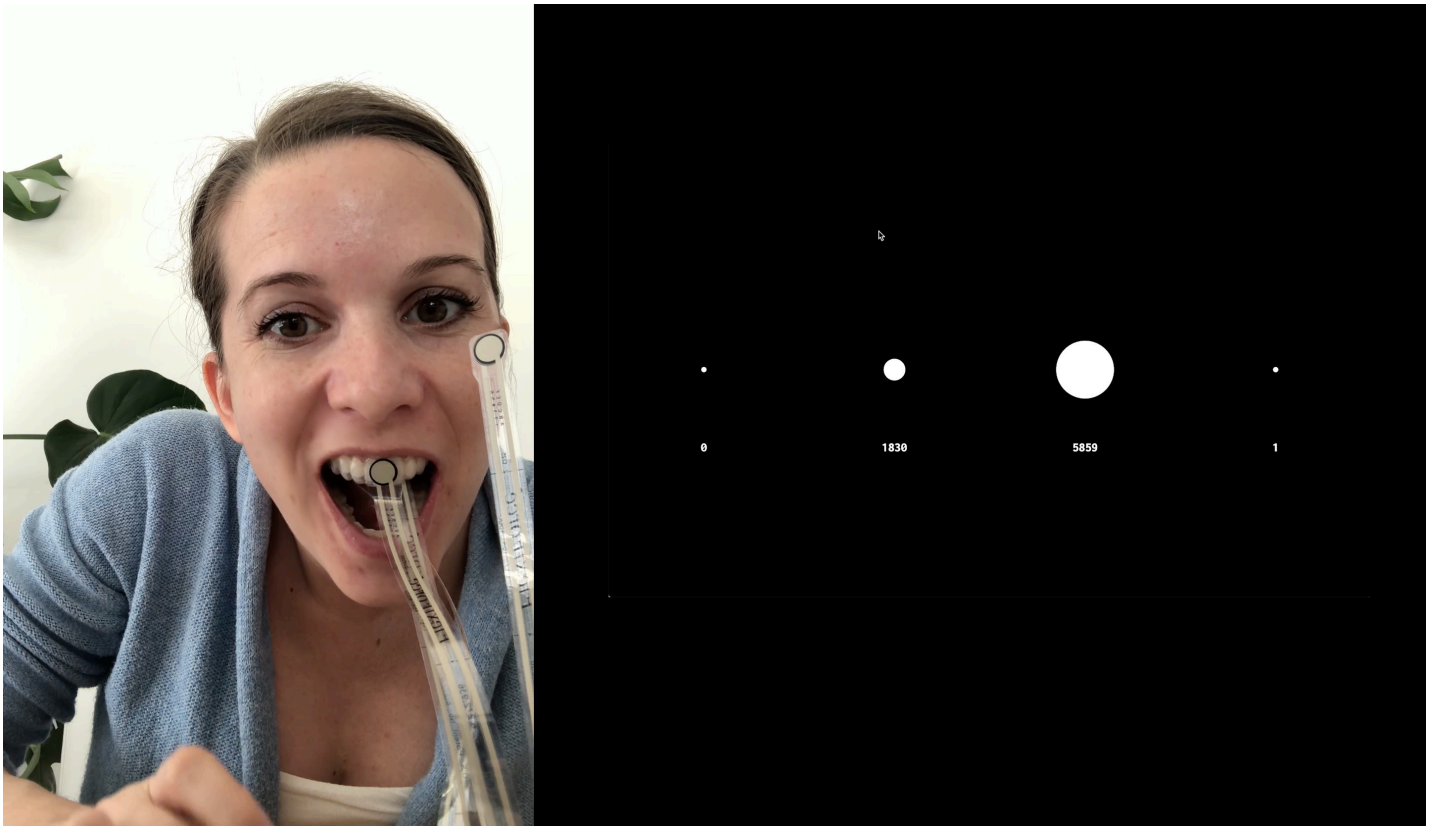



Figure 22 – Sensors experiment


Figure 23 – Mobile application


START RECORDING
Activation delay
STATISTICS
APRIL
GAMES
LET'S START!
SNORING & SL
Snoring
Snoring is caused by slack tissue in the
increasing resistance for the air to pass th
(Dilkes M. and Adams A., 2017). In addition o
and muscles in the throat and soft palate also
naturally relax when we sleep. The combination o
these two factors plus the loss of strength of some
muscles leads to the vibration or flapping of the
tissues or the falling back of the tongue obstructing
the airflow.
Sleep apnea
Sleep apnea is a sleep disorder characterized by
repetitive episodes of upper airway occlusion during
sleep, as well repetitive episodes of complete (apnea)
or partial (hypopnea) upper airway obstruction
occurring during sleep. This occurs when the
that support the soft tissues in the throat, su
tongue and soft palate, temporarily relax,
muscles relax, the airway is narrowed
breathing is momentarily cut off. Th
breathing affects at least 4% of
(Young et al., 1993).
This condition is accompa
sleepiness, a higher risk
quality of life (Hui Ch
linked through
diseases, chron

information for the next steps, not only just about the technology behind this interface, but from a myofunctional side as well.

In earlier meetings was debated the fact that this project should somehow integrate a snoring detection functionality in order to allow the users to measure if their snoring decreases overtime and proportionally to the attendance of the training. Without this functionality, it would be very difficult to prove the effectiveness of this therapy and the motivation could therefore consequently decrease. A couple of solution have been studied as for example a partnership with the company Sleepiz, which develops devices for sleep apnea and is working on new devices for snoring detection as well. However, this snoring detection strategy would mean that an additional device would have to be added and this would overload the usability of this therapy/ service. Instead we decided to use a snoring detection integrated in our app which works basically as an audio recorder that measures the decibels overnight.

After this workshop I collected many relevant information for the app and to better hierarchize the different functionalities of the app, I organized it in 3 categories: must have, nice to have and can have. That way I could define that the main 3 functions for these app would be:

- Training and snoring data;
- Games for myofunctional therapy;
- Snoring detection.

## Training and snoring data

The first main functionality are the statistics, where the user can in a first instance find a data visualization about an overview of the proportion between the time he trained and the amount of time he snored per day during a month.

On the first screen of this statistic function, a wheel displays the amount of data of a month divided by

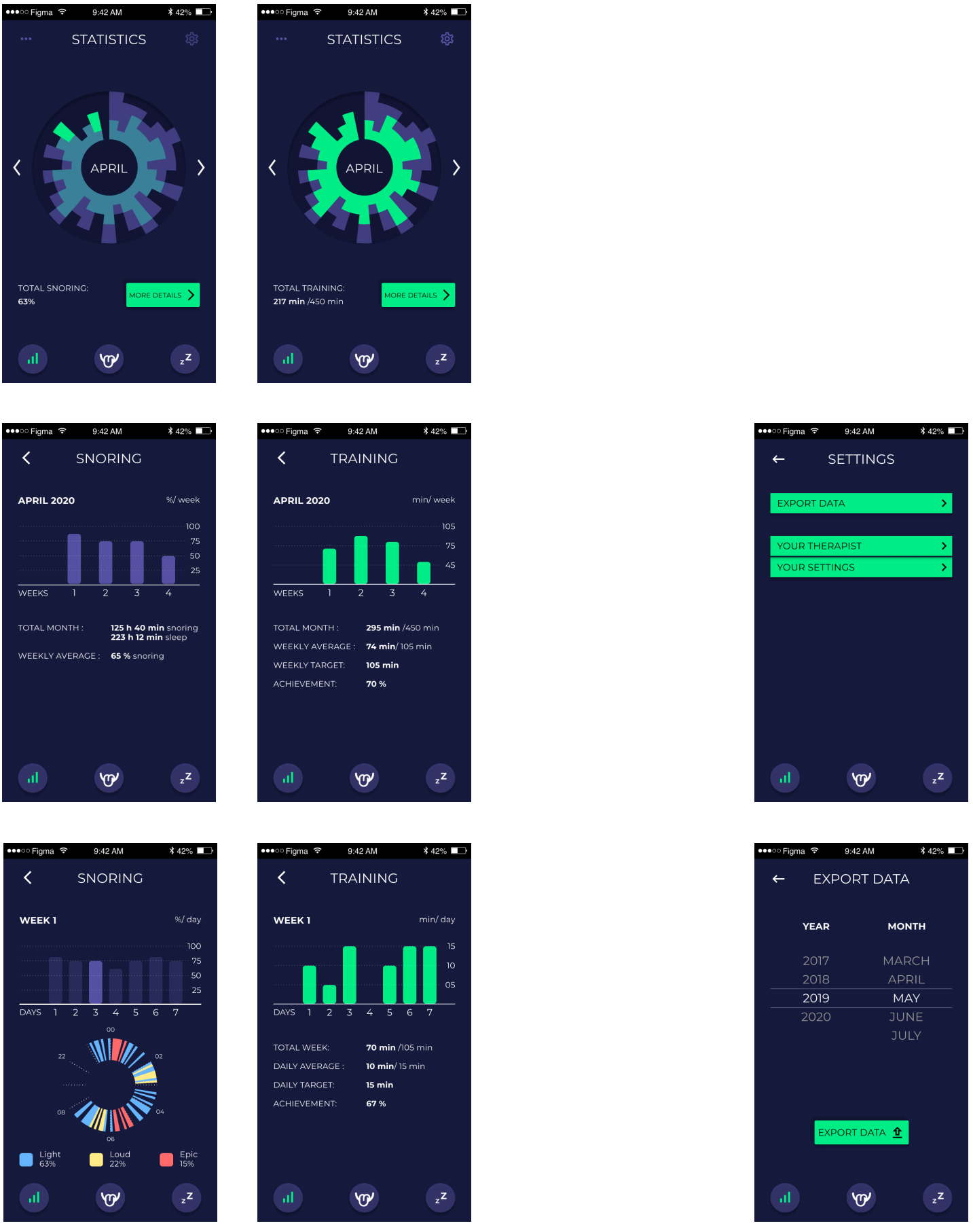



Figure 24 – Mobile application screens

31 days. The green color indicates the amount of time trained and the violet indicates the proportion of snoring during each night of sleep. This scheme displays 2 different information (training and snoring) measured in two different kind of values: training is measured in minutes per day, while snoring is measured in percentage of time per night.
The reason why snoring is measured in percentage is that we usually don't sleep always the same amount of hour per night and therefore it would be erroneous to say, for example, that on the day-x the patient snored only during 2 hours in comparison to the day-y, on which he snored around 4 hours, when on the day-X the user slept only 6 hours and on the day-Y he slept 10 hours. For this reason, this wheel compares training and snoring in a comparative way.
Further screens show separate information about training or snoring per week of the month or days, more in detail. This part of the app is primordial to present information and raise health awareness, enabling users to monitor their own health.
In the users preferences, the patient can select the month and year of the data he wants to export and send it directly to his therapist.

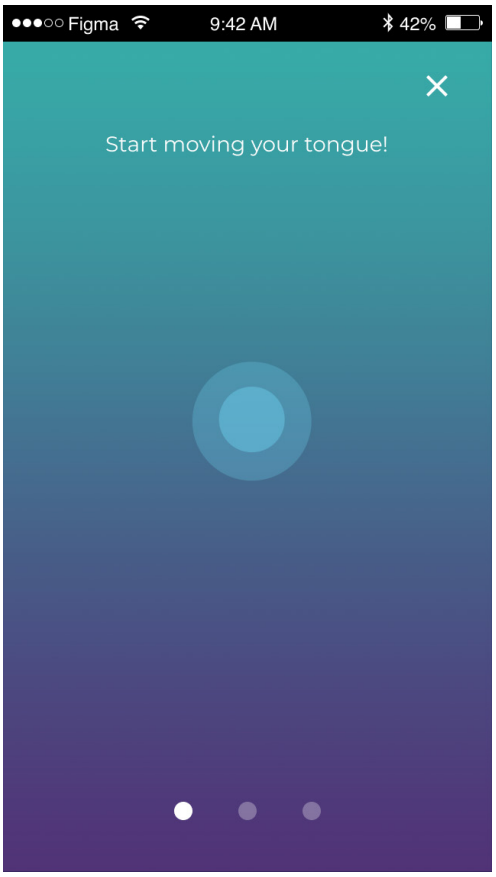
## Therapy games

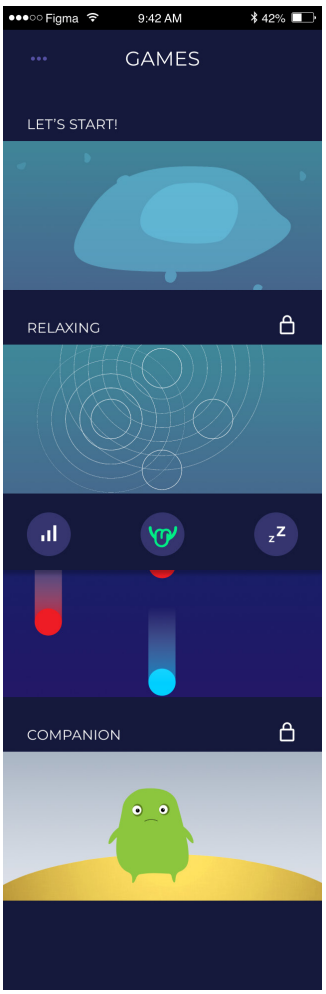
The second main function of the app are the games defined before. As a strategy it was thought that a beginner user only has access to a first very easy game, in order to get familiar with the tongue interface and have a first interaction experience with the games. It might need an initial time to get used to the device in the mouth and as well as to experiment the different kinds of exercises. After a certain amount of time (to be defined), other games

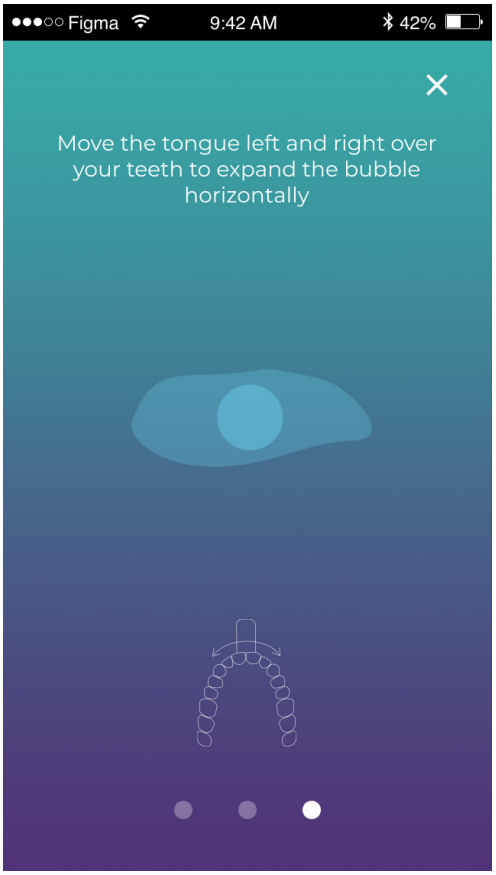
are unlocked, and the patient can freely experiment them all. According to their personality and interests, individuals might be more attracted to one or the other game concept.

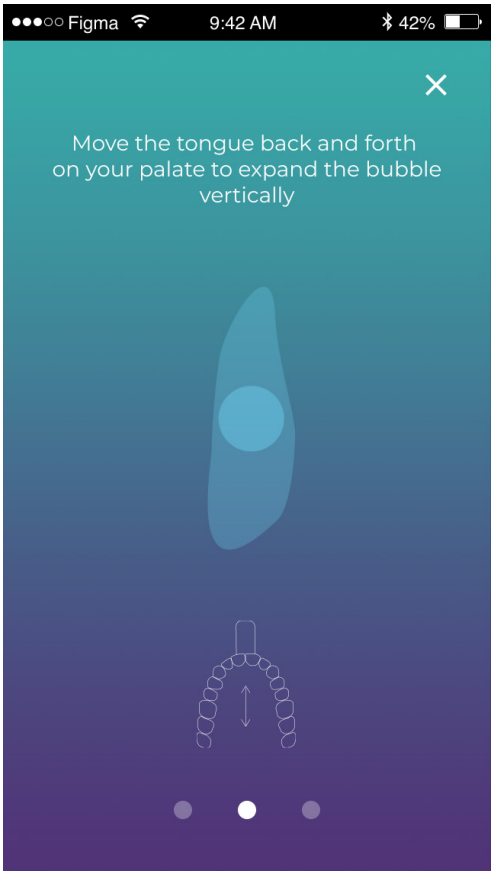
Instead of categorizing and label a user introvert or extrovert giving him access to only some games which might at the end not fit his interests, the strategy is to let users explore the different games and chose the right one. This way we can offer variety of games which can fit different persons, without forcing them into categories.
When choosing a game to play, the patient can start immediately to play, or he can see a small introduction about the game and the tongue movements to do in order to play the game.

Figure 25 – Games screens


Figma 9:42 AM 42%
Start moving your tongue!


Figma 9:42 AM 42%
GAMES
LET'S START!
RELAXING
COMPANION


Figma 9:42 AM 42%
Move the tongue left and right over your teeth to expand the bubble horizontally


Figma 9:42 AM 42%
Move the tongue back and forth on your palate to expand the bubble vertically

## Snoring detection

The third main function of the app consists in the setting of snoring detection. This function is very straight forward, yet very important once it has to be used every night in order to collect the snoring data overnight. For this reason, I choose to put it in a separate tab, to be intuitively and easily accessible.

## Colors and theme

This mobile app has a dark overall visual with dark blue background. The action buttons of primordial information are in a vivid green as well as violet as a secondary color. The reason for this dark aesthetic is that mostly, this application will be used on the evening during therapy before going to bed. Therefore, dark color background has been chosen similarly to a night modus, to not be so aggressive to the eye. During the research phase of this project, when interviewing snorers about what time of the day they would preferably do their snoring therapy the vast majority answered on the evening or before going to sleep. Some said that this is when they have more time to dedicate to this activity and as well because they prefer to use the dental splint after dinner, once they have brushed their teeth.

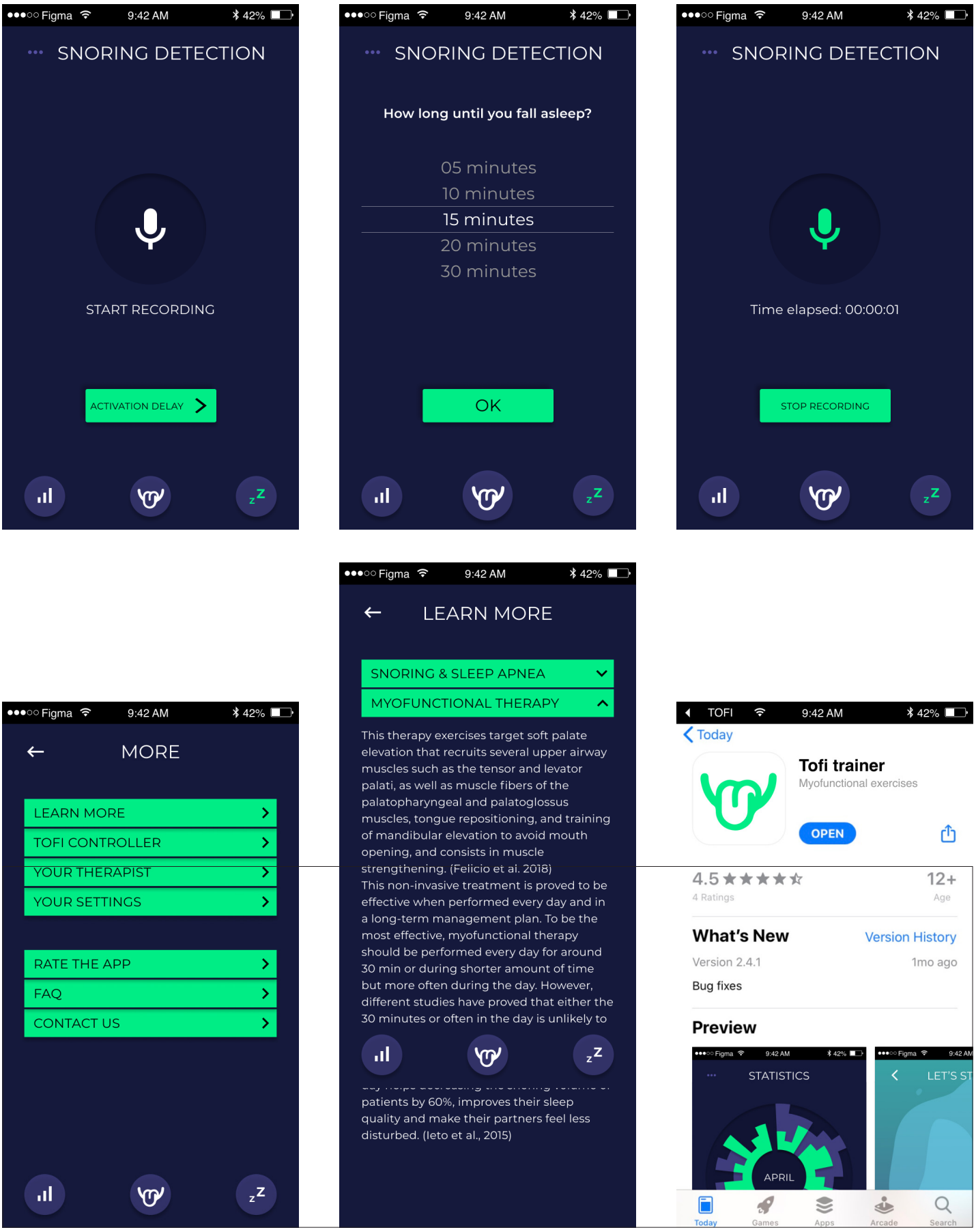



Figure 26 – Mobile application screens

# CONCLUSION

## Contribution

With this thesis and BA project I hope to open up some new perspectives about motivation strategies in rehabilitation.
Throughout this process, I learned very much about motivation perception, and I believe that human motivation cannot be only triggered through rewarding systems and exterior pressure to accomplish a particular task, especially when this task has a direct influence in someone's health rehabilitation.
Instead, finding an approach to make a daily activity be something pleasurable and enjoyable, can activate someone intrinsic motivation and the wish of continuing to execute it during a longer time.

Many solutions for health therapies often use gamification as a tool to enhance the patient motivation and interest. In fact, games have a broad appeal across audiences and have a great accessibility through mobile technology which attracts many different users, however we should not forget that therapy plans should be performed for the sake of rehabilitation itself and not only to play.

From the games concepts, one which retained the most attention was the relaxing feedback because of its innovative concept in the context of rehabilitation. Indeed, contrarywise to many rehabilitation games, this one does not try to push the user to the idea of wining, be the best, perform better scores or getting more rewards. It is based on the idea of being instructed to simply enjoy this moment of therapy ritual.
I believe this can be an innovative way to approach motivation strategies in rehabilitation.

## Findings and further steps

### Sound and motion tracking

During this conceptual phase, with the help of experts and literature, I found out which are some of the best exercises for tongue rehabilitation, and I searched for ways to integrate them into the interface. Not all exercises are suitable for the dental splint, taking into account that we use pressure sensors to track tongue movement. Some exercises, like the isotonic and isometric ones, use mostly voice sound and mouth posture to perform the exercises. However, this is not detectable with pressure sensors.
As well, some exercises like tongue folding or movements of the tongue out the mouth were not selected for the same reasons. A question of other ways for tongue tracking, like sound or motion track, arose in the follow-up of these problems.
However, regarding face tracking, it is known that tongue is difficult to track via image tracking, because of the lack of contrast between the skin of the tongue and the skin of the face. Furthermore, it would be very complicated to recognize the different movements with accuracy, not to mention that some movements happen inside of the mouth and are therefore not visible.

In this project further steps, new technical possibilities for the tongue interface can be considered and explored. Tracking the tongue movements with a camera integrated in the dental splint or infrared sensors which track motion, as well as sound recognition, is something that can be taken into consideration and could be tested in the future.

### Game concepts and user tests

As well, new games should be developed together with myofunctional therapist advisors, to choose the best therapy plan to be integrated. New game concepts with different game affordances should be added to the list of games, in order to give the user more choice for exercising. A phase of user-testing is as well primordial in this project further steps, either for the tongue interface, the games or for the mobile application.

### Tongue interface design

Another challenge for the next steps of this project is to do some advanced prototypes to experiment the textures on the splint together with different design solutions for the dental splint.
The shape of the interface is something which deserves some detail. The splint placed on the upper jaw needs a handle that houses the battery and microchip which runs the hardware of the interface. This element might be as big as a small USB stick, placed next to the front teeth, but its position might interfere with the performance of some exercises like the tongue swipe on the outside part of the upper teeth. Therefore, the design of the dental splint is something to take into account together with an industrial designer, for the next steps.

### Suitable fields

This technology, because of its high potential can also suit other fields related with tongue movement like speech therapy or orofacial disorders treatment for example. This way, other possible directions for further development of this project can be considered.

## Reflection

### Process

During the process of this project I first started to dive into the topic of myofunctional therapy and snoring rehabilitation. I read an extensive amount of related literature in order to get a good understanding of this topic.
Furthermore, I did a lot of self-experiments. From tongue movements, textures prototypes and sensors affordance with the tongue.
Throughout the process of this project I tried to cover the biggest amount of directions, sometimes with great limitations that a lockdown in a pandemic time can carry.
I developed different concepts, as well as visual propositions for the games, while investigating thoroughly the topic of long-term motivation.
Finally, I designed a first version for the mobile application with the concern of integrating all elements in a balanced and intuitive way.

### Lessons learned

With this project I had the opportunity to investigate and learn about a topic that I would not necessarily have explored otherwise. I learned many interesting information about snoring and sleep apnea and its repercussions on health that I unknown so far. The topic of myofunctional therapy as well as motivation, were as well fascinating to explore throughout the process of this project.
After the completion of this project, I will for sure retain the amount of new information that I learned, either through self-research or through the different experts with whom I was lucky to be able to learn.

**Cooperation**

I started my last year of Interaction Design without really knowing beforehand what kind of final project I wanted to do. However, I always reflected about the students from the years before me and saw them working hardly during months to deliver a Thesis and practice project, to present it in front of a jury for 10 min and then all of a sudden it was over. With few exceptions, the majority only retained the experience and the lessons learned.

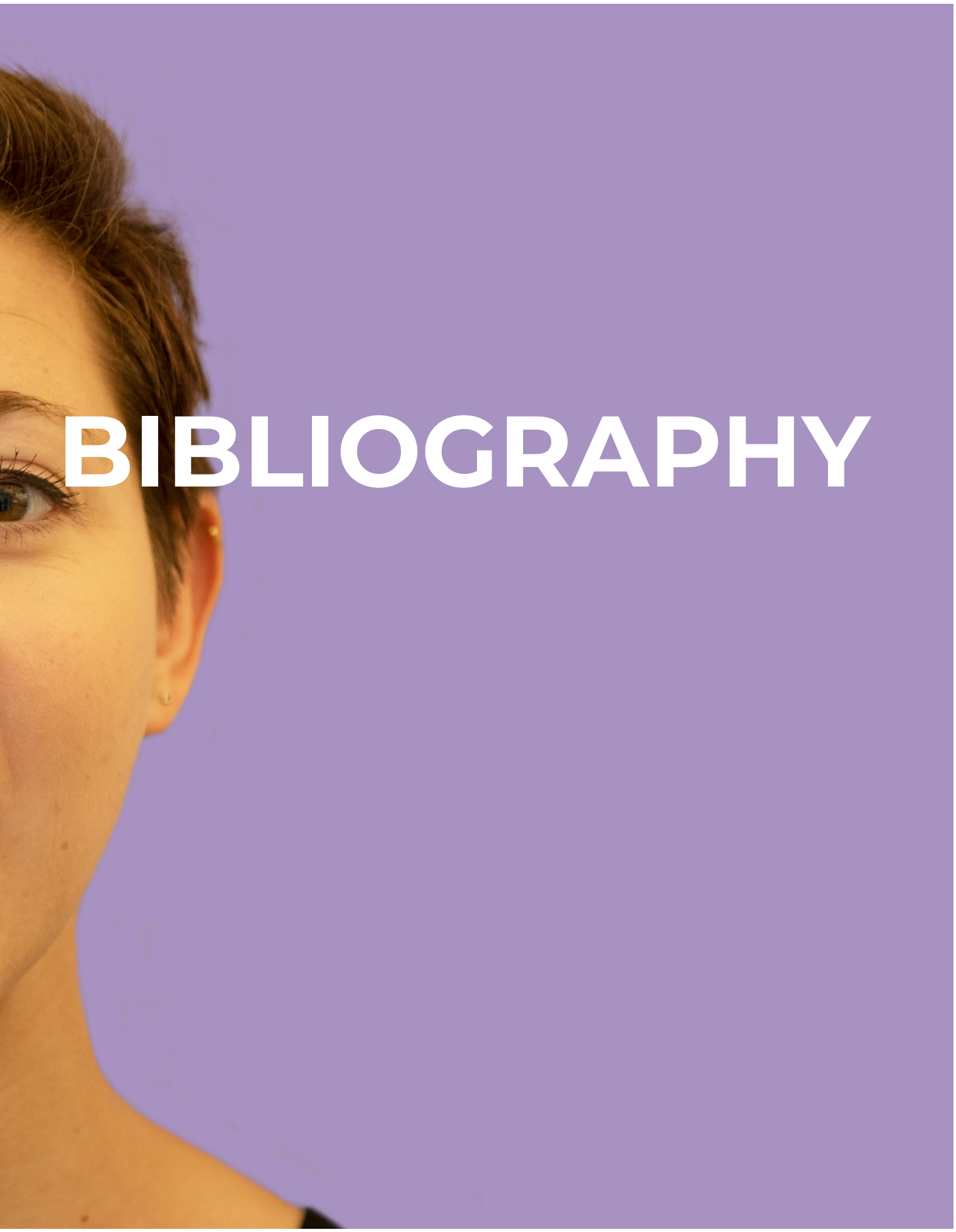
I always thought I would like to work on a project which could continue further after the end of my bachelor, if I had the opportunity. I started orienting myself very soon to health-related projects and ways to help through design methods.
First, because this is a topic which interests me and also because I wanted to tackle a real problem to solve.
When I first heard about the possibility of integrating this project about a tongue interface to solve snoring issues, I immediately got interest on this project. This was not only an interesting topic but also something innovative. To work within this project for my BA final was a great opportunity and I am very grateful for having this chance.

I had the possibility to work within a great team of very competent experts and I learned so much from each one of them. I also always felt supported and valued and felt that I was free to really contribute with my work and ideas on this project, which is not always the case when working together with collaboration partners.

I now got the chance to continue working within this team and project which is the best

ending and opportunity, these 3 years of Interaction Design studies could have given me.
More important, I found out that research is a field a want to continue to explore and working in.

Throughout these last 3 years I asked myself many times in which direction I would like to work within Interaction Design. The truth is, that this field is so broad that it can be sometimes easy to get lost. Now I know that researching about a topic to understand it from as many angles as possible, to be able to propose design solutions to improve someone's life or find new approaches, is something I enjoy and would like to continue to do.



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