

NeodiagVR: Virtual Reality Apgar test environment

L. Ferry¹  J. Gimeno²  F.J. Estañ³  F. Núñez³  E. Balaguer³  M. Fernández²  C. Portalés¹ 

¹ IRTIC Institute, University of Valencia, Valencia, Spain

² Computer Science Department, University of Valencia, Valencia, Spain

³ INCLIVA, Valencia, Spain

Abstract

Owing to the lack of accessibility of postpartum rooms nowadays, which are needed to teach the correct assessment of newborn health status to medical students, virtual reality and simulation are increasingly used for teaching and assessing visual perception tests that evaluate the condition of the newborn. This paper aims to explain the operation of the Apgar test evaluation simulator in a virtual reality environment. This virtual environment can be manipulated externally from a web browser to visualize and control the course of the simulation in real-time. In addition, an offline version would allow initialization and visualization of the Apgar test parameters without the need for synchronization with the virtual environment.

CCS Concepts

• **Human-centered computing** → **Virtual reality**; • **Applied computing** → **Interactive learning environments**;

1. Introduction

Assessment of a baby's postnatal status in the postnatal ward is essential for clinical care and scientific purposes. Scoring systems are used for this purpose, such as the Apgar test, proposed by Virginia Apgar, which describes the postnatal status of the baby using a scoring system that converts clinical observations into quantifiable scientific data [RB*15].

Teaching the Apgar test poses an increasing challenge for medical practice education, as patient privacy concerns and hospital overcrowding [MSSW21] make it difficult for students to access postnatal wards. In addition, the declining birth rate and the vulnerability of the neonate [RYHT17] play an important role, raising the need for effective and accessible alternatives.

Therefore, the aim is to use virtual reality to simulate the clinical assessment of preterm newborns. In this way, the vulnerability of the newborn is reduced, the educational accessibility of this teaching is increased, the attention of the students is increased [Pan09] and the transmission of knowledge is favored by immersing the students in a virtual environment. For this, it would be useful to transfer and model in a simulated virtual environment the indicators of the newborn, such as skin tone, muscle tone, activity, chest movement, sounds emitted, etc.

The newborn can then be explored and assessed in this virtual environment, to provide a multidisciplinary training tool for medical and nursing staff, with the possibility of extending its use to more frequent clinical scenarios.

The NeodiagVR simulator provides a real-time interactive envi-

ronment for teaching and assessing the Apgar test to medical students.

2. System description

The NeodiagVR simulator is developed to present virtual real-time results of an Apgar test interactively. As mentioned before it would be used in educational settings where there is no direct accessibility to a postpartum room.



Figure 1: NeodiagVR used by a student on the Oculus Quest 2.

To get a more general idea of how the system works, it is assumed that a teacher wants to assess his students' understanding of the Apgar test performed on a virtual newborn baby.

First of all, the student is immersed in the virtual environment by putting on a pair of virtual reality glasses, where he/she would find a newborn baby in a post-partum room as shown in figure 1.

The teacher, using a web browser as a support, will be able to preview the neonate's condition without the need to communicate with the VR glasses, as it is an offline preview instance.

Once the initial parameters of the neonate have been adjusted through the web interface, it will be possible to connect with the student's virtual reality glasses to initialize the neonate's state to be in line with the state of the web browser as shown in figure 2.

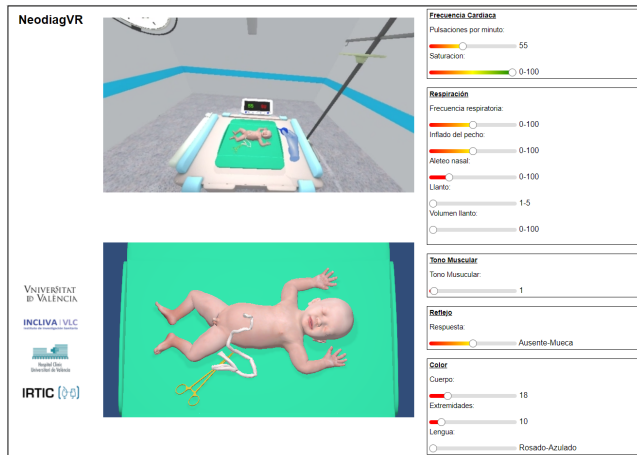


Figure 2: NeodiagVR's web interface used by the teacher in an online state connected to the Oculus Quest 2.

The student is then in charge of evaluating the neonate's state, while the teacher and the audience observe the image and sound of the glasses in the web browser with the possibility of alternating the course of the simulation by adjusting different parameters.

Once all the parameters of the Apgar test have been evaluated (seen in section 2.2), using its scoring system, the student will be in charge of providing a final verdict to the teacher on the condition of the newborn.

In the following sections, the different parts of the system will be presented together with its setup and functionality.

2.1. Architecture

Figure 3 illustrates the architecture of the NeodiagVR interactive simulator.

The components of this system are the following:

1. Android VR Build: Unity Android build that runs on virtual reality glasses (Oculus Quest 2).
2. WebGL Build: Unity WebGL build that runs on the web browser (3) without connecting to the VR glasses.
3. Web browser: Browser that receives the simulation's video and sound using WebRTC data channels and sends messages to the virtual reality glasses (1) and the WebGL build (2) using JSON control messages.
4. Control messages: Messages in JSON form that change simulation parameters in real-time on the virtual reality glasses (1) and the web browser executable (2).

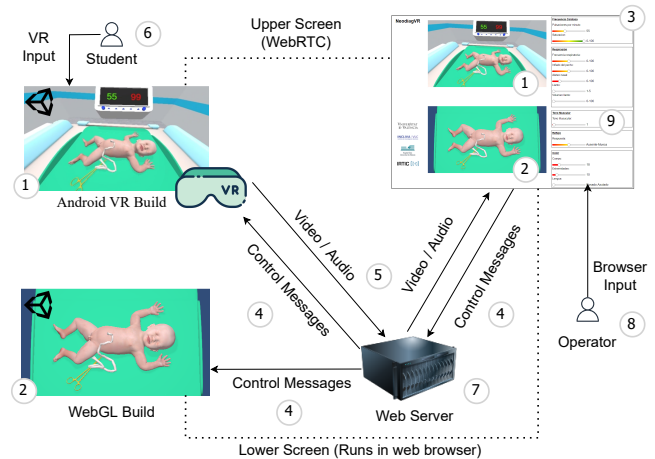


Figure 3: NeodiagVR's architecture.

5. Video and audio: Video and audio stream from the simulation sent from the virtual reality glasses (1) to the web browser (3) using WebRTC as the transfer protocol.
6. Student: Student operating the virtual reality glasses (1) evaluating an Apgar test.
7. Web server: Web server based on Node.js that provides connectivity between the components (1), (2), and (3) using peer-to-peer connections.
8. Operator: Teacher or doctor assessing the Apgar test's correct simulation. The operator is in charge of modifying the simulation's parameters before the test and during the test while visualizing the virtual reality glasses' content in the web browser.
9. Sliders: Sliders that when invoked send control messages to the two different builds (1) (2).

The operator (8) and the student (6) are usually in the same room for a correct evaluation of the Apgar test as the system is currently developed for this use case. However, the system has the potential to be scaled up to allow long-distance assessments by integrating text chat or synchronous voice communication to connect the teacher with the student.

The student (6) is then immersed in the virtual environment application by wearing a pair of VR glasses (1).

The operator (8) is in charge of controlling the parameters of the simulation (9) before and during the execution of the test using a web browser (3)(9) that also integrates a preview of the neonate (2) and the content of the virtual reality glasses in real-time (1).

Once the execution flow between the server (7) and the virtual reality glasses (1) is established, the operator (8) connects to the IP address of the server to create the data stream.

A video and audio stream (5) is sent to the web browser (3) in real-time and control messages (4) are sent once the sliders (9) are modified which changes the behavior of the simulation in both the online (1) and offline (2) versions.

To create a preview of the neonate's state before sending content to the virtual reality glasses (1) the server sends messages to the

WebGL build (2) without having to connect to the glasses. Once the connection between the web browser (3) and the virtual reality glasses (1) is established, the preview values set in the sliders (9) are transferred to the immersive world to synchronize the simulation. The video/audio stream (5) and control messages (4) are interrupted when the browser (3) is closed or the connection is lost.

2.2. Apgar test and simulation parameters

NeodiagVR, being a simulator representing an Apgar test, should be able to be modeled to simulate each of the key behaviors included in this test. The following table 1 contains the Apgar test evaluation sections and their respective scores.

Scoring	0	1	2
(1) Heart rate	Absent	< 100 BPM	> 100 BPM
(2) Breathing	Absent	Slow, irregular breathing and soft crying	Normal breathing and loud crying
(3) Muscle tone	Flaccid	Flexion in arms and legs	Active body movement
(4) Reflex	Absent	Grimace	Grimace and cough
(5) Color	Pale or bluish body	Pink body and bluish extremities	Completely pink body

Table 1: Apgar test scoring system [RB* 15].

Depending on the different scorings on each section of the test, students should be able to assess if the newborn is in critical, bad/normal, and good condition.

To be able to control the behavior of the newborn inside of the virtual environment according to Apgar's test parameters, NeodiagVR gives the operator the flexibility to manipulate different values to get the desired state of the simulation. The necessary simulation parameters for the simulator have been extracted after several researches and evaluations done together with medical staff.

The simulator then presents the following values that can change the course of the simulation (present in the browser's interface):

- **Heart rate (BPM):** Parameter that controls the newborn's heart's beats per minute rate. A higher value indicates a higher bpm rate (1).
- **Saturation (%):** Blood saturation index of the newborn. If this value is changed the newborn will change its color. Less saturation produces a more bluish color (5).
- **Respiratory rate (BPM):** Respiratory frequency of the baby. A higher value produces a faster respiratory movement (2).
- **Respiratory amplitude (%):** Amplitude of the chest movement while breathing. A higher value increases the amplitude of the chest movement and mouth/nose aperture (2).
- **Nasal flaring (%):** Nose aperture index while breathing. When this value is higher nose flaring appears less exaggerated (2).
- **Cry:** Changes the type of crying of the newborn. Its value skips through different types of a newborn crying (2).
- **Cry volume (%):** Volume can be adjusted to control the intensity of the baby's crying and the opening of the baby's mouth and nose. If the value is 0 the newborn will not open its mouth and no sound plays (2).

- **Muscle tone:** Value that controls the movement of the newborn. A lower value produces a relaxed muscle tone and a higher value produces a more nervous muscle tone with movements (3).
- **Response:** This parameter changes the type/velocity of the response that is triggered when interacting with the newborn. A value of 0 gives no response and a value of 100 gives a fast response (4).
- **Body color*:** Controls the body color of the newborn (5).
- **Extremity color*:** Controls the extremity (hands and feet) color of the newborn (5).
- **Tongue color*:** Controls the tongue color of the newborn (5).

*As for the color parameters a lower value produces a bluish color and a higher value produces a pink color.

2.3. Virtual environment and interactions

NeodiagVR's virtual environment seen in figure 4 is located in a post-delivery room where there is a stretcher with a newborn baby, spotlights to illuminate the newborn, and a monitor to control the newborn's heart rate and saturation.



Figure 4: NeodiagVR Postpartum room.

The student is then responsible for assessing the newborn's baby state, by interacting and observing the scene. Once the student has analyzed the newborn, feedback will be provided to the tutor about the state of the baby according to the scoring system using the virtual reality's hand tracking, display, and locomotion system.

The newborn's parameters in section 2.2, which are to be evaluated for the Apgar test, like body color, heart rate, and muscle tone, for example, are controlled externally by an operator using a web interface while the student is evaluating the scene. The parameters of the simulator can also be set offline before the simulation is executed. The operator then sees in real-time the content streamed from virtual reality glasses and can give direct feedback to the students.

2.3.1. Heart rate

Heartbeat evaluation is one of the parameters to analyze in an Apgar test. To do this, the virtual hand should be brought close to the umbilical cord as shown in figure 5, which invokes a heartbeat sound following the beats per minute (BPM) set in the web browser. This can also be visualized through a heartbeat monitor shown in figure 8. This effect has been implemented using coroutines in Unity to synchronize the sound.

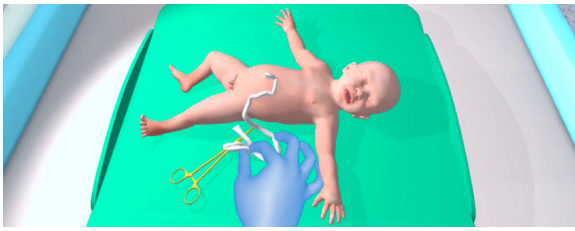


Figure 5: Evaluation of heartbeats per minute of the neonate.

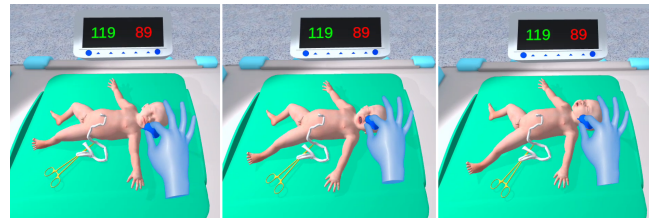


Figure 8: Neonate reacting to a snout sack.

2.3.2. Breathing

Breathing amplitude and breathing rate seen in figure 6 are also evaluated. They can be modified through the web browser. In addition, the intensity of the nasal flaring can be adjusted. These effects have been implemented using coroutines for synchronization, blend shapes, and local bone scaling of the newborn's rig.

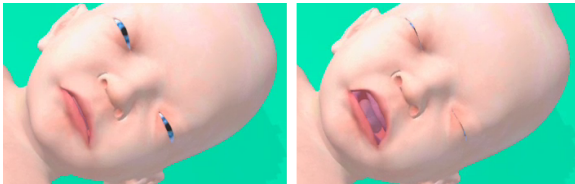


Figure 6: Exhale (left) / inhale, nasal flaring and cry (right).

2.3.3. Muscular Tone

Muscular tone examination is another factor to evaluate inside of the Apgar test scoring. The neonate is assessed as relaxed, with normal movements or nervous movements as can be seen in figure 7. This effect has been implemented using an animator with blend trees and animations in Unity.



Figure 7: Relaxed muscle tone (left), normal muscle tone (center), nervous muscle tone (right).

2.3.4. Reflex

Another parameter to assess is the type of reflex a newborn has. In the virtual environment, the reflex is achieved by bringing the hand or a virtual object close to the neonate's mouth or head as shown in figure 8. This has been achieved by using animations and collision detection for the triggering.

2.3.5. Color

The final parameter to assess in an Apgar test is the newborn's color. NeodiagVR provides a way to control the neonate's color from bluish to normal and then to pink for the body, tongue, and limbs like seen in figures 9 and 6. This effect has been implemented using Unity shaders and masks to control the mesh's color locally.

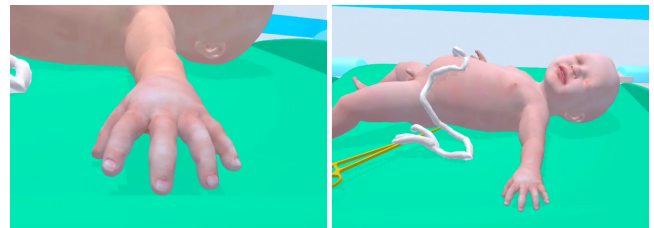


Figure 9: Newborn's hand and body changing color.

3. Conclusions

It has been concluded that a first approach of the NeodiagVR immersive simulator has been implemented as a virtual reality system that simulates Apgar tests in an immersive and interactive environment. In addition, future iterations of this project will demonstrate its usefulness in the medical world and the possibility of extending it to multiple users and other medical fields.

4. Acknowledgments

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