University of Arkansas – CSCE Department
Capstone I – Final Report – Fall 2020

Immersive Video Game to Encourage Proper Breathing and Alleviate Anxiety in Young Patients during Preoperative Anesthesia Delivery

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Abstract

Hospitals have expressed interest in an interactive breathing game for young children wearing a breathing mask that delivers anesthetics before surgery. The purpose of the game is to reduce anxiety in children, facilitate normal breathing while wearing the breathing mask, and aide doctors and preoperative nurses in the anesthesia process. The approach is to design and create an interactive game that detects breathing and encourages good breathing patterns through positive reinforcement in a relaxing and colorful game world. The game would need to run on the available hospital hardware and integrate seamlessly in the preoperative process. Such a solution would significantly benefit young patients in their anxiety and feelings of discomfort around their environment and the breathing mask. It would place a strong emphasis on the emotional wellbeing of children, allowing medical professionals to focus on their physical wellbeing going into surgery. This area of anxiety reduction is currently dependent on the preoperative team and has the potential to benefit greatly from software built for pediatric patients.

1.0 Problem

Young children about to go into surgery often feel anxiety being away from their parents. They are around doctors they do not know, and in an unfamiliar setting. Additionally, the anesthetics they need before surgery are delivered using a breathing mask that can be intimidating or make the children uncomfortable, causing them to breathe in an irregular fashion. Hospitals would like a way to alleviate this anxiety in their younger patients. It is a better experience for the kids and a smoother anesthetic delivery process for the doctors and preoperative nurses. The issue is this aspect of surgery in young kids has often been overlooked. There are not many solutions for hospitals to employ, and it would be easier on everyone, especially these young patients, if there were. Overall, there is a lack of solutions that offer children a calming yet interactive distraction to ease them into the act of breathing regularly in a breathing mask. Such a solution could be integrated with the existing preoperative workflow and could be utilized before any stressful

operation or while getting imaging done. There has been a prototype of a breathing game developed by Stanford researchers and engineers on this topic, but the scope of the project is limited to the Stanford Children's Health hospital. While many other hospitals would benefit greatly from a similar solution, there is a lack of widely available and easily integrated solutions available online.

2.0 Objective

The objective of this project is to create a game that children going into operations will be able to play to simultaneously receive coaching on how to breathe in anesthetic and reduce operation anxiety. The current plan to do this is to interface with onsite machines from Arkansas Children's Hospital Northwest in order to obtain the necessary information regarding the patient's breathing. These readings will then be utilized by to the game to display feedback to the patient regarding their breathing. This feedback will primarily be positive to encourage patients to breathe in such a way that they receive the most anesthetic that they possibly can. The game itself will mostly act as a method of displaying feedback to the patient while they are breathing in anesthetic, meaning that the game will be approximately a minute long at most, will have adjustable feedback triggers based on the age and weight of the patient, and will not feature a defined conclusion since the patient will be inhaling anesthetic during it. This game that utilizes the readings generated by the onsite machines will serve to coach patients to breathe in anesthetic and reduce preoperative anxiety that the patients may have.

3.0 Background

3.1 Key Concepts

The solution we aim to construct in this project is an ensemble of existing technologies. Everyone is familiar with video games; the purpose of this video game is not to level up or progress over time, but to remove anxiety through immersion into the game and encourage deep breathing with eye-catching visual feedback.

The most complicated aspects of this project are the sensors and the data we will use to create visual feedback. We must translate the need for "deep, consistent breathing" into desired measurements from the anesthesia machine's sensors. We are looking for steady tidal volume (amount of air in each breath) and breathing frequency (number of breaths per minute). Our game will need to calculate the desired measurements for each patient based on body weight.

3.2 Related Work

The most notable existing implementation of a game to ease preoperative anxiety in children is "Sevo the Dragon" by Stanford Children's Health's Childhood Anxiety Reduction through Innovation and Technology (CHARIOT) team [1]. In CHARIOT's game, the patient chooses a color for Sevo the Dragon, as well as his hat color. As the patient exhales through the anesthesia mask, Sevo breathes fire, cooking the patient's choice of food. CHARIOT's game is displayed on a projector screen that takes up a large portion of the patient's field of view. Immersive

environments and novel stimuli have been shown in previous research to enhance patient engagement with distractive entertainment [2].

In CHARIOT's description of their game, we could not find mention of direct interfacing between the game and the anesthesia machine. In our introductory meeting, Dr. Allen and Ashlynn Young showed us that the patient's breath mask has connected sensor equipment in the anesthesia machine. Using ports on the machine, we hope to use this real-time, precise data in our game to give accurate visual feedback on inhalation and exhalation to both the patient and the caregivers.

As our work on this project commences, we plan to reach out to both Stanford's CHARIOT team and the manufacturers of the anesthesia machines used at ACNW to explore the feasibility of using measurements directly from the equipment, without the need for installment of additional sensors or modified masks.

4.0 Design

4.1 Requirements and Use Cases

Our application should at least abide by the following hard requirements:

- It does not encourage children to hyperventilate (too much air entering the lungs), which can happen either by breathing too fast or too deep
- It does not encourage children to hypoventilate (not enough air entering the lungs), which can happen either by breathing too slow or too shallow
- It does not gamify the experience of going under anesthesia in a competitive manner
- Data collected (if any) is anonymized

There are several other soft requirements that are less crucial to the core success of the project but are still quite important:

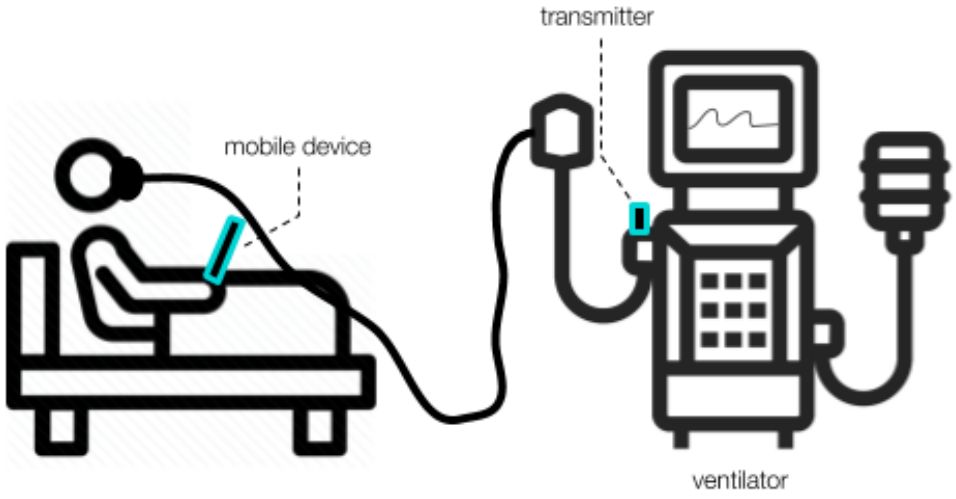
- The application should be intuitive and easy to use by children
- The application would ideally be hosted on a mobile device such that children can use it in a variety of scenarios:
    - In a hospital bed
    - In a wheelchair
    - Standing (with a nurse to guide them to a bed when the patient falls unconscious)
    - Sitting in a parent/guardian's lap
- The mobile device that hosts the application should be able to receive breathing data wirelessly

The application is intended for use with children ages 2-9 receiving preoperative anesthesia.

4.2 High Level Architecture

Ultimately our goal is to have an entirely wireless application hosted on a mobile device. The application will be responsive to breathing data collected live by the ventilator. Because this is sensitive patient data, we will not be able to access breathing information after it has already been sent to the hospital's third-party data management application. Instead, we will have to find another method of extracting this data from existing hardware sensors before the data is anonymized and sent to the cloud. In the worst-case scenario where we find this kind of data extraction is not possible, we may also consider engineering our own custom breathing sensor that would be attached externally to the patient's mask.

If we can achieve this first goal (live data capture using the hospital's existing breathing sensors), the next goal will be to find the least obtrusive means of getting this data to the mobile device. For early prototyping this will be accomplished using a physical wire, yet ideally, we might equip some sort of transmitter to the breathing sensor that would allow us to send this data to the mobile device wirelessly.



The above image depicts a use case where the patient is in a hospital bed. The patient is given the mobile device to hold as the breathing mask is either worn or held up to their face. As the child breathes into the mask, the ventilator uses several sensors to measure air flow and positive/negative pressure. In this image, a transmitter is attached to the ventilator to capture and send this live breathing data to the mobile device, where the native application will respond accordingly.

There are several methods with which we might present the breathing data to the patient in the form of a game. We have not yet settled on the scenario to present to the patient, but will likely choose from one of the following:

- Scuba diver underwater retaining oxygen via consistent deep breaths
- Astronaut in space retaining oxygen via consistent deep breaths
- Patient is wearing a superhero mask
- Maintaining the altitude of a hot air balloon using breathing feedback

The game will present one of the above scenarios (or something similar) where the user is required to breathe in order to interact with the central game object. Using known demographic data for the patient we will know when to display text-based prompts instructing the user through their breathing cycles, i.e., “breathe deeper”, “breathe slower”, etc.

4.3 Risks

Risk	Risk Reduction
Children are encouraged to hyperventilate	We will use known demographic data for ideal breathing rates to inform the application’s design. Patients will not be encouraged to breathe faster/deeper if they have already passed the hyperventilation threshold.
Children are encouraged to hypoventilate	See above. Patients will not be encouraged to breathe slower/shallower if they have already passed the hypoventilation threshold.
Children feel additionally stressed using the application	The game will use an incredibly minimal interface to reduce the possibility of creating a stressful/competitive experience. There is no end goal in the application, merely a general goal to maintain consistent breathing.

4.4 Tasks

1) Investigate hospital equipment
    a. Understand method of data transmission
    b. Understand method of data manipulation and calculation
2) Decide which device/software we will use to implement game
    a. Apple iPad vs Amazon Fire tablet
    b. Swift vs Java
3) Design game
    a. Method of communication (wired vs wireless)
    b. General game design and functionality
4) Implement game on software
    a. Write code for game
    b. Communicate game with hospital equipment
5) Test game
    a. Hospital trial runs
    b. Personal testing if applicable
6) Write final document

4.5 Schedule

Tasks	Dates
1. Background investigation on hospital equipment	11/14 - 11/28
2. Identify software which will be used	1/15 - 1/31
3. Begin Designing game	2/1 - 2/14
4. Begin Implementation of game	2/15 - 2/28
5. Begin Testing of Game	3/1 – 3/15
6. Document	3/16 - 4/15

4.6 Deliverables

- Design document: Contains a listing of each major hardware and software component
- Game source code: Directly from game development software
- Final Report

5.0 Key Personnel

Will Baker – Baker is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses. He was formerly a Biomedical Engineering major, providing him with special insight into the scope of the project. He will be responsible for getting the data from the medical devices into our game.

Gavin Glenn – Glenn is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses. He will be responsible for miscellaneous additions to the code.

Jackson Gregory – Gregory is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses, including Game Design and Mobile Programming, two particularly relevant courses. He will be responsible for designing and coding the levels for the game.

Jared Harris – Harris is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses, including Game Design, a particularly relevant course. He will be responsible for programming the code for the player character in the game.

John Ostermueller – Ostermueller is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses and has many years of frontend and design experience. He will be responsible for the assets and design of the game.

John Shelnutt – Shelnutt is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed several years of programming courses, including Game Design and Mobile Programming, two particularly relevant courses. He will be responsible for coding the main mechanics of the game.

Staci Allen – Pediatric Anesthesiologist at Arkansas Children's Northwest and Assistant Professor at UAMS. Dr. Allen will be working with the team by providing requirements for the team as well as feedback on the project.

Ashlynn Young – Preoperative and Post-anesthesia Care Unit nurse at Arkansas Children's Northwest. Young will be working with the team in a similar manner to Dr. Allen, providing requirements for the team as well as feedback.

6.0 Facilities and Equipment

Facilities:

Arkansas Children's Northwest – Contacts at ACNW will be critical to project success, as they are the ones who define success by detailing patient needs. Team members will visit ACNW under the supervision of the contacts to better understand the process that the game will fit into. This is the only location-specific portion of the project.

Equipment:

GE Avance CS2 – This device is what monitors the patient's breathing while anesthesia is being administered. The readings of the patient's breath from this device will be what is used as input to the game for it to be played.

Amazon Fire Tablets – The hospital has Amazon Fire Tablets which will be used to run the game for the patient.

7.0 References

[1] Rodriguez, S., Tsui, J.H., Jiang, S.Y. et al. Interactive video game built for mask induction in pediatric patients. Can J Anesth/J Can Anesth 64, 1073–1074 (2017). https://doi.org/10.1007/s12630-017-0922-0

[2] Rodriguez, S., Caruso, T. and Tsui, B. (2017), Bedside Entertainment and Relaxation Theater: size and novelty does matter when using video distraction for perioperative pediatric anxiety. Paediatr Anaesth, 27: 668-669. https://doi.org/10.1111/pan.13133