ChillFish: A Respiration Game for Children with ADHD

Tobias Sonne

Department of Computer Science
Aarhus University, Denmark
tsonne@cs.au.dk

Mads Møller Jensen

Department of Computer Science
Aarhus University, Denmark
mmjensen@cs.au.dk

ABSTRACT

Breathing exercises can help children with ADHD control their stress level, but it can be hard for a child to sustain attention throughout such an exercise. In this paper, we present *ChillFish*, a breath-controlled biofeedback game designed in collaboration with ADHD professionals to investigate the possibilities of combining breathing exercises and game design. Based on a pilot study with 16 adults, we found that playing *ChillFish* had a positive effect, helping the participants to reach a relaxed state similar to the one offered by traditional breathing exercises. Further, we analyze the opportunities and challenges of creating a tangible respiration-based controller and use it as a core game mechanic. Finally, we discuss the challenge of balancing engagement and relaxation in physically controlled games for children with ADHD in order to make a game that can be calming and still sustain their attention.

Author Keywords

Games for health, biofeedback, respiration, stress, ADHD, children with ADHD, serious games.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Children with a mental disorder like e.g. Attention Deficit Hyperactivity Disorder (ADHD) exhibit significantly more resistance around bedtime than children without ADHD [5]. Furthermore, children with ADHD also experience emotional outbursts and higher stress levels more often than their peers. For example, in the United States, more than 1 in 3 children with ADHD are reported to have high levels of emotional difficulties, which include poor self-regulation of emotions and problems coping with frustration [26]. Traditional strategies for overcoming these challenges include medication or asking the child to perform breathing exercises, as slow paced respiration techniques (e.g. [4,22])

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Figure 1. ChillFish is a calming biofeedback game designed for children with ADHD. ChillFish is controlled by the player breathing into a sensor-mounted LEGO fish.

are well-documented methods to lower an individual's stress level. Even though existing research within Human Computer Interaction (HCI) on stress reducing biofeedback applications have shown promising results (e.g. [17,20]), the existing research has some shortcomings in terms of being used by children with ADHD. First, most of the applications have been designed for adults, e.g. by being desktop applications incorporated in workspaces [17]. Second, most of the existing applications require the user to wear special equipment [1,6,14,17,20,28], which can be hard for children to put on, especially in stressful situations. Third, some projects have been in the form of biofeedback games e.g. [2,20], however, none of these use respiration as the core game mechanic. Instead they use the effect of respiration as an indirect control of ambient parameters, which can be difficult for children to understand.

In this paper, we present *ChillFish*, a calming biofeedback game designed for children with ADHD (see Figure 1). *ChillFish* is based on an interdisciplinary collaboration with researchers and practitioners from the ADHD domain. As it is often difficult for a child with ADHD to stay focused during regular breathing exercises, *ChillFish* is designed to retain the child's attention by combining a breathing exercise with a video game. Thus, it is a novel technological approach for calming children with ADHD down prior to bed, after an emotional outburst or in situations of acute stress. As children with ADHD are a vulnerable and hard to access group, we evaluated *ChillFish* with 16 adults to investigate the quantitative and qualitative effects of the breath-based interaction and using respiration as the core game mechanic. This study is the pilot study of

a series of studies and developments aiming for children with ADHD, however, here we focus only on the feasibility, design and effect of the controlling mechanism.

We start this paper with an overview of related work in biofeedback application and games, followed by a brief description of our design process and the concepts of ChillFish. This is followed by a study of the game that we analyze quantitatively as well as qualitatively. Finally, we discuss challenges in designing respiration games.

RELATED WORK

In this section, we present existing examples of biofeedback games and digitized breathing exercises that have inspired our work.

Biofeedback games use neurological or physiological data as input to control or affect a game. Biofeedback games have been used in various domains from reducing ADHD symptoms through the use of neurofeedback [15] to facilitate more enjoyable and competitive workouts by sharing heart rate data between athletes [23]. However, biofeedback is not only limited to virtual video games. Broncomatic [16] is a physical installation of traditional bucking bronco (also known as a Rodeo Bull) that has been modified so that the user's breathing rate modulates the movements of the Broncomatic [16].

As controlling a biofeedback game is very different from traditional games, Nacke et al. investigated how direct and indirect physiological control enhanced the game interaction of a 2D shooting game, and which physiological sensors worked best for which game mechanics [19]. Their study showed that participants found it more engaging to use physiological controls compared to none-physiological controller options. Furthermore, the participants preferred to use physiological sensors that were directly controlled (e.g. breath) compared to physiological sensors that were indirectly controlled (e.g. electroencephalogram (EEG)), as a result of the immediate visual response in the game [19].

Within the ADHD domain, biofeedback (especially neurofeedback) applications have received immense attention as a potential alternative treatment to medication [2,7,9]. However, these applications either require the child to wear an EEG headset or other equipment like heart rate monitors. Amon and Campbell found that the biofeedback game 'The Journey to Wild Devine' could reduce ADHD symptoms in children with ADHD [2], however a critique of this study have been raised in [27]. 'The Journey to Wild Devine' is a biofeedback game, where the player has to relax to explore a virtual world. The user's stress level is detected through sensors on the players fingers that measures heart rate and skin conductance level [2], and thus the game is indirectly controlled. Other studies have found issues with children and worn sensors, particularly with sensors on fingers [13].

Biofeedback applications designed for adults to reduce stress both include commercial products (e.g. Inner Balance

[26] and emWave2 [29]) and various research projects. Inner Balance uses an ear clip sensor to detect the user's heart rate variability (HRV), which is a stress indicator, and through an accompanying smartphone application, the user is provided with feedback on how to lower her breathing rate. Similarly, emWave2 is a portable device that measures the user's HRV and provides a visualization of breathing rate for the user to follow in order to achieve a relaxed state. Researchers have also investigated the use of biofeedback games and applications with the purpose of lowering the user's stress level. Chill-Out is an example of a research project that uses a chest worn respiration sensor as input to adapt the gameplay of a smartphone game [20]. The game's difficulty level is altered by the breathing rate of the user in order to reward sustained slow breathing. A study showed that Chill-out was more effective in lowering the participants' physiological arousal level compared to a deep breathing technique and the same game without biofeedback. Another example of a biofeedback game that uses respiration to reduce stress is reported by Moraveji et al. who explored the concept of peripheral paced respiration in a naturalistic workplace setting, and showed that their onscreen visual feedback system helped reduce the participants' breath rate [17]. Sonic Respiration [8] is an example of an auditory biofeedback system, where the user's respiration manipulates an audio signal by adding levels of white noise corresponding to the difference in respiration rate from a target respiration rate. Similarly, the Slow Floor uses auditory feedback to support reflection and mindfulness through walking [6].

Several methods for measuring respiration exist, including chest and abdominal movement detection, optical based respiration rate monitoring and airflow based methods (see [1] for a review). Most HCI biofeedback games use a worn sensor (abdominal or electrocardiogram sensing). An exception is Tennet et al.'s setup [25], where a gas mask mounted with an airflow sensor measures the player's breathing pattern and uses this as input in various games. Tennet et al. developed and evaluated five games for their setup; three where respiration was the core game mechanic and two where respiration affected the gameplay. Even though the participants found the interaction engaging in particular games, they also found the gas mask uncomfortable and disturbing [25]. It is important to note that Tennet et al. investigated the potentials for using breath as a game controller, and not on reducing stress.

We extend the existing work on biofeedback games and physiological sensing in two ways. First, by focusing on using breath as a core game mechanic in a stress-reducing biofeedback game, we explore challenges and opportunities compared to the traditional ways of using physiological input to affect the gameplay. Second, we focus on a non-worn sensor for controlling a biofeedback game, and investigate the stress-reducing effect and the experience of this type of interaction.

DESIGNING A RESPIRATION GAME CONTROLLER

We now describe insights from our design process of designing and developing a breath-based game controller. During the design process, we developed concepts and prototypes, and discussed and evaluated these regularly with ADHD professionals, including a children psychiatrist, two psychologists with ADHD expertise as well as employees at Center for ADHD, Aarhus, Denmark.

Choosing the Right Respiration Sensor

Several techniques exist for detecting respiration e.g. airflow, various vision based techniques and abdominal movement detection [1]. However, as ChillFish is designed for children with ADHD, it was emphasized by the ADHD professionals that the child should not have to put on any equipment prior to use, as it should be as easy as possible for the child to play the game. An alternative solution is using vision- or thermal-based techniques, however, vision-based techniques require special camera setup to capture abdominal movements [1], and thermal-based requires special expensive cameras [1], which limit the widespread use of the system, especially for children. Therefore, we decided to use a thermistor, as it did not have any of the above limitations, like it could also be embedded into a physical device making it easy to initiate the game.

Building a Breath-Based Respiration Controller in LEGO

Our physical design process involved an iterative process with semi-functional paper-, cardboard-, fabric- and LEGO prototypes [18]. Our first intention was to 3D-print the final controller design, however, our versions of the LEGO-based controller received positive feedback from the ADHD professionals. Thus, we decided to keep the controller in its prototypical LEGO design, as it supported a natural and playful interaction. Another benefit of building the controller in LEGO was that it enabled us to quickly change and enhance the design of the controller. As an example of this, we learned that we had to provide an air hole in the controller in order to avoid condensation within the cavity of fish, as this could affect the electronics. By building the controller in LEGO we could quickly adjust, build and evaluate enhancements in a way we could not otherwise do with e.g. 3D-printing.

THE CHILLFISH RESPIRATION GAME

We now introduce our respiration-controlled video game, called ChillFish, as a practical example of a breath-based and calming biofeedback game for children with ADHD.

The gameplay is based on an underwater 2D world where a puffer fish (the player character) has to collect as many sea stars as possible in two minutes. The vertical position of the fish character is controlled through inhaling and exhaling through a physical LEGO fish with embedded electronics (see Figure 2). When the player breathes into the LEGO fish, the digital character inflates as seen in Figure 3 and moves towards the top of the screen and vice versa, as if the player was blowing air directly into the virtual puffer fish. The sea stars are positioned on a path so that the easiest and most comfortable way for the player to collect all of them is to use a slow-paced continuous breath, similar to the breathing exercise “Equal Breathing” or Sama Vritti, i.e. inhaling for 5 seconds and exhaling for 5 seconds continuously.

Implementation

ChillFish is implemented in the Unity Game Engine, and the game controller is built in LEGO and designed as a fish to resemble the main (fish) character. A thermistor connected to an RFDuino is embedded into the LEGO fish, which detect changes in temperature when the player breathes. The sensor values from the thermistor are smoothed and sent from the RFDuino to ChillFish via a Bluetooth 4.0 connection. The movement of the player character is determined by the changes in the incoming sensor values e.g. for each time the change in temperature is larger than a predetermined threshold, the player character moves either up or down, depending on whether cold air is inhaled through the controller or hot air is exhaled into it. By using the change in temperature instead of the absolute temperature, ChillFish requires no calibration and is not affected by the room temperature.

USER STUDY

As children with ADHD are considered a high-risk group, we decided to conduct a study with adults to preliminary evaluate the game. With this study we want to investigate how ChillFish affects player’s HRV values, as these values can be used as a stress level indicator [22]. We compare playing ChillFish to doing a relaxation exercise and playing

Figure 2. Left: The LEGO breath-based game controller. Right: The inside of the controller, showing the electronic

a video game in order to investigate how these activities, separately and combined, impact the player. Furthermore, we want to get insights on how people engage with and experience the interactions with the controller and the game as such, as this can inform changes that needs to be made before conducting a study with children with ADHD.

Participants

16 adults, aged between 25 and 41, participated in our study (14 males, 2 females). The participants were recruited by word of mouth and volunteered to participate.

Procedure

For our study, we decided to use HRV as a quantitative stress indicator, based on previous research documenting the relaxing effects of slow paced respiration exercises [4,22] and biofeedback applications [8,20,29] relying on HRV as a stress indicator as well.

We decided to use a within-subject study design as this typically offers more precise estimates of variations and requires fewer participants than between-subject studies [10]. To measure how the participants' HRV values were impacted by ChillFish and compare it to other activities, all participants carried out a list of activities in a predefined structure:

- Introduction of study (casual conversation). 2-4 minutes
- Play test of ChillFish. 2 minutes.
- Playing Pac-Man. 2 minutes
- Play test of ChillFish. 2 minutes.
- Casual conversation about the games. 2-4 minutes
- Relaxing activity. 2 minutes
- Casual conversation summing up the participants' experiences with the different games and activities. 2-6 minutes.

The activities were carefully chosen in order to enable us to compare ChillFish to a video game (i.e. Pac-Man), to casual conversations and to a relaxing activity. Pac-Man was chosen as an activity, as it is a classical computer game using traditional and stressful game elements, and we wanted to monitor how such elements affect HRV values. In the relaxing activity, the participants were asked to relax as much as possible, by doing either: 1) a breathing exercise they were familiar with, 2) the aforementioned "Equal Breathing" exercise, or 3) just to do as they wished in order to feel as relaxed and comfortable as possible. We asked the participants to do this exercise to give us a comparison between ChillFish and their own ability to relax and reduce

stress. As the relaxing activity measured the participants' natural ability to relax and had no impact on the game activities, and because of the continuous return to the casual conversation activity, we decided not to counterbalance the order of activities, as we could not identify any possible carry-over effects between ChillFish and the relaxing activity. The different sessions of casual conversation were chosen to function as a baseline for the HRV values, as we believe it indicates the natural HRV of the participants. The conversations seemed to ease and relax our participants, where a moment of staring at a spot, which other studies have used as baseline [19], might be uncomfortable with two observers present.

Data Collection and Processing

Before the beginning of the study, we equipped the participants with a Polar H7 heart rate belt in order to monitor their HR data (HR and RR-intervals).

We processed the gathered HR data in three steps. First, we deleted duplicates in the data, which occurred in some of the data sets. Second, all data was filtered using a recursive filtering procedure [12], where RR intervals that differed more than a predetermined limit (50%) from the average of the preceding and proceeding value were removed. Third, we calculated HRV values using the time domain analysis RMSSD (the square root of mean squared differences of successive RR intervals) using a sliding window of 30 beats. RMSSD is a recommended measure for HRV assessment [24]. For each participant, we normalized their HRV values, as these are affected by various conditions, such as age and aerobic capacity [14]. Finally, we calculated the normalized mean HRV value for each of the eight activities. The results from this analysis are presented in the following section.

Additionally, we video recorded 10 of the experiments in order to capture the participants' reactions and responses, and we took notes during all the tests. The video recordings and written notes were structured using a coding process, where we identified key concepts from our study. These key concepts were used in an affinity diagram, where we iteratively sorted the concepts in order to derive at a number of dominant themes that we will present in the "qualitative results" section.

QUANTITATIVE RESULTS: BIOMETRIC OUTCOMES

In this section, we present the analysis of the collected HRV values, followed by results, interpretations and insights from the conducted analysis.

Figure 3: Four screenshots of the ChillFish main character as it changes size and position depending on the player's breath.

As the participants' HRV values were measured over several activities, we used a univariate analysis of variance (ANOVA) with repeated measures to test for significant differences among the different activities in the data set. To ensure that the data was suitable for an ANOVA, we did a Mauchly's test, which did not show a violation of sphericity ($W(20) = 0.2747$, $p = 0.764$), thus no corrections were made to the processed data set. The ANOVA determined that at least two of the activities differed significantly in terms of the mean HRV values ($F(6,84)=13.83$, $p<0.001$, $\text{partial } n^2 = 0.71$). Hence a post-hoc Tukey's pairwise comparison was applied.

The post-hoc analysis showed no significant differences between the three casual conversation activities, indicating that the recorded HRV data is acceptably stable over time, which allows the activities to function as baseline. Even though there is a difference between the baseline activities and the relaxing activity (see Figure 4), the difference is not significant. This illustrates that relaxing exercises can be hard to do in certain contexts and without experience, supported by a participant who pointed out the discomfort of relaxing in a setting with two observers present.

The Pac-Man activity resulted in the lowest HRV values of all activities, and was significantly different from all other activities in terms of the participants' mean HRV values. This indicates that the game elements (e.g. time, score and chase) in Pac-Man stressed our participants during the two minutes of playing. This is consistent with the participants' own description of their experiences, as they also felt stressed during the game. Finally, the HRV values in the two ChillFish activities did not differ significantly from the relaxation activity, though the last ChillFish activity was the only of the relaxing activities that differed significantly from the baseline activities. The HRV values in the ChillFish and relaxing activities were very similar, indicating that they have approximately the same

Figure 4. Graph showing the normalized mean HRV values of the participants during the different activities. The error bars indicate the standard deviation.

physiological impact on a subject, thus we argue that ChillFish have a corresponding impact on a player's stress level as a relaxation exercise.

QUALITATIVE RESULTS: EXPERIENCING CHILLFISH

Sorting, clustering and thematizing our notes and video recordings in an affinity diagram resulted in three main themes: 1) Implications of using respiration as a game controller, 2) game elements and theme impact the calming experience, and 3) game dynamics facilitated reflective experiences. Together these themes capture the main findings from the qualitative part of our study, and we will present these in the following.

Implications of Using Respiration as a Game Controller

The main part of the participants stated that they enjoyed using "the fish" as input device. However, using a breath-based sensor as direct input to a computer game presents some implications.

Breath as a key press

As mentioned previously, the goal of the game interaction is for the player to get calm through a slow-paced respiration, and even though most of our participants achieved that, the interaction did not afford this for all. Three of the participants explicitly interacted exhaling and inhaling in short breaths, described by one of the participants as "I just saw it as like the input of a key or anything. So I just needed to input something when I wanted to move. And when I didn't want to move I didn't input anymore" (P14). Another participant stated that he felt more in control using periodic breaths. However, because of the design of the sensor and the use of changes in temperature to control the player character, it was not possible to get all the sea stars using a periodic tactic, and this caused some frustration for the participant.

Using breath for direct control creates a player-character relationship.

Even though most participants understood the interaction analogy that blowing air into the physical LEGO fish would fill the virtual fish with air, this was not the case for everyone. One participant said, "I love the analogy of the puffer fish, but for me it's the wrong way around. Like when diving you try to stay at the same level, so you breath in to go a bit higher and breath out to go a bit lower" (P12), and when explained of the idea of blowing air into the fish, she responded, "that's true. So I just kind of identify with the fish pretty much. So if I had a [physical] fish that actually inflates I could imagine".

Game Elements and Theme Impacts the Calming Experience

The main part of the participants enjoyed the aesthetics of the game, exemplified by comments like, "It's a beautiful game" (P7), and, "It's really cool. A cool idea. I'm not sure what the effect is but it really makes you concentrate on breathing" (P12), indicating that the game's theme and elements impacted the calming effect.

Underwater theme supports the breathing exercise

The underwater theme reflected in the graphics and the sound scape impacted the participants' perception of the game, as one participant noted, "*The underwater theme fits really well*" (P5) and another stated, "*It's a really chill track you got for the fish. It's nice. It's almost as being scuba diving again*" (P15). This indicates that visual and auditory elements play a role in games' calming effect.

Game play choices impact calmness

In our game design process, we deliberately chose to make the game play about eating starfish and not about getting as far as possible without failing, as in e.g. Flappy Birds or Pac-Man. This was embraced by the participants, and exemplified by one participant comparing it to SuperMario, where "*you don't get disappointed if you don't get all the coins. [...] It doesn't feel like failing, just because you don't get all the stars*" (P5). Thus, removing the possibility of losing the game facilitates a calmer atmosphere, which supports a reduction of the player's stress level. However, the participants were aware of their personal performances, as most of them revealed to know their exact score during the follow-up interview.

Game Dynamics Facilitated Reflective Experiences

The study indicated that the game offered more than simply calming the participants by impacting their breath. We found that the dynamics of the game made them aware of their respiration and how they responded to the game.

It's all about finding the rhythm

The participants revealed that the best way of playing the game successfully was by getting into a rhythm of a natural calm breath, exemplified by one participant noting that, "*it's all about finding the rhythm*" (P5). However, finding the exact rhythm was a challenge in itself, and participants commented that "*it's easy to control, but it's harder to get the timing right*" (P8) and "*I tried to do a more smooth movement, and I had some troubles making it fit in the beginning*" (P11). The rhythm of breath and the calming effect are closely related, supported by a participant explaining, "*if you have the rhythm everything is fine. It's really relaxing. As soon as you miss one then you like [hyperventilate] or something like that*" (P13).

Reflecting on breathing techniques and tactics

By playing ChillFish twice the participants got a possibility to reflect upon their breathing technique and tactic. Several participants emphasized that their interaction in the second game was more "*natural*" (P9) and "*smooth*" (P11). One participant stated that, "*The difference to the second time was really just, I tried to breath out while at the bottom, and I figured out, well okay, breathing out now I need to breath in, okay. It's just well timed*" (P14), thereby realizing that the game calls for a calm and continuous respiration. Another participant realized the same thing in a hard way, noting that, "*I had to figure to inhale and exhale completely. But you can keep blowing even when it's at the top. In the beginning, I almost suffocated myself, because I*

just stopped when it was up" (P7). These examples all indicate that the game over time can teach players respiration techniques, partly explaining the difference in HRV values observed between participants first and second ChillFish game as described in the previous section and illustrated in Figure 4.

DISCUSSION

The results presented in the two previous sections show that it is possible to successfully combine breathing exercises and directly controlled video games using a none-worn respiration controller. We showed that our participants HRV values significantly decreased when playing a classic video game, indicating that game elements can cause a stressful situation. Furthermore, we showed that it can be difficult to relax on command, and we were unable to significantly distinguish the relaxing activity to the casual conversations. On the other hand, despite being a video game, ChillFish showed to significantly increase mean HRV values over time compared to casual conversation. This indicate that our participants were more relaxed playing the game, than in any of the other activities, as a result of the breathing-based input, demanding a continuous relaxed breath, the calming underwater theme, and a point system that stresses the player as little as possible. However, the game still has room for improvement and some unexploited possibilities, especially in terms of balancing engagement and relaxation.

With ChillFish we saw how the participants tried different breathing techniques, and how their success was affected by the hint of counter acting. In ChillFish, players got the best result if they continually inhaled and exhaled through the LEGO fish, ultimately causing a relaxed breathing rate. However, what caused our participants to be engaged was 1) their ability to make their own choices, e.g. completely and directly controlling the game with their breath (causing a player-character relationship and a search for rhythm), and 2) the game elements, e.g. points and sounds (causing underwater sensations and leading to calmness). Had we decided to instruct the participants on how to win the game before we started, chances are they would have received it with less enthusiasm, as a result of the limitations in the game's core mechanics [21]. On the other side, by not instructing them, we risked that players hyperventilated, used periodical blows and tried to force the input through, which is physically impossible. Balancing the difficulty and in-game guidance is especially important when designing games for children with ADHD. If the game is too obvious and easy the child will lose interest and stop doing the underlying breathing exercise, due to the challenges of sustaining attention as characterized by the ADHD diagnosis. Contrary, if the child is in the middle of a stressful situation, chances are that too hard a game will inflict further frustration and make the situation even worse.

Balancing learning, outcome, seriousness and engagement is a well-known challenge in serious, learning and training

games, for example explained by Jensen et al. as the challenge of introducing points without reducing relevance [11]. Thus, in order to make a respiration game both engaging and relaxing for the player, it is important to assist the player to get the desired breathing rate, without making it too obvious. We believe this can be achieved by using game design techniques, for example by adding additional exciting and challenging elements to the beginning of the game, e.g. different types of stars in varied places, combos, power-ups. By adding these elements, we might be able to create a more engaging interaction experience that we can gradually reduce, so it ends up being a breathing exercise with points, like the current version of ChillFish. However, engaging game elements can also stress the player, as shown in our study during the Pac-Man activities. Another way of approaching the challenge is to focus on visual and auditory elements. The underwater theme in ChillFish calmed the participants in our study and additional attention to these peripheral elements might increase the players engagement without changing the actual game play, thus maintaining the breathing exercise. This is consistent with Chang's requirement of providing visual and auditory stimuli for children to dwell on in order to help them during relaxation procedures [3].

In summary, when designing respiration games, it is important to balance the engagement of the game elements, the difficulty of the game and the visual and auditory stimuli, so the player gets relaxed without getting bored or frustrated.

FUTURE WORK

Based on the findings from this study, we have received approval to evaluate ChillFish with children with ADHD. In collaboration with our research partners from the ADHD domain, we have redesigned the study design specifically for children with ADHD.

LIMITATIONS

The main limitation in this work is the lack of children with ADHD as participants in the study. However, as they are a high-risk group, we found it important to investigate the initial qualities and challenges of ChillFish without putting them at any risk or in any discomfort. Another limitation is the use of HRV as a measure for stress. In spite of the frequent use in similar studies, HRV values are affected by the respiration of the subject, and hence breathing exercises will have an effect. However, because breathing exercises have significant positive impact on stress and relaxation, and the use of ChillFish causes a similar or slightly stronger effect on HRV values as breathing exercises, we argue that ChillFish have the same impact on a player's stress level and feeling of relaxation.

CONCLUSION

In this paper, we have presented ChillFish that combines a breathing exercise with game element designed with children with ADHD in mind. A pilot study with adults showed positive effects on the participants' stress levels in

terms of HRV values, compared to other activities. We also presented a qualitative analysis of participants' experiences with ChillFish, eliciting for example implications of using breath as a core game mechanic, the importance of auditory and visual stimuli and how the game facilitated a reflection of rhythm and breathing techniques. Based on these results and our experiences from designing ChillFish, we discussed the challenge of balancing engagement and relaxation to sustain attention and avoid frustration of players, and children with ADHD in particular. Our work shows that it is possible to combine a breathing exercise with game design and still achieve positive results.

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