Avances en Interacción Humano-Computadora

Research in Computing Science

Research in Computing Science es una publicación trimestral, de circulación internacional, editada por el Centro de Investigación en Computación del IPN, para dar a conocer los avances de investigación científica y desarrollo tecnológico de la comunidad científica internacional. **Volumen 89,** abril 2015. Tiraje: 500 ejemplares. *Certificado de Reserva de Derechos al Uso Exclusivo del Título* No. : 04-2005-121611550100-102, expedido por el Instituto Nacional de Derecho de Autor. *Certificado de Licitud de Título* No. 12897, *Certificado de licitud de Contenido* No. 10470, expedidos por la Comisión Calificadora de Publicaciones y Revistas Ilustradas. El contenido de los artículos es responsabilidad exclusiva de sus respectivos autores. Queda prohibida la reproducción total o parcial, por cualquier medio, sin el permiso expreso del editor, excepto para uso personal o de estudio haciendo cita explícita en la primera página de cada documento. Impreso en la Ciudad de México, en los Talleres Gráficos del IPN – Dirección de Publicaciones, Tres Guerras 27, Centro Histórico, México, D.F. Distribuida por el Centro de Investigación en Computación, Av. Juan de Dios Bátiz S/N, Esq. Av. Miguel Othón de Mendizábal, Col. Nueva Industrial Vallejo, C.P. 07738, México, D.F. Tel. 57 29 60 00, ext. 56571.

Editor responsable: *Grigori Sidorov*, *RFC SIGR651028L69*

Research in Computing Science is published by the Center for Computing Research of IPN. **Volume 89**, April 2015. Printing 500. The authors are responsible for the contents of their articles.

Printed in Mexico City, in the IPN Graphic Workshop – Publication Office.

Volume 89

Avances en Interacción Humano-Computadora

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Instituto Politécnico Nacional, Centro de Investigación en Computación
México 2015

ISSN: 1870-4069

Instituto Politécnico Nacional (IPN)
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http://www.ipn.mx
http://www.cic.ipn.mx

Indexed in LATINDEX and Periodica / Indexada en LATINDEX y Periódica

Printing: 500 / Tiraje: 500

Printed in Mexico / Impreso en México

Prefacio

El área de Interacción Humano-Computadora (IHC) es una intersección de varias disciplinas como lo son ciencias de la computación e ingeniería, ciencias de la conducta y diseño. La comunidad mexicana en IHC ha estado promoviendo durante algunos años esta área a través de la organización de diversos eventos y recientemente un libro de texto para estudiantes universitarios en el área. Sin embargo aún hay mucho por hacer, esta edición especial representa una iniciativa más de la comunidad, esperando que ayude a los esfuerzos de consolidación de esta incipiente área en México.

Los artículos incluidos en esta edición especial fueron seleccionados a través de una rigurosa revisión realizada por un comité de 24 investigadores adscritos a diversas instituciones nacionales e internacionales. Cada artículo fue revisado por al menos tres miembros del comité. Se evaluó la originalidad de las propuestas, la importancia de la contribución en el área que se aborda, la relevancia técnica y la presentación. Creemos que este proceso de revisión a culminado en la selección de un conjunto de artículos de alta calidad que presentan resultados significativos derivados de una investigación científica en temas como Diseño y Evaluación de Aplicaciones Interactivas, Teorías para IHC y Evaluación del Usuario.

Nos gustaría agradecer a todos los autores involucrados, a la Asociación Mexicana de Interacción Humano Computadora (AMexIHC), así como al Sistema de Universidades Estatales de Oaxaca (SUNEO). Es un placer presentar esta edición especial compuesta por artículos originales que ofrecen una interesante perspectiva sobre la investigación que se realiza en México en el área de Interacción Humano-Computadora y la Usabilidad de Sistemas Interactivos.

Abril 2015

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Aprendizaje de Vectores Euclidianos utilizando un Sistema de Realidad Aumentada

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Resumen. La realidad aumentada es una tecnología que puede ser implementada como una herramienta práctica y eficiente para mejorar las técnicas de aprendizaje en estudiantes de bachillerato. En este artículo, presentamos resultados recientes de investigación en desarrollo sobre un sistema de realidad aumentada para asistir el aprendizaje de vectores euclidianos en física para estudiantes. Para comprender tales conceptos físicos, el sistema proyecta componentes virtuales en el mundo real, y se controla a través de una interfaz interactiva con el cuerpo del usuario. En este trabajo, se describe el prototipo, su interfaz de usuario y su evaluación preliminar.

Palabras clave: Augmented reality, physics education, educational technology.

1 Introducción

Los avances constantes en tecnologías de la información y comunicación (TICs) han tenido un impacto positivo en la educación, motivando la implementación de nuevas herramientas, aplicaciones, medios y ambientes educativos para promover el aprendizaje.

Las innovaciones tecnológicas tales como escenarios virtuales, dispositivos móviles inalámbricos, plataformas digitales de enseñanza, realidad virtual y aumentada, incrementan el interés y motivación de los estudiantes, así como su experiencia de aprendizaje [1], [2], [3].

La realidad aumentada (RA) es una tecnología que mejora la percepción visual del usuario a través de la superimposición de objetos virtuales, generados por computadora, al mundo real [4], [5]. Opuesto a la realidad virtual (RV), donde el usuario se encuentra completamente inmerso en un ambiente virtual generado por computadora, la realidad aumentada permite al usuario observar directamente el mundo real pero agregando objetos virtuales. De esta manera, la RA complementa la realidad en lugar de remplazarla totalmente.

Según Cai et al., un ambiente educativo basado en la RA va de acuerdo con varias teorías del aprendizaje. Una de ellas, por ejemplo, se centra en que el aprendizaje es el resultado de asociaciones formadas entre estímulos y respuestas. Por el lado del constructivismo, una plataforma de enseñanza basada en RA provee a los estudiantes con herramientas y escenarios de construcción de modelos, diseñados para ser fácilmente utilizados por ellos [6].

Existen varias aplicaciones de realidad aumentada propuestas para asistir diferentes áreas académicas. En astronomía, por ejemplo, Shelton y Hedley, desarrollaron un sistema de RA para enseñar la relación entre el Sol y la Tierra a través del uso de formas tridimensionales (3D) virtuales del astro y del planeta [7]. En química, Fjeld et al., implementaron una interfaz de usuario tangible, denominada 'Augmented Chemistry (AC)', para mostrar a los estudiantes modelos moleculares tridimensionales a través de RA [8], [9]. Por otro lado, Maier et al., evaluaron una interfaz de usuario 3D de realidad aumentada para mejorar el entendimiento de la química molecular [10]. En biología, Blum et al., desarrollaron el 'Mirracle', un sistema de realidad aumentada que funciona como un espejo virtual que permite entender la estructura y funcionalidad de la anatomía y órganos internos del cuerpo humano de manera intuitiva [11]. En el área de matemáticas y geometría, Kaufmann y Schmalstieg, diseñaron el sistema multiusuario Construct3D para construir formas geométricas virtuales [12]. En física, Duarte et al., utilizaron la RA para mejorar el aprendizaje de propiedades cinemáticas [13].

La enseñanza de las ciencias básicas ha sido siempre una problemática presente en la educación media superior, especialmente la de la física, principalmente por la necesidad de que el estudiante adquiera un nivel cognitivo tal que le permita inferir los aspectos abstractos que están detrás de situaciones que se presentan en la vida real. Esto se hace más patente en la física de vectores, que tiene una importante relación con la dinámica, la mecánica de fluidos, la fuerza, entre otros. En México, el aprendizaje de vectores euclidianos y, en particular, sus operaciones aritméticas son vistos de manera implícita (graficando líneas en un plano cartesiano bidimensional) y en una medida gradual, acorde a las capacidades intelectuales de los estudiantes. Sin embargo, el uso de nuevas tecnologías, como la realidad aumentada, podría enriquecer las limitantes de los actuales recursos educativos para facilitar el aprendizaje de dichas temáticas.

En matemáticas, física e ingeniería, los vectores euclidianos son objetos geométricos que caracterizan cantidades físicas que poseen magnitud y dirección (ej. fuerza, velocidad, aceleración), contrarias a cantidades escalares que no poseen dirección (ej. tiempo, temperatura, distancia). A dichos vectores se les puede aplicar una diversidad de operaciones matemáticas. Una de ellas es la adición, que es la suma de vectores, y puede representar, por ejemplo, la red de fuerzas que experimenta un objeto, es decir, el vector suma de todas las fuerzas individuales interactuando sobre ese objeto. La sustracción es otra operación, la cual puede ser vista como una adición con un vector negativo (operación opuesta a la adición). El producto cruz (también llamado vector producto), $\mathbf{a} \times \mathbf{b}$, es un vector perpendicular a ambos vectores $\mathbf{a}$ y $\mathbf{b}$, y se define como:

$$\mathbf{a} \times \mathbf{b} = \|\mathbf{a}\| \, \|\mathbf{b}\| \sin(\theta) \, \mathbf{n} \,, \quad (1)$$

donde θ es la medida del ángulo entre $\mathbf{a}$ y $\mathbf{b}$, y $\mathbf{n}$ es un vector unitario perpendicular a ambos vectores $\mathbf{a}$ y $\mathbf{b}$. La magnitud del producto cruz es el área del paralelogramo de lados $\mathbf{a}$ y $\mathbf{b}$. La dirección del producto cruz es ortogonal al plano que contiene dicho paralelogramo.

El objetivo de este trabajo es presentar el desarrollo de una herramienta de realidad aumentada diseñada para permitir al profesor el uso de técnicas modernas para la enseñanza de conceptos de la física (ej. propiedades y operaciones vectoriales), ayudando, de esta manera, a los estudiantes a tener un aprendizaje más completo a través de ambientes de realidad aumentada.

2 Métodos

2.1 Configuración del Sistema

El sistema de realidad aumentada presentado en este trabajo ha sido desarrollado para apoyar el aprendizaje de conceptos de física en el aula de clases. En particular, se enfoca en el entendimiento de las propiedades relacionadas a los vectores euclidianos (magnitud y dirección), y algunas operaciones de vectores (suma, resta y producto cruz).

Nuestro sistema consiste de un monitor externo, una cámara de color y una de profundidad (ver Fig. 1). El monitor permite la visualización del mundo real y los objetos virtualmente aumentados. Las cámaras de color y profundidad forman parte del sensor Kinect de Microsoft^{TM}, desarrollado para el juego de consola Xbox 360. Dicho sensor habilita el uso de señas y movimientos del cuerpo como interfaz de control del sistema. La estación central para el cómputo en general consiste en un procesador Intel^{TM} Core i7-3630QM con 8GB de RAM y una tarjeta de gráficos dedicada Nvidia^{TM} GeForce GT 640MB.

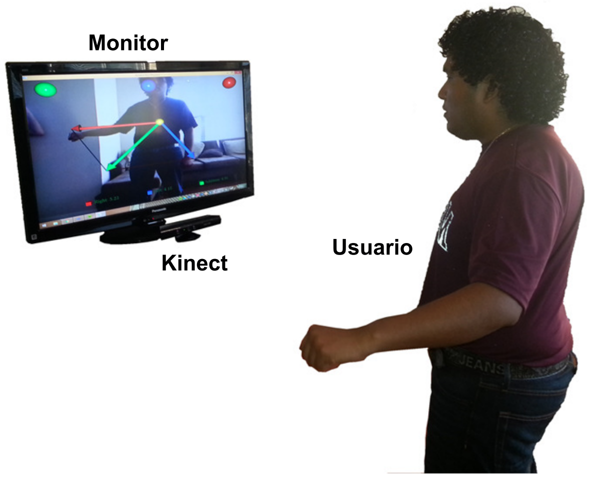

Fig. 1. Configuración del sistema de realidad aumentada. El usuario puede visualizar los vectores virtuales en la pantalla mientras mueve las manos para cambiar magnitudes y direcciones.

2.2 Interfaz del Usuario

La posición del usuario es rastreada, constantemente, con la cámara de profundidad utilizando las librerías NITE de rastreo del esqueleto (www.openni.org). Las coordenadas 3D del mundo real obtenidas por el Kinect son transformadas al sistema de coordenadas 2D del monitor a través de las librerías de OpenNI. Finalmente, los gráficos generados son utilizando las librerías de OpenGL (www.opengl.org). Ver Fig. 2.

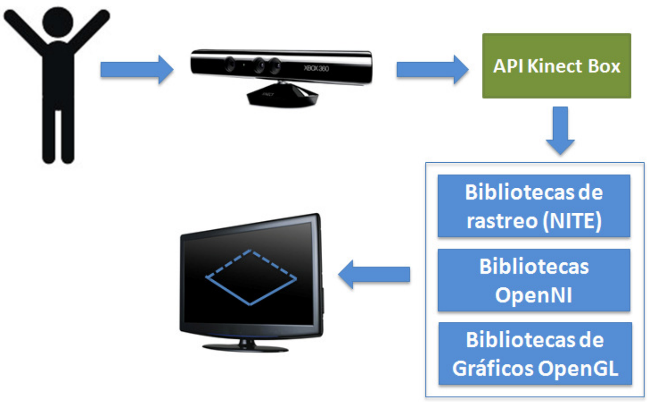

Fig. 2. Arquitectura funcional del sistema de RA.

El sistema de RA permite al usuario seleccionar una de tres operaciones de vectores diferentes: adición, sustracción o producto cruz. Cada modalidad puede ser elegida tocando, durante tres segundos, botones virtuales desplegados en una ubicación 3D fija visualizados en el monitor.

Las coordenadas 3D del torso del individuo, obtenidas con el Kinect, son usadas para dar lugar al origen común para formar dos vectores concurrentes **i** y **d**. La posición 3D de la mano izquierda y de la mano derecha son continuamente rastreadas para obtener los puntos finales de los vectores **i** y **d** correspondientes. El vector resultante de cada operación es generado virtualmente y visualizado en el ambiente de RA. Asimismo, al cambiar de posición las manos, el sistema le permite observar, dinámicamente, diferentes magnitudes y direcciones de los vectores. La información de las magnitudes correspondientes a cada uno de los vectores visualizados se despliega como texto en la parte inferior de la pantalla.

Inicialmente, el sensor Kinect requiere ser calibrado para el usuario con una postura específica del cuerpo con el fin de que el sensor rastree correctamente el esqueleto del individuo (pose de letra griega 'Psi', Ψ). Para ello, la persona tiene que pararse derecho frente a las cámaras del Kinect con las manos por encima de la cabeza (en escuadra). Una vez que el sensor ha identificado al usuario, el sistema de RA inicia el rastreo de los puntos de interés (torso y manos).

3 Resultados

La visualización final de la adición de vectores se puede observar en la Fig. 3. Las posiciones de las manos izquierda (azul) y derecha (rojo) del usuario definen los puntos terminales de los dos vectores **i** y **d**, correspondientes, con los cuales la suma será calculada. El vector resultante de la suma se puede visualizar en el vector virtual color verde. La posición del torso del usuario se identifica con una esfera amarilla, indicando el origen común de los vectores. Para esta operación vectorial, el usuario puede mover las manos en diferentes posiciones para cambiar de magnitud y dirección los vectores, observando, de esta manera, diferentes resultados de adición.

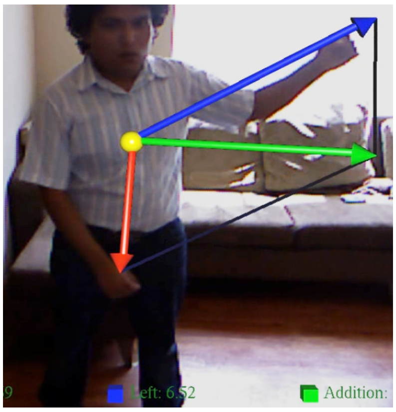

Fig. 3. Vista aumentada del sistema de RA para la operación de adición de vectores.

La visualización de la sustracción de vectores se presenta en la Fig. 4. El sistema resta el vector **i** en color azul del vector **d** en color rojo. El vector resultado de esta operación se visualiza en color cian.

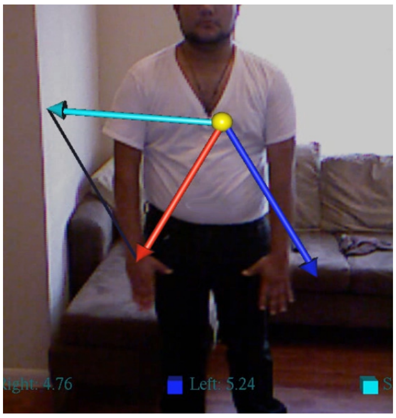

Fig. 4. Vista aumentada del sistema de RA para la operación de resta de vectores.

La visualización del producto cruz de vectores se muestra en la Fig. 5. El vector producto-cruz (en color naranja) es el resultado de aplicar la ecuación 1 a los vectores **i** (azul) y **d** (rojo). En la visualización aumentada se puede observar la propiedad de ortogonalidad del producto cruz.

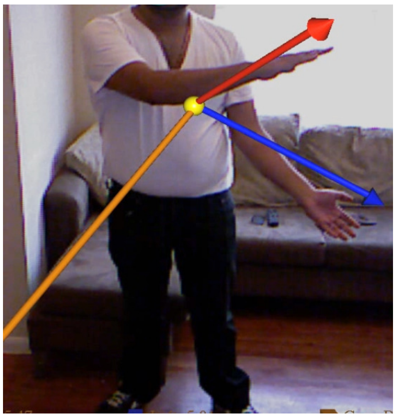

Fig. 5. Vista aumentada del sistema de RA para la operación producto cruz de vectores.

Evaluamos el sistema de realidad aumentada para enseñar operaciones vectoriales con 12 estudiantes de enseñanza media-superior y un profesor mediante una encuesta de opinión abierta. La retroalimentación de los sujetos fue muy positiva y motivadora, haciendo notar desventajas menores del sistema, como por ejemplo, la pérdida de rastreo de la posición de las manos cuando éstas estaban fuera del rango del sensor. Durante los experimentos, los usuarios no requirieron de una explicación exhaustiva de cómo utilizar el sistema.

4 Discusión

Como podemos observar en las Fig. 3, 4 y 5, el usuario puede crear vectores de varias magnitudes y direcciones utilizando únicamente las manos de una manera dinámica. El usuario puede trasladar las manos a diferentes posiciones tridimensionales dentro del área de rastreo del sensor Kinect para generar los vectores virtuales con varias magnitudes y direcciones.

La interacción observable de los sujetos con el sistema de RA fue muy interesante. Los usuarios analizaban los vectores virtuales generados que ellos mismos controlaban con las manos. Intentaron varias posturas de cuerpo y manos para ver y entender los efectos de la salida de cada operación. Al cruzar las manos, observaron como el vector producto-cruz cambió su dirección 180°. Al cambiar las magnitudes y/o direcciones de los vectores, los estudiantes observaron las diferencias en el vector resultante de la adición y sustracción de vectores. La mayoría de los estudiantes expresaron que el sistema es una buena herramienta para aprender conceptos de física como son los vectores y sus respectivas operaciones. Asimismo, mencionaron que la interfaz del sistema es bastante fácil de utilizar, entender y aprender interactuando.

En los métodos tradicionales de enseñanza, los materiales didácticos estáticos (ej. pizarrón, proyección, láminas) están restringidos para presentar información dinámica, como, por ejemplo, el movimiento continuo [14], [15], a diferencia con nuestro sistema de RA que permite al usuario, inclusive, interactuar con los elementos de estudio. Asimismo, nuestro sistema propuesto puede ser eficiente para la fácil comprensión de conceptos y propiedades existentes en un espacio tridimensional, como es el caso del producto cruz.

Como trabajo a futuro, un sistema de RA para la enseñanza de vectores más completo, necesitaría considerar más propiedades y operaciones de vectores (ej. vector de proyección, producto punto); asimismo, analizar las posibles mejoras a la interfaz de usuario para hacer más sencillo aún su uso.

Aún cuando los métodos actuales de aprendizaje son frecuentemente eficaces, existe un constante interés por desarrollar métodos pedagógicos más útiles y prácticos para mejorar las experiencias de enseñanza.

5 Conclusión

Mientras las tecnologías continúen su progreso, los educadores se encuentran en constante búsqueda de herramientas pedagógicas más eficientes para mejorar el proceso de aprendizaje de los estudiantes.

Este trabajo presenta el desarrollo de un sistema de realidad aumentada basado en una interfaz de interacción con el cuerpo para asistir el entendimiento y aprendizaje de propiedades y operaciones de vectores en física. Los usuarios fueron capaces de crear vectores virtualmente con diferentes magnitudes y direcciones, así como visualizar sus propiedades y operaciones. Asimismo, todos tuvieron una reacción positiva hacia el uso de un sistema de RA para el aprendizaje de vectores euclidianos.

Agradecimientos. Este proyecto fue financiado por el Programa de Mejoramiento del Profesorado (PROMEP) 2013 - 103.5/13/6979.

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HAREVIR: A Methodology for Developing Virtual Reality Projects with Haptic Rendering

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Abstract. This paper presents a methodological proposal, which is focused on the task of rendering and manipulation of virtual objects via kinesthetic. Our project involves two key areas: Virtual Reality and Haptic Rendering. Virtual Reality is related to the creation of virtual environments, considering physical and virtual aspects, levels of immersion and interaction with the user. Haptic rendering is used to provide kinesthetic stimuli in order to improve the man-machine interaction. We identify three main processes as a part of the methodology: i) selection of algorithms and methods for haptic rendering according to the project developed, ii) selection of languages and specialized software tools for virtual applications and iii) selection of haptic devices, all these considerations are key for developing a project using haptic rendering.

Keywords: Virtual Reality, Haptic Rendering, navigation.

1 Introduction

Currently, rendering of haptic cues is a challenge, mainly due to the bidirectional communication process between the user and the virtual project that must be provided. Haptic rendering allows the user to perceive through the skin (temperature and texture) and rendering through muscles, tendon and joints (position, velocity, acceleration, force and impedance). Due to such kind of complexity, these projects are limited to some cues. Haptic is still an incipient research area, then there is no enough information in literature related to the development of haptic rendering projects, so we consider imminent the creation of this proposal.

This paper presents a methodological proposal for developing robustness in projects using haptic rendering. The proposal has emphasis on different algorithms related to the haptic rendering. It was necessary to consider the state of the art of haptic rendering, to select the most relevant works, which have the necessary maturity to guide in the ad-hoc project development.

The rest of the paper is organized into the following sections: section 2 provides an over-view of haptic and virtual reality, section 3 describes the proposed methodology which presents a classification of haptic rendering algorithms, indicate the software used in the topic, also presents the main haptic devices, then in section 4 an analysis about possible selection of algorithms is presented, finally the last section concludes this work.

2 Virtual Reality and Haptics

Virtual reality, in terms of functionality, is a simulation in which computer graphics are used to create a realistic-looking world [9]. A virtual environment (VE), specifically a computer-based simulated environment intends for its users to inhabit it and interact with it via avatars. These avatars are usually depicted as textual, two-dimensional or three-dimensional graphical representations, although other forms are also possible. Some virtual environments allow multiple users to participate simultaneously. The perception of these environments can be done via visible, audible, or tactile means.

Virtual reality considers four elements: virtual world, immersion, sensory feedback and interactivity: A virtual world is an artificial computer-generated environment in which users are able to interact with each other by means of characters and manipulating objects. Immersion is usually defined as the full sensory replacement by artificial means instead of being generated from the real world. The interaction between the system and the user should be natural. A good interaction helps to get a better immersion sense. Unlike traditional media such as video games, animation and other applications in virtual environment users can interact with systems, influence events in the world and receive a dynamic feedback.

To increase immersion in virtual environments different areas have been involved, such as haptic rendering, which focuses on making someone sense of touch or feeling the force using a haptic device [1]. The key features of a haptic device are: force range, degrees of freedom, workspace, etc. The devices allow users manipulate a virtual environment and their 3D objects.

3 HAREVIR Proposed Methodology

In this section a methodology for developing projects using virtual reality and haptic rendering is proposed: HAREVIR, (see Figure 1. Methodological proposal). Our methodology includes three important tasks: the selection of haptic rendering algorithms and methods, selection of specialized languages and selection of haptic devices. Next sections detail those tasks.

3.1 Algorithms and Methods for Haptic Rendering

While a haptic device provides interaction between the user and a given virtual environment, captures user positions, and others qualities [5], the algorithms related with haptic rendering generate kinesthetic stimuli in the users. They have two main tasks: compute the position and orientation of the virtual object manipulated by the user (avatar) and calculate the forces and torques that should be returned.

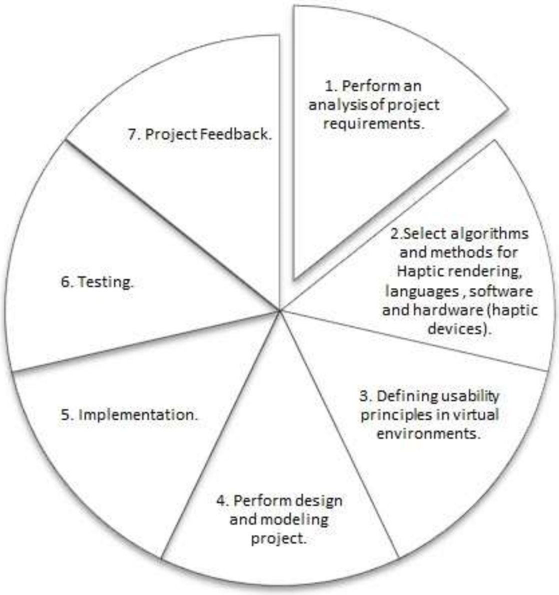

Fig. 1. Methodological proposal.

Most haptic rendering methods divide the process of calculating the collision force and torque in three stages: collision detection, collision response and control algorithms. In the first stage, the position of the haptic device and virtual environment information is considered to check any collisions. In the second stage, if there were a collision, information would be taken, the ideal position of avatar and the ideal strength of interaction between the avatar and the environment would be calculated. In the third stage, a force returns to the user, which approximates the ideal force according to the capacity of the haptic device (see Figure 2).

After having a requirement analysis of the project, it is possible to select a specific haptic rendering algorithm. It is important to considerate that there are simple and complex virtual environments. The algorithms have different approaches; the Figure 3 shows several haptic rendering algorithms considered by HAREVIR.

Penalty methods

Penalty methods calculate the collision force based on the amount of interpenetration of the virtual objects in a collision, either by using a model of elastic contact, viscoelastic or a different one.

The elastic model calculates the forces and torques collision, in the simplest case.

This method calculates the magnitude of the penetration p, the normal collision direction n and the contact point cp, where cp is the center of inertia of the avatar and K represents the virtual stiffness contact (see equation 1).

$$F = Kpn, M = (cp - cg)F \qquad (1)$$

Penalty methods are divided into two main types: polygonal methods and voxel-based methods.

Polygonal methods

These methods use polygonal representations, usually triangle mesh to define the surface of the virtual objects, and the collision response calculated from the information associated with the detected collision triangles. Once detected the triangles, the position information of its vertices and the normal vector of each triangle it is calculated the normal direction, penetration and a point of contact to obtain a force and torque representative of the collision.

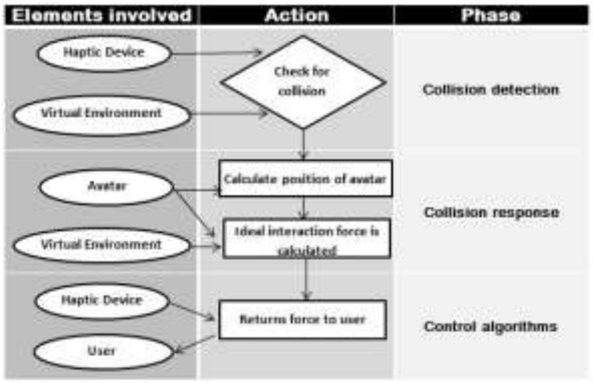

Fig. 2. Stages of forces and torques collision calculation.

The most basic representation for a volume is the classic voxel array in which each discrete spatial location has a one-bit label indicating the presence or absence of material, in volume haptic rendering technique. Sometimes it uses additional physical properties like stiffness, color and density during the voxel representation [8].

Voxel-based methods

Virtual environment is divided with mesh container boxes, in several researches, called voxels, to simplify the calculation of collisions and penetrations between two virtual objects.

Polygonal representations are replaced by two different structures, named Voxmap-PointShell. The first, Voxmap, is a partitioning spatial structure voxels based replacing the geometrical model of the virtual scene. The second, PointShell, is a cloud of points defining the surface of the avatar associated with each data point. Both facilitate the calculation of the normal and the resulting penetration in avatar collisions with objects of the scene.

Constraints-based methods

Constraint-based methods do not use interpenetration forces in rigid objects to calculate the collision response. These methods use the virtual coupling and restrict decoupled virtual object on the surface of the obstacles, guiding their dynamics by restrictions. An example is the God-object method, this algorithm locates a virtual object minimizing the distance between it and the position of the haptic device at every moment under restrictions [8].

Impulse-based methods

Impulse-based methods are less quoted in the references. They restitute forces in impulse form in collision events. Continuously collisions are treated like series of small collisions, in every of them impulses are applied to avoid penetration between objects. They produce visually acceptable results, but not very convenient in haptics.

Degrees of freedom
Another classification of haptic rendering methods is based on the degrees of freedom on which they can act. When they only act on the translations of the virtual object they are called methods of three degrees of freedom (3DOF), but if they also act on the turns of the object they are considered methods of six degrees of freedom (6DOF). For example the haptic rendering algorithm of Three Degrees of Freedom (3DOF) [1] takes as input the position and orientation of the haptic device and transforms them to the reference system of 3D dataset.

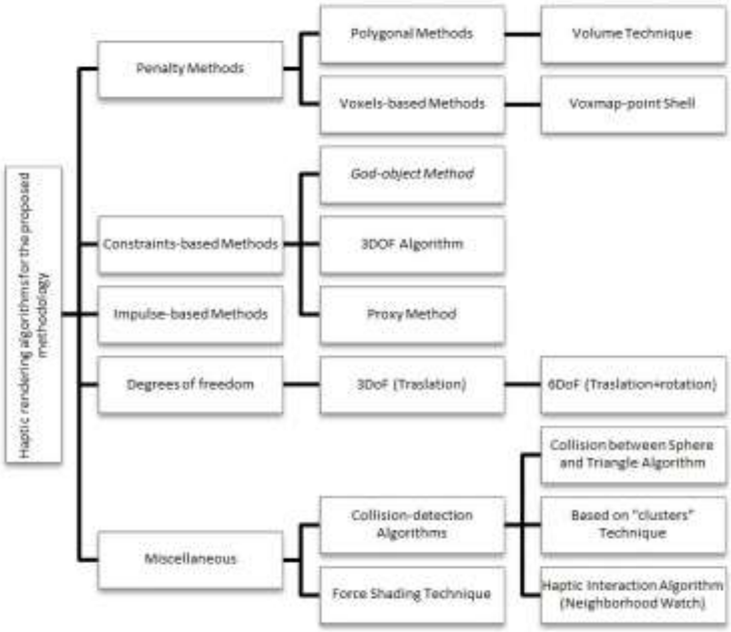

Fig. 3. Classification of Haptic Rendering Algorithms.

3.2 Languages and Tools

Several tools, libraries and languages support the development of haptic applications. They interact with haptic devices and even reveal implementation details of certain device function features such as HDAL, then they are described briefly some of them.

Object and model generation
Generation of models and objects is performed by a wide range of specialized software. Examples of these programs are: Blender is an open source suite to create 3D animations, 3DStudioMax is useful for creating virtual objects and scenes, Panda3D is a game engine and OpenGL is a multi-platform library that allows developing 3D graphic applications. Some features of the software are: professional support in modeling and animation, varied file formats allowed, simulations and high quality sculptures creation, etc.

Game engines

Today there are a variety of game engines for creating applications with a wide diversity of languages some of which include their own Software Development Kit (SDK). Two of them are: Unity, a game development engine to create interactive 3D content and Panda3D that is a framework for 3D rendering and game development [7].

Languages

General purpose languages such as C++, C#, Java and Visual Basic and interpreted programming languages such as Python (that through scripts makes Blender extendible) are commonly used to develop haptic applications.

Libraries and plugins

Some libraries detect whether objects in a virtual environment are colliding with each other or with devices, there are commercial and other free distribution, such as ICollide, Vcollide, Rapid, etc. [4]. They are designed to work with specific models and algorithms. Others as H5H, which is a plugin to provide haptic web effects, HAPI (Haptic API) provide haptic effects, H3DAPI uses OpenGL to handle graphics and haptic scenes and CHAI3D that is an open source set of C++ libraries for haptic rendering [6].

HDAL

The Haptic Device Abstraction Layer (HDAL) provides a uniform interface to all supported type devices. The API provides means for selecting a device, initializing it, reading its state, etc. This includes implementing a callback function that HDAL will cause to be executed at a 1 KHz rate, to achieve the required haptic fidelity [2].

For the development of this proposal it is used: C++ programming language, OpenGL to model some objects, Panda3D to generate interaction between the 3D model and the user, and to control the haptic device it was considered HDAL interface.

3.3 Haptic Devices

A haptic device stimulates tactically the operator, this information is received through the skin by pressure of a certain area, through twists and movements supported in a virtual environment. In [4] they are classified according to their portability in: desktop, fixed and portable.

Desktop

Desktop devices provide information about embossing, texture and even temperature of the virtual environment. They are used like a joystick and are subdivided into spherical, cartesian, parallel, serial and made out of cables. Some examples are: Novint Falcon, Phantom Omni, Excalibur (Cartesian), MantisFlyer (made out of cables), etc.

Fixed

Fixed devices reproduce the movements of the operator in the remote environment through an anthropomorphic robot with similar operator arms. In this classification fixed exoskeletons and robot arms are found, for example, the Master Arm, Haptic Master, etc.

Portable

In Portable devices the user can support the whole weight of the interface. They can be exoskeletons hold to operator and others like gloves, for example, CyberGrasp and Rutgers Master II.

Novint Falcon Haptic Device

The Novint Falcon desk haptic device provides information about embossing, texture and feedback force. It is a commercial haptic device to develop video games. It has three degrees of freedom, a removable end-effector, a USB interface and bears three Newtons of force. It is a parallel robot with three arms joined by an end effector. It is considered as a manipulator robot. Its dynamic model is shown in Equation 2.

$$H(q)\ddot{q} + C(q,\dot{q})\dot{q} + g(q) = \tau \qquad (2)$$

Where $(q,\dot{q}) \in R^{2n}$ are vectors representing the position and velocity, n is the number of degrees of freedom, $\mathrm{H(q)} \in R^{nxn}$ is a matrix meaning robot inertial forces with $H(q) = H(q)^T$ defined as positive, $C(q,\dot{q}) \in R^{nxn}$ is a matrix that symbolizes the Coriolis force, $g(q) \in R^n$ is the vector of gravitational torque, $\tau \in R^n$ is a vector which forms the entrance wall of a joint [3].

Today we can see affordable devices, compatible with different languages, easy to use, give the user a more immersive experience and a realistic sense of touch, whose applications are in several areas: education, telemedicine, robotics, surgical training, etc.

3.4. Analysis

Phases and activities of the methodology

Some activities of the first two stages analyzed in this paper, are presented here, which could be applied in concordance with the needs of any project (see Figure 4. Activities to do in each phase).

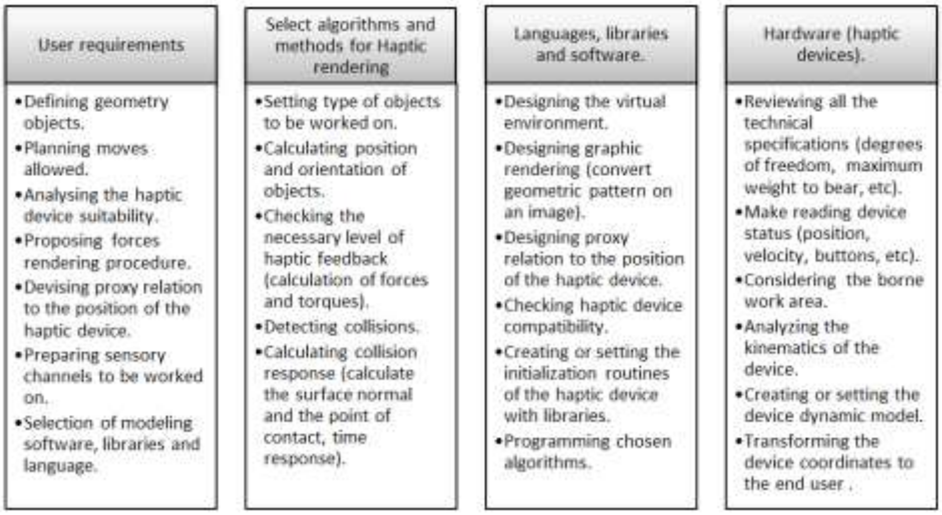

Fig. 4. Activities to do in each phase.

Selection of tools, languages, devices and objects
In this section a table of possible choices of algorithms, tools and languages is presented, as well as some aspects to consider for the use of algorithms according to the type of interaction and Virtual Reality project you want to develop.

The first is an effective rendering technique with mesh models of objects, but it fails in the use of point cloud based models. Second, it renders smooth objects and it is used to create the illusion of a smoothly curved shape. The third allows working with thin objects, but it is invalid to represent applications where there are twists. The fourth is capable of rendering Monge surfaces represented by a non-uniform point cloud data. And the fifth helps to prevent that collision method detect a high number of different contacts at the time of decomposing convex primitive geometric models (see Table 1. Selection of tools for different types of projects).

The use of algorithms, languages, tools, devices and objects depend on the parameters set for any project and after a whole review the most appropriate tools and languages can be chosen.

Table 1. Selection of tools for different type of projects.

NO	ALGORITHM	LANGUAGE AND TOOLS	DEVICE	OBJECTS
1	God-Object	C++, Java, C#, CHAI3D	PHANTOM Omni / Falcon	Point, plane
2	Force Shading	Python/ Panda3D	PHANTOM Omni	Polyhedral meshes
3	Virtual Proxy	C++, Java, CHAI3D	PHANTOM Omni / Falcon	Spherical object
4	Haptic rendering on different scales	OpenGL, C++, HAPI library	Falcon	Point cloud based 3D models
5	Based on clusters Technique	C++, Java, C#	PHANTOM Omni SARCOS Dexterous	Convex objects

4. Conclusions

In this article it was presented the use of a methodology that will provide support and guidance in developing focused haptic rendering applications, as well as, a classification of a set of algorithms. Three main processes have been identified: Selection of algorithms and methods for haptic rendering according to the project developed, selection of languages and specialized software tools for virtual applications and selection of haptic devices, all these considerations are key to the development of a dedicated project in haptic rendering. The detection of the key elements was achieved after a thorough research on haptic rendering and virtual reality topics, as well as, the experience developed during the doctoral project Haptic Rendering for Navigation and Manipulation of Virtual Objects.

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A Qualitative Study for the Design of an Integrated Development Gestural Environment for Task Flow Modelling Diagrams

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Abstract. The design of tools for software development still have improvements on the user experience side of it, for that reason it would be beneficial to experiment with a natural interaction paradigm. In order to do this, a first step is required to understand the environment and the real needs of software developers as well as qualitative research by improving the proposal obtained by a gestural Development Environment.

Keywords: IDEG, UsaLab, natural interaction, human factor, software development.

1 Introduction

Software development is a totally intellectual activity [16], it should pay special attention to the tools which support software developers, the most important, the integrated development environment (or Integrated Development Environment IDE). Despite all of the above, for this tool and other development tools, there is no significant progress in terms of adaptation and use of new technologies to diversify the user experience [1]. To raise the project proposal is imperative to first analyse the origins and trends IDEs.

According to the studies presented in [7], it is difficult to measure a developer's productivity. While it is true, there are methodologies such as Personal Software Process, which provides metrics to know time and productivity [5], although this neglects the human factor. Therefore, we should put more emphasis on other aspects, such as teamwork (beyond Team Software Process metrics) and improving the user experience. In the latter case, the tools on which rests the developer. For that reason our first step would be to know what do software developers think about it.

2 IDE's Background

The use of IDEs go back to the early 70's, it became popular when the need to develop complex software arose. Software prior to that time (late 60's) was designed using flowcharts and subsequently implemented by punched cards or paper tape, so there was a lack of support for a review by a compiler [12]. It wasn't until 1975 when the first IDE history, Master I [11] was developed by SoftLab in Munich. Master I consisted of a hybrid arrangement of hardware and software. As input means using a similar current computer keyboard; thus it was possible to input a fully intuitive manner.

IDE's projects, focusing on integrating complex and powerful tools available in modern IDE 's, in most cases, are not fully utilised. No one takes into account the capabilities of visual languages [13].

3 Visual Programming

The visual programming is commonly defined as the use of visual expressions (such as graphics, animation or icons) in the process of programming [4].

The visual programming objective is to improve the understanding of programs and simplify programming itself. The VPL (Visual Programming Language) can be classified according to the type and extent of visual expression used, such as languages icons, forms-based languages and diagrams language. The integrated visual programming environments provide graphics or icons that could be manipulated by users in an interactive way according to some specific spatial grammar for program construction [8].

4 User Interface

An important amount of devices having a form of natural interaction, have appeared implementing a natural user interface (NUI for its acronym in English). Natural user interface is one in which the user interact with a system or application without using control systems or input devices, instead, gestures are used as input gestures performed with the hands or body, the latter being a control stick [10].

The objective of this work is to experiment with gestural interaction into the software used by developers, specifically in the IDE, that would apply when using a language

The objective of this work is to experiment with gestural interaction into the software used by developers, specifically in the IDE, when using a visual language and flowcharts tasks will be designed. So far, we haven't found applications for development that would have the form of interaction we propose to use, so by building the prototype we could perform this experiment.

4.1 New Technologies

Kinect is a device that facilitate gestural interaction; with the release of the Libfreenect free driver project, Kinect was used outside video games console environment, thus enabling new forms of interaction aimed at supplementing the classic peripherals, as the pointer and keyboard [9, 14, 15].

4.2 Interaction Paradigm Change

Today we are witnessing the gradual change occurring in the paradigm of human-computer interfaces, everyday devices without keyboards are improved and controlled with elements such as voice, touch and movement. Maybe a crucial as when it happened in the 60's when an element appeared called XY Position Indicator for a Display System, which evolved up to the pointer we use today. This device came to create the basis on which the all-graphic applications that we are totally accustomed today [1] were built.

While you can find some resistance to change of form of interaction, everyday technology advances in the design and construction of innovative, novel devices. However, despite all, built applications to develop software continue without showing major changes in terms of interaction are concerned.

5 Proposed Solution

Using a high-fidelity prototype built using a User Centered Design methodology to explore the gestural interaction by designing workflow diagrams is proposed.

For this purpose there is a Kinect (which provides the facility to perform visual recognition) as a supplementary mean of the new pointer and keyboard interaction. It is through this device that arm movements made by users would be captured and from this captures an answer which will be then displayed in the IDE.

6 User Analysis

One of the most important points is to know the environment and the people with whom you will work to properly build the software tool. Information on how to build software models is required, so a series of Focus Groups were conducted. To find the right people, we performed an analysis by which the individual profiles were created, also known as *Personas* [3]. In this context, *Personas* refers to a person profile and not to a specific human being, to avoid confusion the term "user profile" [3, 6] is used.

6.1 Profiles Definition

In order to properly present and document the profiles definition, a template was used (presented in Figure 1) [3]. The purpose of the use of the template is that the information collected for the profile of the person is consistent and was organized in a clear and simple way.

Fig. 1. Personas profile template.

Constructed profiles have been helpful in establishing priorities for the project, so far served to prioritise and / or add necessary features that users must follow to get the right information.

7 Focus Groups Development

The main objective of this study was to determine, define and experiment with gestural interaction through hand movements, while using a functional tool for the development of workflow diagrams. As a first step, we should know in depth the areas that only professional developers could provide. To identify those facets of interest, users contributed by given through knowledge and experience of people with different perspectives, but focused on the software development

Despite Focus Group has its origins in market research; it provides qualitative results by ability to interact with the target group being studied. In this way, it can be know and understand broadly the attitudes, needs, interests and motivations of the participants. In addition, Focus Groups follow the rigorous development of the research stages, starting with the problem statement and concluding with an oral and written presentation of research [6].

7.1 Description of Qualitative Research

For qualitative research three Focus Group sessions were conducted in the laboratory facilities of the *UsaLab Laboratorio de Usabilidad* at the *Universidad Tecnológica de la Mixteca* (UTM). Professional Developers who work in the two existing companies in the *Mixteca* region, attended the sessions, specifically in the city of Huajuapan de León, KadaSoftware SA de CV and VEUREKA SA de CV. Similarly master degrees students participated as well.

7.2 Instrument Design

Instruments required for the study are presented.

- Defining the problem: one must know the concerns and aspirations over the traditional way of creating software. To do this one start in the modelling phase, because that is where ideas involved in the projects are given. This is to know in depth how software modelling stage is done in actual practice and which chances are that they may decide to migrate to a tool that poses a new form of interaction.
- Study proposal: the opening subject will be how they begin a new project from an individual perspective. From this, the new questions and commentaries addressed the different phases of the professional life when was required to develop the system model, including the student stage and the small projects where the person was the only developer. After knowing the personal experiences and techniques we proceeded to begin the main subject of the focus group, which is that the developing team create a system model. The evaluated topics included the actual technique in which this activity is realized, the tools used and, the responsibilities of each team member. These two subjects are the basis of our research since provide the minimal necessary information.
- Session guide design and testing:

Below are the initial basic questions for the focus groups and the questions for the main subject.

1. How important is the modelling phase when developing a system individually?
2. How easy or difficult can be carried out that phase? Or can it be omitted?
3. Do you use some software tool to help with the modelling?
4. How important is the modelling phase when developing a project with a team?
5. How easy or difficult can be carried out that phase? Or can it be omitted?
6. How do you rate the development of a meeting of the development team for the modelling software?
7. In the meeting, the team leader is strict, bring forth participation, is purposeful?

7.3 Site Selection

The suitable site to carry out our focus group was the Usalab. It has specialized equipment such as video cameras, video edition, software, a Hessel camera (ideal for observation.) Additionally, it has monitoring equipment with IP cameras, digital recorders and equipment for measuring physiological signals. For these reasons and for its accessibility (within the university campus) it is the best option.

7.4 Selection of Participants

The selection process was realized considering employees from the software companies in the region. The basic criteria was as follows: study level, working directly as a developer, working in development teams, working as a team leader. It is noteworthy there was not economical or kind incentive for the participants in the focus group.

7.5 Focus Group

All were carried out at the premises of the Usalab of the UTM on a schedule of 19:30 to 20:30 hours. As instruments for each focus group, in addition to the session handbook, was presented a low-fidelity prototype as can be seen in Figure 2. This prototype was disclosed to the participants when explaining its characteristics and functionality.

The whole focus group process was recorded from two different angles. These video files were used to complement the final report.

7.6 Profile of the Participants

Following we describe the profile of each one of the participants of the focus group.

Miriam: computer engineer, postgraduate student of the master in applied computing program, 26 years old, junior programmer at KadaSoftware, 3 years of experience.

Carlos: computer engineer, postgraduate student of the master in applied computing program, 25 years old.

Noé: computer engineer, 27 years old, developer at Veureka S.A. de C.V., 3 years of experience.

Alfonso: computer engineering studies, 29 years old, developer at Veureka S.A. de C.V., 3 years of experience.

Erick: computer engineer, postgraduate studies of the master in applied computing program, 34 years old, technical leader at KadaSoftware, 8 years of experience.

Ana: computer engineer, 27 years old, analyst and developer at KadaSoftware, 4 years of experience.

Fig. 2. Low-fidelity prototype presented to the different focus groups [2].

8. Discussion of the Results

In this section we offer a detailed summary of the answers provides and the general attitudes of the people. The questions presented in section 7.2 are taken as a basis, these ones were exposed to the participants of the focus group.

8.1 How mportant is the modelling phase when developing a system individually?

The general answer was the expected "very important". Because it was possible to increase experience in software development and, at the same time, with the increasing of the complexity of the projects different strategies were adopted for the system modelling phase. It was evident that being personal projects there was no formal documentation related to the process. In most cases the modelling was simply an informal draft on paper to have a visual perspective and was not really defining for the development of the software.

8.2 How easy or difficult can be carried out that phase? Or can it be omitted?

In relation with this question none of the participants decided to skip the modelling system phase. Everyone carry out this activity with different level of formality.

8.3 Do you use some software tool to help with the modelling?

There was not a specific type of tool used to create the design when working individually. Basically the idea of a tool is having a visual description as a no formal guide to document the model.

8.4 How important is the modelling phase when developing a project with a team?

The participants indicated that this phase is imperative. Essentially because it is the part where they really get to know the details of the project. It was evident that this phase is carried out with a meeting, which could be informative or participative. In an informative meeting the team leader shows the architecture and the model that him or another team member propose and usually it is focused in technical details of the project. In a participative meeting the team leader presents the project and a set of sketches where the general solution of the software problem is depicted; the solution is discussed and improved by the team members. The team usually discuss technical aspects related to content and design, proposing at any time changes to the base model of the project.

8.5 How easy or difficult can be carried out that phase? Or can it be omitted?

There were a variety of opinions but in general the participants agreed that this phase has to be carried out in meetings as a team effort even if they shown some apathy.

8.6 How do you rate the development of a meeting of the development team for the modelling software?

For different reasons, the participants have some displeasure for the team meetings. The main identified reasons were the time loss, some disagreements with the requirements and a strict project approach.

Most of this displeasure was detected in relation with developers having a strict model for the meetings, whilst in the teams where the participation of all the members is encouraged, the developers believe their teams achieve a more precise model in less time.

8.7 In the meeting, the team leader is strict, bring forth participation, is purposeful?

In general the team leader encourages the participation of the team members. The exception is when the suggested modifications or improvements to the model are not under control to be accepted or rejected by the leader. In this case, the opinion of the development team is rejected. This kind of leader look for consensus on the technical aspect where the team can really take decisions.

9 Conclusions

From the opinions expressed by the participants of the focus group we could conclude that the development teams start out from a model when developing software, even when no specific process or methodology is used. Although sometimes no formal process is followed, the actions carried out in the meetings accomplish the general aim for this phase. Because the result from this modelling phase is useful as an approach to the solution, sometimes this solution is documented in order to have historical information of the project.

In addition, there seems to be a general consensus that the meetings are tedious and, for this reason, the proposal of improving the interactions and logic mechanisms in the work meetings were well received by the developers.

Unfortunately from the information provided, it was detected that the team members sometimes have no power of change the models presented by the team leader, in this cases they only can suggest implementation details.

As a result from the information analysis, we present in Figure 3 a prototype for the boardroom we will explore the improvement of the user experience, using the modelling software for task flow diagrams.

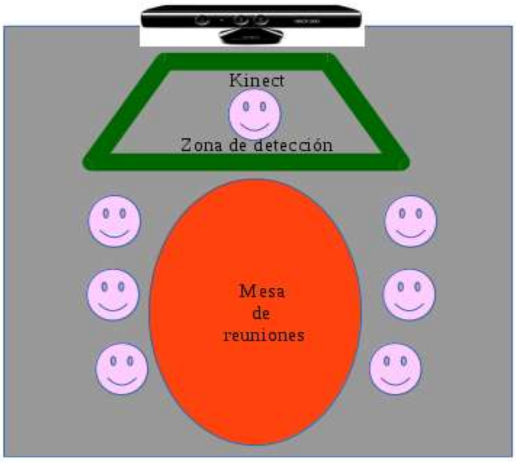

Fig. 3. Boardroom design for the low-fidelity prototype.

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Requirements for a Proposed Distributed Attention System for Supporting Awareness of Omissions in Healthcare

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Abstract. Noticing errors of omission can be challenging in complex, distributed processes. A prime example is outpatient care, where multiple distributed processes require attention. Teams must pay attention to patients currently in the clinic, to processes happening in the background, and to potential omissions in those processes. Detecting possible omissions may be supported with software, serving as a distributed attention system by guiding the team's attention to important areas. However, to ensure the software supports rather than disrupts attention, proper user requirements must be defined. This paper presents our study to identify high-level user interaction requirements for software planned to support attention to omissions in Chronic Heart Failure treatment. We interviewed outpatient clinic team members to identify information needs for addressing possible omissions, and how notifications should fit with team communication patterns. The findings are discussed in terms of high-level requirements for effective functioning of teams of humans and software agents.

Keywords: Monitoring systems, notifications, distributed attention, functional requirements, omissions, healthcare.

1 Introduction

In this paper, we present the results of a study conducted to identify functional requirements about user interaction for a proposed software program to aid with detection of specific omissions. First, we describe the problem of omissions, and the proposed software. We then present risks posed by software that attempts to guide attention, and how these risks need to be addressed via requirements informed by users' cognitive and workflow patterns. After presenting the methods and results from our interviews, we discuss high-level requirements for how software can best facilitate attentional flow under uncertain and dynamic situations.

1.1 Background

In the US Veterans Affairs healthcare system, any patient receiving out-of-hospital care is assigned to a Patient Aligned Care Team (PACT). This team consists of: a Primary Care Provider (PCP, either a general practice or internal medicine doctor, or a community Nurse Practitioner); a Registered Nurse care manager (RN); a clinical assistant (Licensed Practical Nurse); and an administrative assistant [24]. The PACTs are supported by other healthcare workers, such as pharmacists. Except during hospitalization or treatment by a medical specialist, the PACT assumes responsibility for the ongoing healthcare of that patient.

However, there are challenges affecting the PACT's capability to deliver ongoing care to a patient. The pool of patients assigned to a PACT can be over 1000. There may be 10 to 15 patients seen in one day. Tasks must be coordinated across the PACT members. Many tasks also involve groups outside of the core team. For example, diagnostic services draw blood, conduct laboratory tests, and take x-rays. Pharmacists evaluate and fill medication prescriptions. In this system the delivery of healthcare services to a patient is distributed across several different processes.

The work is multi-threaded [33], because at any given time there are multiple patients at different points in these care delivery processes. The demands of coordinating and managing disparate tasks result in work fragmentation [19]. Under these conditions, it is easy for some steps in patient care to be missed [22].

One example is when a patient with Chronic Heart Failure (CHF) is discharged after being treated in the hospital. It is important to review and adjust the patient's CHF medications to reduce the chance that the patient will need to be re-hospitalized. However, many of these patients qualify for but are not prescribed the recommended medication doses [2].

If omissions like this are identified soon, they can be remedied. However, it is difficult to notice an omission, especially when the patient is not present, and the team is heavily occupied with other tasks. Additional support is needed.

1.2 Framework for Omission-Detection Software

In the Veterans Affairs (VA) healthcare system, all medical documentation is integrated into the VistA Electronic Health Record platform. It is possible to use software to automatically scan patient records to identify patients who have medical issues for which they may not be receiving guideline recommended care. Previous work has used this technique to identify patients who may have abnormal test results that are overdue for follow-up [21]. In that study, the medical records of those patients were reviewed by clinicians to determine if the patients likely needed follow-up. If so, the appropriate PCPs were contacted. However, because that approach requires manual review by a clinician, it will not be cost-effective at a large scale.

This limitation can be addressed by adding on a component to automatically notify the appropriate person of the potential problem. Once the software identifies a patient who has warranted a particular guideline recommended treatment but shows no evidence of having received it, the software would notify the appropriate PACT.

The study presented here was conducted for proposed software focusing on the problem of undertreatment of CHF. However, the basic strategy, and the attendant issues regarding coordination between software agents and human team members, are applicable to detection of omissions in other critical processes that are distributed across people and time [9]. This proposed software will run nightly scans of the medical records in a large network of VA outpatient clinics. It will look for patients who have been discharged after being hospitalized for CHF exacerbation, but who are not prescribed the guideline recommended levels of a particular type of medication (beta-blockers) [13]. If it finds such a patient it will inform the PACT for that patient. Based on historical data, it is expected that the average for a typical PACT will be 1-2 undertreated CHF patients per month.

The software will be able to monitor the whole population of patients in the network of clinics, and it will be able to identify delays spanning across long time frames. It will identify patients that would otherwise not cross the mind of any PACT member. In principle, the proposed software will expand the ability of the PACT to detect omissions. It can help team members shift perspective [33]—between a narrow but deep focus on the rich complexities of the small set of patients at hand, and a broad but shallow focus on which patients among the 1000+ assigned to the PACT might have omissions (in this case, beta-blocker titration). More specifically, this software will be sensitive to omissions that happen in the time after a patient event (in this case, discharge from hospital and standard follow-up), when PACT members have finished performing their routinized tasks. A PACT with a software agent monitoring for problems is an example of a distributed attention system, in which multiple agents (human and/or software) serve to facilitate the flow of a member's attention to where it is currently most warranted [34].

1.3 Automation as Help or Hindrance

Often the introduction of automation software into a work system causes problems [5, 33]. Many of these problems come from a poor fit between the software and the larger work system [7]. To prevent these problems, the software design should take into account such factors as the workflow, the existing software, and the communication and organizational patterns [26]. For example, the notification software tools under development should fit with the technical and organizational communication channels.

Another factor that affects the impact of the software on the work of practitioners is how data on patients, medical conditions, and care processes are organized and presented. In complex domains like healthcare, data displays can support cognitive work if the design takes into account the meaningful properties of the relevant system and its functions [6, 14, 29, 32]. The meaningful properties involved in managing care for these sorts of medical issues in the outpatient setting include: the goals of the team members, the patient's condition, the status of the care processes, possible courses of action, applicable criteria, etc. These can be integrated into a frame of reference which can be used to portray relationships, trends, and other important patterns [31].

Organizing and presenting information along these lines can be helpful for detecting patterns [31] and interpreting and making predictions about the status of a situation [11]. These cognitive processes are especially important for the tasks of understanding and responding to an anomaly (the possible omission of care) while simultaneously managing other work under the difficult conditions that led to the anomaly [33].

Another potential automation-related problem is how messages from a software agent to a human team member may cause unnecessary disruption. This is especially true of push notifications like pop-ups or alarms. However, in re-directing a person's attention, any notification can incur a re-orientation cost. This cost is dependent upon the interaction between the workflow and communication channels, and the patterns of activation of knowledge structures. When a team member is engaged in a particular area of their work, their attention is focused in that area, and relevant knowledge structures are activated (enabling the interpretations and expectations necessary for the process of situation awareness) [34]. If an external stimuli pulls the team member's attention towards an arbitrarily different area of their work, any newly relevant knowledge structures are not instantly activated [4]. The process of situation awareness does not plateau instantly [5]. A notification that initiates a shift across (rather than within) "working spheres" will present more disruption [19].

1.4 Requirements Elicitation

The success of the proposed software tool at expanding the attention of the PACT members depends on: a) the fit with the current workflow and communication channels; b) the fit with the basic functions and meaningful properties of the task domain; and c) the fit with the attention flow of the team members (as their knowledge structures are dynamically activated in response to workflow and communication events). It is important that the functional design requirements for the software incorporate information on these aspects of the system and the work. Therefore we conducted research to elicit information about these aspects from relevant primary care professionals (PACT members and supporting healthcare workers).

2 Methods

2.1 Participants and Setting

Our settings were three different Veterans Affairs outpatient clinics: one in a large city, one in a medium city, and one in a rural area. All sites were part of the same regional VA network.

Participants were recruited from all PACT PCPs, RNs, and all pharmacists at those outpatient clinics. There were a total of 16 participants: 7 Primary Care Providers (2 doctors, 5 nurse practitioners), 5 Registered Nurse care managers, and 4 pharmacists.

2.2 Procedure and Data Collection

We conducted semi-structured interviews with each participant individually on site. The interviews were audio-recorded, and notes were taken. One research team member led the interview (MS) and another took notes (CB).

The interviews were loosely based on two approaches to cognitive task analysis: ACTA (Applied Cognitive Task Analysis) [20] and GDTA (Goal Directed Task Analysis) [11, 15]. We asked participants about which communication channels they used, when, and for what types of information. We asked about how notifications are handled in their PACT, and for examples of helpful and unhelpful notifications. We also asked questions about clinical activities (such as the timing and processes for medication review, and for post-discharge follow-up). We asked what factors they considered when making treatment decisions for CHF patients, and especially when considering titration of a beta-blocker. Afterward we asked what information they think would be important to present on a notification about possible omission of beta blockers, and what they thought they would do if they received such a notification. The specific set of questions varied depending on the role of the participant (PCP, RN, or pharmacist). Institutional review board approval was obtained for this study.

2.3 Analysis

We conducted a framework analysis [23] on the interview data. This incorporates both a "top-down" framework-driven approach and a "bottom-up" data-driven approach. In our analysis, some aspects of the interview topics were analyzed with particular use of frameworks: the different communication channels used in the VA, and general models of CHF treatment and beta-blocker use.

The analysis was conducted by the two research team members who were present at the interviews. One performed iterative reviews, coding the data and identifying patterns (MS). The other critically evaluated this initial analysis to establish independent confirmation (CB). The results reflect the consensus of the two research team members.

3 Results

The items and issues raised by the participants are presented below, structured by themes. When necessary the types of participant(s) who expressed the specific item or issue are identified afterward: PCP (Primary Care Provider); RN (Registered Nurse care manager); and Pharm (pharmacist).

3.1 Communication Channels

Among the several electronic communication channels mentioned, three were brought up most frequently: View Alerts, Secure Messaging, and Message Manager. Other channels are used, but were not mentioned as frequently. Different channels are used by different roles, and for messages of different urgency.

View Alerts. These notifications appear in a list on the user's home screen of the VistA Electronic Health Record software. Each is linked to new information entered into a patient's medical record (e.g., lab results, notes from specialists). Among our participants, PCPs used View Alerts the most, followed by RNs and pharmacists. View Alerts are for actions that need to be acted on within a short time (PCP), but not for highly urgent tasks. If it can be done anytime throughout the day then it should be sent via View Alerts (RN).

Especially for PCPs, "processing" alerts involves reading the new information, and performing any EHR-based tasks required (such as prescribing new medication, ordering new labs, etc.). In general, checking View Alerts is done when time is available: throughout the day (RN), or whenever they can (PCP). The challenge of finding time to process alerts is exacerbated by the high rate of incoming View Alerts, a known problem [25].

A View Alerts notification serves to inform the recipient of new information added to the patient's record. Thus, the information provided can include a brief narrative on what was done, preferably including an assessment and plan (Pharm). It allows clinical staff to communicate with one another (RN, Pharm). View Alerts are one mechanism that directs the attention of the PCP to a patient's record. Another mechanism that directs attention to the record is an upcoming appointment with that patient (PCP).

Secure Messaging. Secure Messaging is a system for the patient to send a message to the PACT using a secure patient web-portal. Once received, messages can be assigned to specific team members to take care of. They sometimes consist of lengthy and detailed feedback requests from the patient (RN). The fact that it is a direct message from the patient is valued (RN). It can be easily added into the patient's record in the VistA EMR (RN). However, it is not a good channel for reporting medical symptoms or other more urgent issues (RN). Recipients have three days to address a secure message before the director of the clinic is alerted.

PCPs and their PACTs may allocate different team members to check Secure Messaging, based on what works best for them. Some teams have multiple members check the messages (RN). Messages are checked multiple times per day (2 RNs).

Message Manager. Message Manager is a system for delivery of telephone messages from the patient. Staff at the regional call center receive the patient's telephone call, type up the patient's message in Message Manager, and send it to the patient's PACT. The notification is then listed in the Message Manager web-tool, to be accessed by a PACT member. The item can be assigned to specific team members. An email is also sent to the team members indicating that a new Message Manager item has been delivered. There is an optional function to receive a pop-up notification on the computer as well.

Most users check Message Manager periodically, such as once in the morning and once in the afternoon (2 RNs). Messages are often patient requests for medication refills or to find out the results of laboratory test (RN). This channel is not good for urgent issues or those regarding medical symptoms, which should go through triage (RN). Recipients have two days to address these messages (RN).

Patient Almanac and Data Warehouse. These are two similar tools that provide reports on patients assigned to the PACT who may have medical issues to be addressed. The Data Warehouse lists patients who have high "critical need" scores, indicating a high risk for hospitalization (2 RNs). The almanac provides information on patients with chronic diseases, and on patients who have been admitted to the emergency department or discharged from the hospital (RN). These tools are used primarily by the RNs, and not by PCPs (RN, PCP). The Patient Almanac is checked throughout the day (RN). The Data Warehouse is checked first thing each morning (RN), or once a week (RN).

Instant Messaging. Instant Messaging is a real-time chat system. It is used for urgent issues (2 RNs). It is used to communicate with PCPs (Pharm), and used by PCPs to request help in the middle of a patient visit (PCP). Some use Instant Messaging frequently (RN, PCP), while others don't use it at all (RN).

Email. Email is not used consistently. One RN checks email throughout the day. Others don't use it at all (2 RNs). For PCPs, it is one of the communication channels they look at the least (RN).

3.2 Events and Factors Affecting Assessment and Care

Doctors and nurses need to take many elements into consideration when evaluating a patient for potential treatment with beta-blockers. Factors mentioned by participants included: age, blood pressure, heart rate, kidney function, symptoms, medication history and adherence, patient's goals, and co-morbidities (such as kidney disease). In addition to these clinical factors, they must be aware of the status of relevant care processes (i.e., what steps or events have or have not taken place). Events mentioned by participants included: pre-discharge medication review, discharge, post-discharge call with RN, stabilization, and each titration event.

3.3 Attributes Related to the Usefulness of Notifications

Participants gave examples of useful and non-useful notifications. The set of examples reflects attributes of the needs of clinical users regarding notifications. These attributes are listed below, with positive (+) and negative (-) examples provided under each attribute.

Aiding Re-orientation of Attention.
+ The items in the Message Manager web-tool list show the subject of the message (Pharm).
+ Using markers (such as “ATTENTION”) in a long note in a patient record to indicate which part the recipient should focus on (Pharm).
+ Pop-up notifications indicate the arrival of a new Message Manager item (PCP).
- The Message Manager web-tool does not refresh automatically, so the displayed list is not up to date (Pharm).
- The VistA EMR View Alerts system does not support prioritization (Pharm).

Providing Clear Information and Instructions.
+ Some discharge summary notes in VistA contain specific information on what needs to be attended to (PCP).
+ E-consults (responses to requests from specialists in VistA) are good because they explain what to do (PCP).
+ Patients’ records often contain brief narratives where the doctor or other clinical team member explains what they did, what the assessment is, and what the plan is (Pharm).
+ Consult notes from specialists often explain why they are using a particular medication (PCP).
- Message Manager items that address a clinical issue but are written by a non-clinical clerical assistant can contain inaccuracies or be missing information (RN).
- Some notifications are for tasks that are out of the recipient’s scope of work (RN), or could just as easily be performed by the clinical or clerical assistants (RN).

Notifications Directly from Originating Person.
+ Secure Messages are most helpful because they are directly from the patient (PCP, RN).
- Calls being routed through the call center can cause problems and make it hard for the patient to reach the PACTs (RN).
- Some calls through triage are not routed properly (PCP, RN).

Easy Access to Relevant Information.
+ The Patient Almanac provides information on multiple patients, and includes relevant data (e.g., dates the patient was hospitalized and discharged, deadline for post-discharge call) (RN).
+ A reminder at each stage in the processing of diagnostic imagery (e.g. echocardiograms, mammograms) would be useful (PCP).

- Message Manager items lack background information, and are not specific or descriptive (Pharm).

Relevance.
+ Getting an Instant Message about an urgent issue is appropriate (RN).
- View Alerts that are simply “For Your Information” are not helpful (PCP, Pharm).

3.4 Participants’ Thoughts on Responding to a Notification

To elicit potential factors concerning the role of notifications, participants were asked about how they might respond to a hypothetical notification about a possible omission of appropriate beta-blocker titration. Participants said they would try to determine what happened that caused the omission of the beta-blocker titration (3 PCPs). They would look to see who was involved (PCP). One PCP said they would go ahead and order beta-blockers upon receiving the proposed notification. Another PCP said they would try to find out more about the guideline being applied in the software, to see if it was applicable to that particular patient.

Note that when a PACT member is responding to one of these notifications, they will be in a different situation compared to when they have been following a pre-planned process to address an anticipated task (i.e., evaluation for beta-blocker titration). For example, less time and less planning means that it will be more difficult to coordinate follow-up activities with the patient’s previously scheduled appointments (PCP).

4 Discussion

4.1 Coordination of Attention Flow

In dynamic domains, it is important for all team members to be able to direct attention to the important signals in the world. These signals can pertain to expected changes, deviations from a prescribed plan, or critical unanticipated events. This study provides further evidence for the necessity of good attention management within a notification system. We found that notification mechanisms correlate with different levels of urgency, and are checked with different frequencies. Accessing different channels with different frequencies is a way that team members can control when and how they permit the system to re-direct their attention. Instant Messaging is for immediate issues. Message Manager, View Alerts, and Secure Messaging are for issues with a time frame of a couple of days. Email, and the Patient Almanac and Data Warehouse, are for less urgent issues. When the nature of the channel itself conveys information about the urgency of the notification, the team member is able to direct their attention flow at a pace that corresponds to the urgency of the notification, before knowing the content of the notification.

This mechanism for managing attention functions at both the individual and team levels. For instance, PCPs do not attend to the low urgency channels. They primarily use View Alerts, with some use of Instant Messaging. PCPs primarily focus on individual patients and their time-sensitive, medically important issues. PCPs need to be able to easily re-orient to new patients and new urgent tasks as they arise.

In contrast, RNs attend to information about patients in less urgent states. They manage messages from patients regarding care maintenance issues. They access the Patient Almanac and the Data Warehouse tools which are designed to identify sets of patients at risk, before problems become more critical. Thus, they are focusing on a somewhat different scale and different time frame than the PCPs. By accessing other more urgent channels (Secure Messaging, Message Manager) at specific times, they are able to reduce the frequency of re-orienting to more acute issues.

In principle, the way the software selects the channel and the recipient should be based on the type of response required, and the time frame required. For example, relatively urgent medical issues might be directed to PCPs using View Alerts, while non-urgent issues that pertain to nursing care management functions might be directed to RNs using Data Warehouse. If the software is sensitive to the different levels of risk experienced by patients with omissions, it can be more nuanced in its interaction with the PACT. The PACT can be kept informed of issues at various stages, instead of simply receiving a uniform alert at one particular threshold.

Note that there are challenges to implementing an elaborate algorithm to determine who should be notified and how. Much of the data in the Electronic Health Records are not structured or standardized sufficiently to support automated inference. A human team member must play a primary role in evaluating the nature of the problem and the type of response required. A fully automated approach, without a human there to evaluate situations, will be brittle in a domain like healthcare, where variation is high and deviations from plans can involve many interacting factors.

4.2 Making the Omission Observable

To support the human team member in evaluating the nature of the problem and the response required, the software should make the relevant clinical processes and care management procedures observable [17, 33]. It should reveal the factors related to the event (e.g., the omission of beta-blocker titration) and to the possible courses of action. To do this requires a clear understanding of how these clinical practitioners make sense of meaningful events and assess possible risks to the patient [10, 16]. The knowledge structures involved in these processes relate to a meaningful frame of reference which can be used to make supportive data representations. Our study shows the way practitioners use significant aspects of a clinical situation to make sense of possible omissions.

One significant aspect was the applicability of the clinical guideline to a hypothetical patient with a notification. The practitioners needed to know if there were reasons why the patient should not be given higher doses of beta-blockers. This included information like clinical contra-indications or patient preferences.

A second significant aspect concerned the status of the patient's care activities. They wanted to know about where the patient was in the sequence of steps, and what else may have been omitted. Associated with an assessment of progress along the prescribed plan was the need to know if care was being provided by a doctor outside of the VA but not documented in the VA EHR.

A third significant aspect was the causal factors related to the omissions. They wanted to understand what led to the CHF patient not being prescribed the correct medication and/or dose. For example, did an order from the doctor not get sent, or was there a follow-up appointment that got canceled?

The complexity of these significant aspects cannot be easily accounted for in a software algorithm, which is why a human team member is required to make sense of these aspects. However, this sense-making process can be facilitated by the software making these significant aspects more observable by presenting the relevant information in meaningful frames-of-reference. Our findings in this study suggest that the care plan and associated guidelines is one potential frame-of-reference. Within this care plan frame-of-reference it is possible to organize information like diagnostic data, appointments, tests, and plan progress. These types of integrated displays leverage the benefit of the human-machine team [18].

4.3 Directing towards Courses of Action

For effective coordination to happen in the human-machine team, the members of the team need to be able to direct the application of resources, and the synchronization and prioritization of activities [33]. One aspect is how the notification should not only help human team members notice and interpret possible omissions, but also support them in recognizing and assessing possible courses of action.

Our findings stress the importance of notifications that provide actionable information. By incorporating representations of guideline recommended courses of action (e.g., time frames, treatment options and dose levels) into the frame-of-reference, this will facilitate practitioners in responding to the potential omissions. By presenting this information in the context of other factors (patient history, clinical status, etc.), we can mitigate the risk of the human team member focusing only on the computer's reference to guidelines and neglecting these other important factors [28].

4.4 Accommodating the Limits of Automation

One fundamental limit of notifications or alerts within a team of humans and automated monitoring agents is the information value of the alerts [30]. The information value of an alert is related to the positive predictive value. The positive predictive value of the software algorithm is projected to be 80%, meaning that 1 out of 5 notifications will be false positives. False positives may be from: the beta blocker being prescribed but not documented in the VA record (i.e., from a non-VA physician); from exclusion criteria or contra-indications documented in a way that is not machine-readable; or from the PCP determining that the guideline is not applicable in that specific situation.

However, the notification can make the decision process of the software observable by presenting information on how the software came to its conclusion. It can show the way in which the patient meets the algorithm's criteria for inclusion, and what contra-indications it checked for but did not find, and what data it had access to. In so doing, the notification can support easier recognition of false positives by the recipients. They will be able to directly check a few things to verify that the software missed something. Listing the factors will also help remind the recipient of what should be checked as part of assessing for beta blocker use. This will not decrease the number of false positives, but it will decrease the cognitive burden from them.

One way to help manage the rate of false positives is to enable human team members to continue to direct the focus and priorities of the software agent as part of human-machine coordination [17, 33]. The ongoing maintenance and updating of the software must involve mechanisms for the users to easily provide input and guidance to the software as part of normal use. Because healthcare is a dynamic system, and even clinical documentation practices change over time [1], the algorithms will become out of date without fresh feedback from the PACT members. Ensuring the end user has a role in the control of the software evolution will help the software stay resilient [8, 27], potentially reduce the rate of false positives, and addresses some of the political concerns raised by software that monitors workers [3].

4.5 Proposed High-Level Requirements

The system shall select the delivery channel based on the urgency of the notification. E.g., if the patient has an appointment scheduled within 60 days, or is being treated by a cardiologist, it is less urgent, and the notification should be delivered via Data Warehouse. Otherwise, it is more urgent, and the notification should be delivered via View Alert.

The software will scan the structured data in the chart for the following clinical factors: previous use of beta-blockers; current use of heart and kidney medications; current lung, kidney, and heart diagnoses; and presence of documentation from any cardiologist in the past 6 months. The notification will list all of these factors and the results of the scan (positive or negative/inconclusive).

The software will extract the date and the name of the healthcare provider responsible for the following care delivery events: CHF diagnosis; hospital admission and discharge; medication reconciliation; post-discharge follow-up call; pending orders for heart medications; and pending appointments with PCP, cardiologist or pharmacist. The notification will list each of these items with either the dates and names, or an indicator that the event was not found.

The above clinical factors and care delivery events will be displayed in the notification using the format of a care plan, chronologically ordered and structured by functional area.

4.6 Study Limitations

This study has relied on interviews to collect data on how the PACT members use communication channels, how their knowledge about particular tasks is structured, and their patterns of attention flow. With interviews there is a risk of inaccurate recall and reporting about such issues. However, our general findings reflect accounts from a wide range of participants, but do not reflect any systematic self-serving or social desirability biases. This strengthens the validity of our findings.

Because many of the relevant communication activities occur infrequently (e.g., using the Data Warehouse, receiving discharge reports), observations of communication and attention flow patterns were impractical. Computerized monitoring to detect work activities has been shown to work in hospital settings [12]. However, for this study we did not have enough information at the beginning to operationalize a sufficient set of indicators of communication and attention flow patterns.

4.7 Next Steps

Working with clinical subject matter experts, we plan to develop notification designs which incorporate the meaningful clinical factors and care process events. Prototype designs will be used in usability testing with PACT members. Throughout the design and implementation process, representatives from the clinics will be involved.

Acknowledgements. The authors thank the participants and the leadership of the VA VISN and participating facilities. Thanks to Julia Akeroyd, Natalie Kelly, Daniel Murphy, Elise Russo, Hardeep Singh, Salim Virani, and the anonymous reviewers. The research reported here was supported by the US Department of Veterans Affairs, Veterans Health Administration, Health Services Research and Development Service (CRE 12-037). The views expressed in this article are those of the authors and do not necessarily represent the views of the US Department of Veterans Affairs.

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Diseño de la Experiencia del Usuario para Espacios Interactivos de Aprendizaje no Formal

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Resumen. El diseño de artefactos digitales o espacios interactivos orientados a la educación requiere de metodologías de desarrollo adecuadas que permitan que el producto final favorezca el aprendizaje esperado. En este trabajo se propone utilizar el enfoque del *diseño de la experiencia del usuario* como guía en el proceso de diseño de espacios interactivos de aprendizaje no formal, ya que una de las principales metas al diseñar este tipo de artefactos digitales es crear una "experiencia" en el usuario que propicie que se alcancen los objetivos de aprendizaje. El objetivo de este trabajo es describir una metodología para el diseño de este tipo de artefactos digitales que vaya más allá de la usabilidad, tomando en cuenta otros aspectos cognitivos, socio-cognitivos y afectivos de la experiencia del usuario al interactuar con estos artefactos, como son: el disfrute de los usuarios, la experiencia estética, el deseo de volver a usar el artefacto, entre otros; todo esto con el fin de favorecer el aprendizaje de acuerdo a los objetivos propios del artefacto. En el trabajo se describe cómo se ha utilizado esta metodología para la construcción de un espacio interactivo orientado a crear una experiencia musical dentro de un museo interactivo dirigido a niños.

Palabras clave: Experiencia del usuario, metodología de diseño, aprendizaje no formal.

1 Introducción

En [1] se indica que la investigación tradicional en el campo de la Interacción Humano-Computadora ha centrado su estudio en las habilidades y procesos cognitivos del usuario, estudiando principalmente el comportamiento guiado por la racionalidad y dejando de lado la influencia emocional en él. Si bien, la definición de experiencia del usuario aún es discutida en la comunidad de interacción humano-computadora; existe el consenso de que es necesario considerar aspectos más allá de la usabilidad en el diseño de productos o servicios.

Bajo este panorama se propone utilizar el enfoque metodológico del diseño de la experiencia del usuario para complementar el proceso de desarrollo de espacios interactivos orientados al aprendizaje no formal del grupo Espacios y Sistemas Interactivos para la Educación (ESIE) del Centro de Ciencias Aplicadas y Desarrollo Tecnológico de la UNAM.

1.1 El Aprendizaje no Formal en Espacios de Difusión de la Ciencia y la Cultura

En los últimos años ha surgido un gran interés en el tema del aprendizaje que ocurre en modos alternos al que plantea la educación formal. Tanto educadores e investigadores del aprendizaje o del desarrollo cognoscitivo, científicos interesados en la difusión de la ciencia y la cultura, y museólogos han explorado y desarrollado conceptos como el aprendizaje informal, no formal, a lo largo de la vida, entre otros, que si bien comparten muchos elementos en común, sus seguidores hacen hincapié en sus diferencias. Pese a los problemas derivados del costo, instalación, uso, adopción y mantenimiento de las TIC en la educación, la UNESCO sostiene que las TIC pueden mejorar el acceso a los programas de educación no formal [2].

Mejía [3] indica que una de las tendencias en la investigación del aprendizaje, derivada de las actividades que caen dentro de la educación no formal, es el aprendizaje en espacios cuyo propósito es la difusión de la ciencia y la cultura. Ejemplo de estos espacios son los museos, zoológicos, centros tecnológicos, galerías de arte, entre otros. Estos espacios están caracterizados por formas de interacción libres y variadas que brindan condiciones favorables al aprendizaje.

La interacción espontánea que se da en museos y espacios de divulgación de la ciencia y la cultura, es un reflejo de la interacción cotidiana de los participantes en su comunidad ya que los visitantes eligen cómo abordar las actividades y exhibiciones de acuerdo a la comunidad de la que forman parte. Es importante hacer notar que la interacción entre las personas alrededor de los temas y la información de las exhibiciones ofrece una gran oportunidad para el aprendizaje, así como la autoregulación y autodirección del aprendizaje; es decir, estos espacios permiten una participación libre, voluntaria, graduada y dirigida por el mismo participante. De esta manera, los participantes pueden enfocarse en la información y la actividad que les interesa y avanzar a su propio ritmo. Por todo ello, hoy es aceptado que los museos interactivos pueden proporcionar escenarios para propiciar modos alternativos de aprendizaje por medio del contacto directo con objetos, y por la interacción en actividades interesantes y divertidas.

2 La Experiencia del Usuario

2.1 El Enfoque de la Experiencia del Usuario

Nielsen y Norman [4] hablan sobre la necesidad de distinguir experiencia del usuario y usabilidad, considerando que la usabilidad es un atributo de calidad de una interfaz de usuario asociada a la facilidad de aprender a usar un sistema, su uso eficiente y placentero, mientras que la experiencia del usuario es un concepto más amplio que involucra el análisis de la experiencia de interacción más allá de la relación entre usuario y producto. Por su parte, la definición que ofrece la ISO sobre experiencia del usuario se enfoca en las percepciones de una persona y las respuestas sobre el uso o uso anticipado de un producto, sistema o servicio [5].

Desde el punto de la interacción humano-computadora, la experiencia del usuario es un tipo específico de experiencia que considera un mediador particular, los productos interactivos [6].

2.2 Diseño de la Experiencia del Usuario

En [7] se define el diseño de la experiencia del usuario como la creación y sincronización de elementos que afectan la experiencia del usuario con la intención de influenciar sus percepciones y comportamiento. Los elementos que se consideran incluyen cosas que el usuario puede tocar, escuchar u oler. También incluye las cosas con las que el usuario puede interactuar, más allá de la interacción física, como las interfaces digitales y las personas que están involucradas. Como se puede apreciar, esta noción del diseño de la experiencia del usuario hace hincapié en la habilidad de integrar los elementos que afectan y enriquecen la experiencia en diferentes sentidos.

Así, para diseñar una experiencia del usuario exitosa los productos deben tomar en cuenta los objetivos del negocio del proyecto, las necesidades de los usuarios del producto y cualquier limitación que pueda afectar la viabilidad de las características del producto.

2.3 Evaluación de la Experiencia del Usuario

A través de la evaluación de la experiencia del usuario se puede determinar si el producto está produciendo una experiencia placentera para el usuario, existen diversos enfoques de la evaluación, pero la mayoría de ellos se centra en la identificación de los estados emocionales, ya que estos influencian procesos cognitivos como la capacidad de atención, memorización, rendimiento del usuario y, en general, su valoración del producto.

Bajo este contexto, el grupo que colabora en "*All About UX*" ha recolectado y clasificado más de 80 métodos para evaluar la experiencia del usuario [8]. En [9] se habla de la evaluación de la experiencia del usuario en los videojuegos y su relación con los estados emocionales. Desde su punto de vista la evaluación de la experiencia del usuario basada en cuestionarios puede ser complementada con el uso de mediciones fisiológicas, ya que al enfoque tradicional de detección de estados emocionales se han ido incorporando otros canales fisiológicos y no fisiológicos.

2.4 Aprendizaje no Formal a través del Diseño de la Experiencia del Usuario

En la actualidad, la mayoría de las investigaciones donde se haya utilizado las TIC como apoyo para el aprendizaje no formal, se reporta el uso de estrategias de interacción basadas en juegos o videojuegos con objetivos educativos. Schwartz y Bransford [10] llaman a este enfoque, "preparación para el aprendizaje futuro". Su propuesta indica que las experiencias de aprendizaje significativo, como las que se busca construir a través de las experiencias de los juegos, pueden tener mayor impacto en el participante porque son planteadas en un contexto concreto, que ayuda a que tenga sentido para él.

Si bien este enfoque favorece que el tema que trata el interactivo sea explorado de una forma más lúdica y, junto con las estrategias de la experiencia del usuario, se espera que logren despertar el interés por parte de los usuarios, el aprendizaje del tema puede ser reforzado por a través del contexto del usuario. Este planteamiento puede verse con más claridad en los museos interactivos, donde los sistemas interactivos se acompañan de entornos que permiten apoyar los temas desarrollados en cada una de las exhibiciones.

3 Diseño de la Experiencia del Usuario en Espacios Interactivos de Aprendizaje no Formal

Como se mencionó en la sección anterior uno de los puntos centrales al diseñar un espacio interactivo orientado al aprendizaje no formal es crear una experiencia adecuada a los objetivos de aprendizaje. En la propuesta presentada en este documento consideramos que para evaluar la experiencia del usuario de un espacio interactivo es necesario integrar en la metodología de diseño el enfoque de experiencia del usuario. En esta sección se indica cómo hemos adaptado nuestro proceso de diseño de software interactivo para crear una experiencia del usuario en espacios interactivos de aprendizaje no formal.

3.1 Metodología General para el Diseño de la Experiencia del Usuario en Espacios Interactivos

La metodología utilizada por el grupo ESIE para desarrollar software interactivo plantea las siguientes fases generales: (1) Planteamiento, (2) Diseño, (3) Realización (4) Pruebas y evaluación, (5) Cierre, (6) Retroalimentación y mantenimiento. Esta metodología se basa en el proceso de diseño centrado en el usuario, por lo una parte fundamental es el análisis de las necesidades de los usuarios del software interactivo. Este análisis puede será complementado usando el enfoque de diseño de la experiencia del usuario. En esta sección se describe cómo se propone complementar esta metodología incorporando el enfoque de la experiencia del usuario.

Planteamiento. Esta fase se definen los objetivos de aprendizaje, quién es la audiencia y principalmente se trata de entender las necesidades del cliente. El trabajo con los expertos del tema y el aprendizaje es central, el equipo se debe empezar a familiarizar con los contenidos así como con las estrategias que se utilizan para favorecer el aprendizaje. Cuando resolvemos nuestro problema desde la visión del diseño de la experiencia del usuario, las estrategias de aprendizaje son una referencia para elegir la forma en que se plantea una actividad pero también deberá analizarse si las actividades se pueden hacer de forma lúdica.

Otro elemento central es conocer el contexto en el que se usará el espacio interactivo. Para crear la experiencia del usuario es fundamental considerar el contexto, como una herramienta para el refuerzo de la experiencia que se está construyendo. Por ejemplo, si es un espacio bajo el auspicio de un patrocinador se debe tomar en cuenta la imagen del patrocinador, si es para un museo se debe considerar el papel que tiene el espacio dentro de la sala del museo y la imagen misma del museo.

Diseño. En esta fase se define el concepto central del espacio de interacción, se propone la historia y el estilo de diseño. Esta es una fase central para la definición de la experiencia del usuario, ya que se debe definir una historia que sea capaz de captar la atención de los usuarios y logre integrar los objetivos de aprendizaje de una forma natural. De acuerdo con Schell 11, el diseño de una buena experiencia ocurre cuando se observa el juego desde distintas perspectivas. En su libro "The art of game design: a book of lenses" plantea 100 lentes para apoyar el diseño de un juego, cada uno de estos lentes guía el diseño a través de una serie de preguntas sobre el diseño del juego.

La idea general de la experiencia propuesta se plantea al cliente a través de un guión conceptual y un primer prototipo que pueda representar la idea. El guión conceptual debe especificar los objetivos de aprendizaje planteados así como la estrategia utilizada para favorecer el aprendizaje.

Realización. En esta fase se crean los detalles del juego, las reglas, los retos y la relación con los objetivos de aprendizaje. Dependiendo de las necesidades específicas de cada espacio interactivo, se buscará que los objetivos de aprendizaje estén asociados con los avances en la historia, que se incluyan retos que mantengan la atención de los usuarios y que la interacción produzca una retroalimentación que refuerce la experiencia que se diseñó.

Se elige una parte representativa del concepto para desarrollarse con el detalle suficiente para hacer una prueba del espacio propuesto.

Pruebas y evaluación. El nuevo prototipo del espacio interactivo se pone a prueba con usuarios finales. En el enfoque de evaluación de la usabilidad se observa y analiza cómo un grupo de usuarios reales utiliza un sistema interactivo, adicionalmente, en el enfoque de experiencia del usuario se deberá conocer la percepción del usuario, para ello se pueden utilizar diferentes instrumentos.

El experimento estará controlado por el evaluador en un laboratorio de usabilidad y deberá tratar de reconstruir el contexto real del espacio interactivo, ya que la experiencia no estará completa sino se tiene el contexto adecuado.

A partir las observaciones realizadas en esta evaluación, se retroalimenta al equipo y se hacen las correcciones correspondientes en una nueva fase de realización.

Cierre. La fase de cierre se gestiona la entrega del producto, incluyendo manuales de uso, instalación y las condiciones de uso que favorecerán la experiencia creada.

Retroalimentación y mantenimiento. Cuando el producto se ha entregado y ha estado en uso, nuevamente se analiza su funcionamiento y determinan las modificaciones que se deben realizar de acuerdo a la experiencia planteada originalmente.

3.2 Diseño y Evaluación de la Experiencia del Usuario para un Espacio Interactivo Orientado a la Experimentación Musical "¿A qué Suena la Vida?"

Para ilustrar la aplicación de nuestra propuesta para el desarrollo de espacios interactivos describiremos un caso concreto donde se construyó y evaluó una experiencia específica.

Planteamiento. La empresa "Siete Colores, Ideas Interactivas", solicitó el desarrollo del espacio interactivo "¿A qué suena la vida?" que forma parte de las exhibiciones del museo "La Rodadora" ubicado en Ciudad Juárez, Chihuahua. Los temas principales que abordan en el museo son: entorno natural, donde se presenta información sobre las características geológicas, climáticas y la biodiversidad de la región; entorno social, en este espacio se retoma la vida social de Ciudad Juárez, también se busca fomentar la expresión y reflexión para promover la cooperación y la participación de la comunidad. Estos temas definen las dos secciones más importantes del museo.

La exhibición "¿A qué suena la vida?" pertenece a la sección de entorno social y tiene como objetivo proporcionar un espacio lúdico colaborativo que permita a niños de ocho años en adelante participar en un ensamble musical y simular experiencias básicas de una sesión de grabación usando guitarras eléctricas y una consola de efectos sonoros.

El espacio designado para la exhibición tiene forma cilíndrica con tres metros de diámetro. El espacio interactivo está diseñado para niños de 8 años en adelante.

El objetivo general del espacio interactivo es el desarrollo de un espacio musical interactivo en modo colaborativo siguiendo el enfoque de los juegos rítmicos [12].

De manera más específica se plantean los siguientes puntos:

- Desarrollo de un espacio interactivo y colaborativo en donde se simulen experiencias básicas de un ensamble musical.
- Crear un espacio de experimentación lúdica musical.
- Desarrollar una sesión de grabación de un tema musical.

Diseño de la experiencia del usuario. El reto más importante para los usuarios es ejecutar una sesión de ensamble musical donde su participación esté acorde con un género musical y que la participación de todos sea congruente con el resto de las intervenciones. El desarrollo de estas habilidades requiere práctica individual y en conjunto. En el caso de este interactivo se plantea guiar a los participantes de forma grupal a través de una melodía base y con información visual en el espacio interactivo, así como sincronizar de forma automática las ejecuciones individuales para que sean congruentes musicalmente entre sí.

Adicionalmente, se indica que escuchamos la melodía pero sentimos el ritmo [13], a partir de esta percepción la gente mueve sus cuerpos al ritmo de la música. Este movimiento involucra percepción de la posición del cuerpo, percepción del movimiento y balance, percepción visual y auditiva. La capacidad de sentir e interpretar los tiempos fuertes de patrón rítmico permite que las personas se muevan y reacciones al tiempo de la música. Por lo general los pulsos fuertes de un patrón rítmico se ejecutan más fuerte, son más largos o presentan ambas características, y la estructura métrica (la que te hace moverte) se deriva de estos pulsos.

Esta revisión de las temáticas del aprendizaje y percepción del ritmo en los niños nos da un marco para el diseño de una experiencia de usuario. De esta forma, el espacio interactivo "¿A qué suena la vida?" deberá ser un espacio atractivo que permita a los visitantes tener una experiencia colaborativa a través de la formación de un grupo o ensamble musical, donde los participantes deberán sentir la experiencia de ser un ídolo musical.

Al ingresar al espacio interactivo el visitante encontrará cuatro guitarras y una consola de efectos sonoros tipo DJ (figura 1).

Fig. 1. Espacio interactivo

Realización. Una vez que se define el concepto con el que se trabajará se detallan las características del funcionamiento del espacio interactivo. Se identifica que el público principal de la exhibición es de la región norte de México y que algunos de los géneros musicales más representativos para este público de la zona son: rock, pop y tribal.

Este análisis nos permite identificar qué géneros musicales serán mejor recibidos por los participantes.

Para reforzar la experiencia de tocar un instrumento se utilizarán dispositivos que simulan una guitarra eléctrica real y una consola de sonidos (figura 1).

Para iniciar la experiencia del usuario, el interactivo se reproduce un mensaje auditivo y visual que invita a los participantes a alcanzar uno de los objetivos del interactivo ser un "ídolo musical" (figura 2). Al finalizar, se apagan las luces y la grabación de la sesión de los participantes se reproduce mientras los usuarios salen del espacio con sonidos vitoreó y aplausos, como sucede al final de un concierto.

Fig. 2. Mensaje de bienvenida al espacio interactivo

Pruebas y evaluación. De acuerdo con lo presentado en la sección de evaluación de la experiencia del usuario, debemos tratar de obtener la percepción del usuario sobre la experiencia planteada. Para este espacio interactivo se desarrolló un prototipo del interactivo y se realizaron pruebas con usuario. En la sesión de evaluación participaron 21 usuarios en grupos de 3. En cada sesión de evaluación, se grabó la interacción, reacciones y comentarios de los usuarios.

A partir de los videos de las sesiones de evaluación se pueden analizar las actividades de los usuarios e identificar sus estados afectivos y de los usuarios al realizarla. Por ejemplo, se solicita a los participantes que tienen guitarra que empiecen a probarla y al participante que está frente a la consola pruebe los botones de la misma.

A partir de los videos se observa lo siguiente:

- La mayoría de los usuarios tomaron la guitarra se la colocaron y de inmediato intentaron presionar los botones de la misma para poder generar algún sonido.
- Los usuarios que utilizaron la consola de DJ, se quedaron desconcertados, la mayoría de los usuarios no identificaron si ellos generaban algún sonido aunque si presionaban los botones de la consola.

Una vez identificada la reacción de desconcierto del usuario y que no pudo realizar la actividad debemos buscar una estrategia de diseño que nos ayude a mejorar la experiencia. De acuerdo con las guías que proporciona Schell, el lente de "lo básico de la experiencia" nos permite identificar que lo básico de la experiencia de la consola de DJ es agregar efectos de sonido sobre la ejecución de todos los participantes, mientras que la consola de DJ es un instrumento muy específico que no es tan fácil de usar por una persona que no ha tenido un entrenamiento previo (figura 2), así que es necesario rediseñar la consola por una más simple pero que cumpla con los objetivos del espacio, es decir, un instrumento que permita que el participante se integre a la creación musical (figura 3).

Fig. 3. Interfaz de usuario con consola de DJ realista

Fig. 4. Interfaz de usuario con consola de DJ rediseñada

La identificación del estado afectivo también puede ser usada para apoyar el análisis de las respuestas en los cuestionarios de salida. Una de las preguntas que se hicieron fue "¿volverías a jugar este juego?", hubo algunos participantes que contestaron que no, o bien que si pero que ahora quisieran "tocar música" refiriéndose al uso de las guitarras. Al analizar el estado emocional de los participantes que indicaron que no volverían a jugar o lo harían siempre y cuando usen una guitarra, observamos que en la sesión donde participaron les tocó usar la consola de DJ y la experiencia no les fue placentera.

Estos resultados nos indican que la experiencia del usuario de la consola de DJ no es la adecuada, no es suficiente clara, no es divertida y por lo tanto no es placentera. Así que fue necesario rediseñar esta parte del espacio interactivo.

4 Conclusiones

En esta propuesta se plantea que un espacio interactivo que busque apoyar el aprendizaje no formal debe estar diseñado pensando en crear una experiencia del usuario para obtener una mejor aceptación por parte de los usuarios.

La primera aproximación hacia una metodología de diseño de espacios interactivos de aprendizaje no formal, descrita en este documento, nos permite identificar de mejor forma si nuestro producto interactivo cumple o no con los objetivos de aprendizaje para los cuales fue creado, en contraste con una metodología guiada sólo por la usabilidad, donde sí se puede observar si el producto será usable pero no sabemos si le agradará suficientemente al usuario para que concluya la actividad propuesta y con esto se tengan mayores probabilidades de alcanzar los objetivos de aprendizaje.

Junto con la formalización de la metodología se trabajará en la evaluación de este tipo de espacios, para ello, es necesario contar con instrumentos que nos ayuden a identificar la percepción del usuario cuando interactúa en el espacio, ya sea durante la misma evaluación o en una fase posterior de análisis.

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User Experience Design for Brain-Computer Interfaces to Support Interaction in Points of Interest

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Abstract. This paper discusses the potential of brain-computer interfaces (BCI) in the interaction between users and objects in points of interest in a city. We present an initial design of the user experience with BCI, aimed to include users with disabilities but also to enhance the experience of the general public. This design includes a physical space to be conditioned specifically for BCI so users can interact with certain objects in a museum, as well as enhancements throughout the museum based on BCI. We report results of a formative evaluation of the main design concepts.

Keywords: Brain-Computer Interfaces, Points of Interest, Objects of Interest, Augmented Reality, Accessibility.

1 Introduction

Many museums have been incorporating innovative technologies, such as multimedia kiosks, audio tours and interactive displays [1- 3]. Unfortunately, people with some disability cannot always enjoy these enhancements. For example, in Mexico only two museums have programs for blind people. For people with hearing or speech disabilities, only guided visits are offered using sign language [4].

In this context, brain-computer interfaces (BCI), which make it possible for users to interact with computer systems through sensors of brain activity, offer great opportunities for addressing the needs of disabled users as well as for enhancing functionality available to the general public. This paper explores the use of BCI for interacting with objects of interest (OIs) in a museum, in the context of the REAUMOBILE project, discussed below.

The remainder of the paper is organized as follows: In Section 2, related work with BCIs is presented; Section 3 further explores the needs of users with disabilities in the context of POIs. Section 4 discusses an initial user experience design involving BCI, whereas Section 5 presents results of a formative evaluation of the proposed design, which relied on feedback provided by two focus groups and three individual interviews. Finally, Section 6 discusses ongoing work and the conclusions we have drawn thus far.

2 Related Work

A brain-computer interface (BCI) is a communication system that allows the user to send messages to a computer with only brain activity [5]. In general, a BCI works as follows: Neurons are connected to one another by dendrites and axons. When they start to work, small electric signals are generated by ions on the membrane of each neuron. Although paths followed by signals are insulated, some can be detected by mechanisms such as electroencephalograms (EEG) or magnetic resonances. Signals can be interpreted by a computer program and associated to activities as required by the user [6].

BCI applications are often related to the goal of supporting users with disabilities. Some examples include research to help patients control their prostheses and improve signal reception. Nevertheless, BCIs can be used in other areas [7-10]. For the purposes of this paper, device control, gaming and entertainment are areas of particular importance and thus are discussed in further detail below. We also summarize salient work and issues on usability and user experience involving BCI.

Device control. Various techniques have been developed in order to improve control by the user in a BCI system. One example is the technique allows the user to rely on only three commands: left, right and foot Motor Imagery (MI: brain signs are generated when users imagine the movement of their own limbs). In addition, there are two types of navigation: free (the user can select POIs) and assisted (the user can rotate the camera in order to find a specific POI) [11]. Another example is Command Selection Training (CST), which determines the subject's initial response to an oscillating visual stimulus. The brain produces a corresponding response and this response can then be used to create a BCI command [12].

Gaming and entertainment. Control in games that rely on BCIs can be based on the user's affective state or on the user's brain activity [13]. In the first case, the system can detect the experience of the users in certain tasks by sensing their cognitive activity. In the second case, researchers are using mostly MI, Event-Related Potential (evoked by external stimuli to which the brain responds automatically), evoked by artificial stimuli and oscillatory rhythms of the brain activity [14]. Games such as World of Warcraft, Second Life and Son of Nor can be used now with BCIs [15], [16].

Usability and User Experience with BCI. Research on usability with BCIs might be just as important for their acceptance and widespread usage as their technological aspects. Usability components in this context present some specific traits [14]:

Learnability and memorability: Sometimes performing a mental task to communicate with the computer is new for most of the people. It has to be made clear to the users what is expected from them if they want to use a BCI.

Efficiency: Some BCI applications can adapt the way they present information or react to user input depending on the user's psychological state.

Errors: Error Related Negativity (ERN) can be used in order to detect when users are aware of their errors and undo previous movements.

Satisfaction: This is mostly related with the ease with which the user could learn and memorize the control of the BCI and with which accuracy they could control the system.

Although there has been progress in BCI applications, they still exhibit common problems that can affect the user experience (UX). For example, users get exhausted from the intense concentration they have to undergo in order to use a BCI system; some distractions, like noise, can detonate unwanted commands; the environment can produce internal effects such as changes in the user's state; users cannot use headsets for more than one hour; the sensor connection can take some time; there are chemical processes which the EEG cannot sense; the signal may be weak and prone to interference [6], [14], [17].

3 Use Scenario for BCI

REAUMOBILE is a project aimed to disseminate the cultural heritage and to improve the experience of visitors and residents of a smart city. The project is exploring the use of augmented reality, social networks and the interaction with existing sources of media content of points of interest (POIs) such as museums, archeological sites and religious buildings [18]. REAUMOBILE provides a platform that can be used in mobile devices for visitors to have access to various information layers and interactive features associated with objects of interest in POIs. Normally, anyone with a smartphone is able to use REAUMOBILE functionalities, but in order to be more inclusive, there are issues this project needs to consider: What happens with a person who cannot hold a smartphone or a tablet due to physical disabilities? What happens if a user cannot see or has visual limitations? How can someone on a wheelchair enjoy the experience offered by REAUMOBILE? What about users with hearing and speech disabilities?

4 UX Design for a BCI Scenario

Taking into account the challenges posed by users with disabilities, we have produced an enhanced scenario for a museum in which BCIs are introduced. Fig. 1 illustrates our scenario by means of a storyboard (Fig. 1).

As noted in the figure, a family that includes a disabled person decides to visit a museum. A special area in the museum has been adapted to allow users to experience various aspects of their objects of interest via BCI. This space can be considered an interactive area for anyone interested, regardless of whether or not users have some disability. In the BCI area, users can interact with specific OIs to find additional information, to situate OIs in the context of the collection, and to manipulate 3D models of the objects. This area should have the following characteristics (also illustrated in the storyboard):

•Total silence, so users do not get distracted with noise of other museum visitors or events.

•Engaging BCI applications, which may include videogames and collaborative learning functionality. These should offer multiple skill levels so users can practice, train the BCI and eventually become experts. Naturally, these applications will be related to the OIs available in the area.

•Access to in-depth information about OIs as well as translation mechanisms for OIs that are described in a language different from the user's.

•3D models for some OIs so users can rotate them, play animations, scale them up or down, and view their relationships with other OIs.

•Access to consulting museum services, such as location of wheelchair ramps, elevators and other services required by visitors.

The specific case of a game that can be operated via BCI is illustrated with more detail in Fig. 2, relying also on a storyboard (Fig. 2). With simple facial expressions such as winking, users can select whether they want to perform a task or play a game. Confirming the action can be accomplished by another pre-defined facial expression. For users with visual disability, the system may produce voice expressions indicating which button is being selected. The storyboard illustrates the case for a user who selects a game ("Arrange"), and then is presented with options to complete level 0. This level has two main objectives: the player gets used to the headset and to perform all the tasks only by focusing his mind on the expect result, and the system is trained in order to identify the player's brain patterns and activities. In our example, the user must visualize the desired movement with a cube, such as "up", "down", "left", "right", etc. After level 0 is completed, the selected game can be played more smoothly.

Fig. 1. Storyboard of the BCI area.

5 Formative Evaluation

In order to gather more information and different points of view regarding our proposed scenario, we interviewed 11 users (6 male, 5 female) with the following characteristics: Five with visual disability, two with motor disability, three without a disability and one with hearing and speech disability. Two focus groups (the people with visual disability and the group without a disability) and three individual interviews were conducted in different days for two reasons: the difficulty of transferring people with visual and motor disability to the same place and the availability of the 11 users.

Fig. 2. Storyboard of the pattern game.

All subjects answered the same questionnaire, which included questions about the following: frequency of visiting social places (parks, downtown and more), difficulties they have when they go to those places, and if they have used a technology adapted to their needs (question only for the people with a disability). After applying the questionnaire, technical concepts were briefly explained, such as BCI and AR. Then, the proposed scenario endowed with BCI was presented. Finally, questions about which kind of activities and games users would like to add to the system, about the display of the museum's services and about how to encourage people to go to the museum (Table 1).

The main ideas were explained in a different way for each type of user: For users with visual disability we described verbally every detail, like what kind of objects the area will have, the incorporation of large screens next to OIs, the expected interaction sequences, and so on. We also followed this approach for one of our subjects with motor disability due to her limited availability, as she was interviewed over the phone. For people without a disability, another person with motor disability, and a subject with hearing and speech disabilities, we used the storyboard presented in the Figure 1. The following results were obtained:

•People with a disability reported the following difficulties: They depend on family support to transport them or guide them, they find few services that consider their disability (ramps, parking, etc.) and they generally have to make a great effort to communicate with other people. The main difficulties found by people without a disability are related to the distance to POIs and public transportation.

•Some features they would add to our design include: Audio- based, more detailed and portable information (some would like to take it to their homes); exchanging comments upon tour completion (whether they liked the area, what was their favorite object and why, etc.); and cooperative interaction.

•Games suggested by users include linguistic games such as riddles or word play, memory, cooperative games, treasure hunting and virtual routes of the museum.

•All of the users liked the idea that of being able to generate a route with the map and see what services the museum has.

•Ten of the eleven participants would use the BCI system; only one user explained that he had not visited a museum before, so he could not answer this question.

• Some of the users with a disability insisted that the museum should provide a web site adapted to their needs. One suggested that on certain days, the government or the museum's administration could rent some buses in order to take disabled users to these historical places.

Table 1. Main information of the focus groups and personal interviews.

User	Disability	Age	Schooling	Frequency of visiting places	Technology for their needs
1	V	84	Undergraduate	Relatives	B,S
2	V	71	Graduate	Parks, trips, galleries	B,S,C
3	V	56	Teacher	Downtown and relatives	B,S
4	V	54	Elementary	Church and therapy	B,S
5	V	28	Secondary	None	C
6	M	82	Not available	None	Books
7	M	42	Not available	Therapy	C
8	DM	24	Not available	Once a week	Sign language
9	N	22	Undergraduate	5 times a month	-
10	N	23	Undergraduate	Once a month	-
11	N	23	Undergraduate	3 times a month	-

Disability: V = Visual; M = Motor, DM = Deaf-Mute, N = None;
Technology: B = Braille, S = Speakers in the computer, C = Cell phone.

6 Conclusions and Future Work

This paper has discussed initial work in designing the user experience for interactive systems that involve brain-computer interfaces. Rather than focusing on the functionality offered by existing BCI technologies, we have started by working with potential users and learning about their needs, capabilities and limitations. Although they were enthusiastic about the proposed idea, people with disabilities expressed their concern about the infrastructure of the museums that is not appropriate for them. This is one of the reasons they do not go to these places and they also explained that they do not want to be all the time in their houses or in their rehabilitation centers. They want to coexist with other people without being excluded. At the same time, they want to learn more about history, science and technology without their disability limiting them in this regard.

As for future work, we plan to integrate the observations of our users. Low and high fidelity prototypes will be created and usability and user experience tests in the museum will be made. For an actual implementation, we currently are considering the use of the Emotiv EPOC neuroheadset, as its Software Development Kit (SDK) provides three detection libraries that will be useful [19]: Expressiv Suite (interprets facial expressions in real time and uses an avatar that imitates them), Affectiv Suite (shows real time changes in the subjective emotions experienced by the user) and Cognitiv Suite (evaluates a user's real-time brainwave activity to discern the user's conscious intent to perform distinct physical actions on real or virtual objects).

Finally, museums should publicize their BCI facilities among schools and rehab centers for a better interaction with their objects and insist that anyone can use it, regardless of whether or not they have a disability.

Acknowledgments

The authors would like to acknowledge the support received from Conacyt through the REAUMOBILE project number 192321. We also express our gratitude to IECEDEVI, Ilumina Tu Vida, the Inclusion Department of UDLAP, for welcoming us and allowing us to learn about their needs. Centro Sustenta was key in introducing the authors to the first two institutions.

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Developing a Serious Game to Improve Reading Comprehension Skills in Third Graders

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Abstract. Results of different evaluations about reading comprehension in Mexico are not positive. Different methods and techniques have been implemented to counteract such numbers, and the support of serious games (video games that both entertain and educate) is one of them. Recently, video games demand has importantly increased in Mexico, which suggests that serious games can be successfully used by Mexican players. This paper presents the development and usability evaluation of a serious game intended to supporting and improving reading comprehension skills of third graders (ages 8-9 years old) from Mexico.

Keywords: Serious game, reading comprehension, third graders.

1 Introduction

Reading is a process that each person does by himself/herself and it allows to examine the content of what is being read, analyzing each part of the reading material, stressing the essential and comparing reader's already existing knowledge with the one that has been just acquired [1]. In essence, acquiring the ability to read and understand well is a basic requirement for the social and economic demands in today's society [2]. For [3], reading difficulties have important implications for the emotional development of children. Reading may represent a painful process that demands a great effort and is extremely frustrating for some children, which explains the development of a low motivation for academic achievement, low self-esteem and seriously compromises the prognosis of any therapeutic intervention.

1.1 Reading Comprehension

Reading comprehension is not just the mere decoding of meanings of a text, but the construction of meanings that result from the interaction of the reader with the text

[4]. It is an act that takes time and effort to develop; it is impossible to demonstrate a lack of reading comprehension in children who have not yet learned to read with enough precision and fluency. Therefore, researches report that children at the age of 8 and older are the ones that start suffering the lack of such activity [5].

According to [6] readers acquire the meaning of a text by using skills and knowledge that involve different levels of complexity. This involves five processes: (1) global comprehension, where the reader considers the text as a whole and create a generally understand; (2) interpretation, where reader creates an idea based on the association of two or more parts of the text; (3) location or extraction of information, where the reader obtains specific data from the text through search, localization or selection of relevant information; (4) construction of the meaning of an expression. This happens when readers construct general or specific meaning that a term or expression acquired, and; (5) analysis of the content and structure, where the reader takes into account how the text is developed in order to reflect about its content, quantity and form.

1.2 Serious Games

One way of supporting the development of reading and to encouraging the reading in general is through playing video games. Some research studies show that video games encourage the acquisition of certain cognitive skills and improve student comprehension of learning materials presented through a video game [7].

Serious games are a genre of video games, and they are not used just for entertainment, but also for serious human spontaneous activities [8]. In addition, serious games use pedagogy to infuse instruction into the playing experience, and they are by nature suited to engage the learner and encourage active construction of meaning and development of skills.

Nowadays, serious games are receiving interest from researchers and industry because of the reasons explained above. In Mexico, on one hand, some scholars [9-10] have noticed this, and use serious games for different purposes. On the other hand, video games are already part of Mexico's daily use. In 2010, the video game Mexican market was worth $757 million of U. S. Dollars, placing the country among the top 15 video game markets worldwide, being the first one from Latin America [11].

Taking into consideration all this lead us to think about the impact that video games can have in the field of reading comprehension, as proved by several studies on how they have been applied to education in different areas [12].

2 Problem Statement

Currently, there is a huge problem regarding reading comprehension in Mexico. According to a report written by [13], 41% of students do not reach basic skills level in reading comprehension. The Organization for Economic Co-operation and Development (OECD), which includes many highly-developed countries, estimates that Mexico would take 65 years to reach the current OECD's average in terms of reading comprehension. Regarding, reading comprehension and reflection on language in Spanish in Mexico at a national level, one in every four third graders is on the "Under basic" level, while 56% of them is on Basic level (Figure 1).

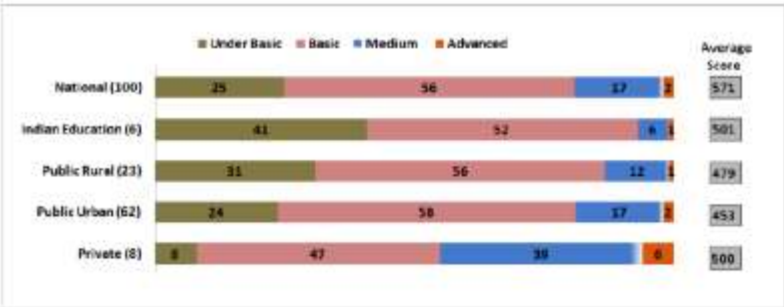

Fig. 1. Percentage of students by level of educational achievement and school stratum in Spanish.

3 Method

After making a systematic literature review, we chose to work with the User Centered Design (UCD), which is a design philosophy that involves a set of techniques that focus on knowing end user's needs, wants, limitations and context in each stage of the serious game design process and development life cycle [14].

Designing serious games for children brings with it different sets of demands and challenges, as children have different perceptions and make sense of the world around them differently from adults. Their ideas on motivating and fun aspects of technological systems may likely be different from what the adults can anticipate [15].

Our research project has the following steps:

1. Specifications of the context, where we identified the end users' main characteristics, in this case third graders; and under what conditions the project is going to operate.
2. Specifications of the user requirements, where we identify which skills the users need to improve [16], see Table 1.
3. Designing the solution, where it was were we held our greatest contribution, and that it is subdivided in the following stages: (a) video game design: in this phase we design menus, characters, scenarios, textures, scripts, among others; (b) development: we develop the actions and give functionality and interaction to the video game; (c) functionality test: in this step we make sure that there is no fatal or unexpected error when the end users are playing our serious game.

4. Evaluation. We conducted a usability test to make sure problems are fixed and the serious game has a good functionality.

Table 1. Part of the obtained results on some of the problems that were part of the assessment instrument.

Skill	Activity	$\bar{x}$
Global comprehension	Recognize the central message of the text	0.04
Interpretation	Recognize, in an advertisement, to whom the message is directed to	0.69
Locate or extract information	Locate specific information	0.35
Constructing the meaning of an expression	Identify persuasive elements in a commercial	0.35
Analyze the content and structure	Identify a special condition	0.21

4 Designing the Solution

It is important to mention that the storyline, scripts, characters and scenarios were based on the needs of third graders [16].

4.1 Designing Sprites

We created sprites (two-dimensional images) that represented the following roles in our developed serious game: Main character, antagonist, secondary characters, scenarios, main elements, and menus.

In order to develop the scenarios, we took into account the plot and script of the game that was previously assigned to perform a design that was consistent with it. We also created graphical elements so the third graders could see, for example, how many coins the student has, health, time and score.

4.2 User Interfaces and Menus

User interfaces were previously prototyped with Balsamiq Mockups (www.balsamiq.com).

4.3 Development

In this step of the project, we gave basic functions to the characters and scenarios of the game. For example motion has to be related with to the sprite that shows the character when it is moving, so it was necessary to create a script in Unity (http://unity3d.com) that should move the plane of the character through the plane of the scenario by using the keyboard arrows, and at the same time changing the orientation of the sprite coordinated with the plane motion as the plane of the character.

Once motion was provided to the character, it was necessary to establish limits within the scenario, so we implemented some features for 3D simulation games as the use of a physics engine

To set the necessary boundaries for delimiting the traffic area with objects of this type, we used walls with an attribute (rigidbody), so then, the character was unable to move through them and had no access to non-permitted areas of the game (see Figure 2).

In order to develop the scenarios, we took into account the plot and script of the game that was previously assigned to perform a design that was consistent with it. We also created graphical elements so the kids could check, for example, how many coins the student has, health, time and score.

Fig. 2. Scenario with barriers and traffic areas.

4.4 Evaluation

A study was conducted by third graders to measure the usability and acceptance of our serious game.

Procedure

Phase 1: Students were given a 10 minute introduction to study the serious game.

Phase 2: We performed a live demo showing the students the game features. The aim of this was to put in context the use of the controls to the participants.

Phase 3: The participants were given a task list to complete on the game.

Phase 4: Participants were asked to complete a game heuristics questionnaire and a game experience questionnaire (GEQ) with two dimensions.

Results and Discussion

Game Heuristic Questionnaire

We applied the game heuristics questionnaire to the participants with the following items:

H1: Does the game reacts in a consistent way to the player's actions?

H2: Could you customize the profile, music, video, and the game difficulty and speed?

H3: Could you find a predictable and reasonable behavior of the controls?

H4: Does the game provide information about an action to take?

H5: Can the player can skip not-playable content (i.e. videos or texts) to return to the game?

H6: Are the controls intuitive and customizables?

H7: Are the game controls consistent within the game?

H8: Does the game present information about the game status?

H9: Does the game provide instructions, help and training?

H10: Are the status score indicators seamless, obvious, available and do not interfere with game play

Participants found that the game controls were consistent, predictable, intuitive with reasonable behavior and customizable (see Figure 3). Also, they believed that the game presented quality and usable information about its status, actions to take and provided useful instructions, help and training.

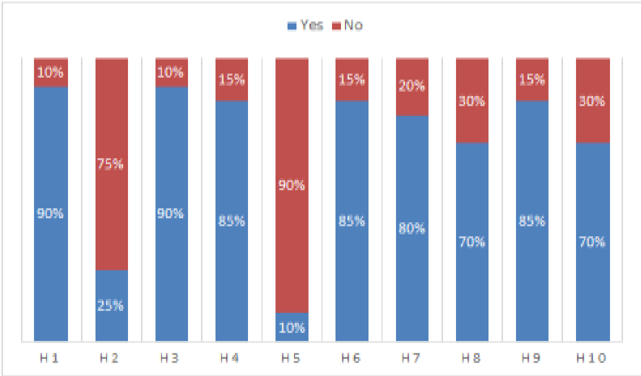

Fig. 3. Game heuristics questionnaire.

Two heuristics got bad results: H2 and H5. H2 is related to game customization; the participants found few options to customize the game. It is a good area of opportunity for improving the game usability. H5 is about skipping the not-playable content. This game was developed to improve the child reading comprehension and on a big part of the gameplay the user had to read several paragraphs; in order to achieve this goal it was important not to skip these paragraphs.

Game Experience Questionnaire

The GEQ is divided into two parts: (1) four questions, where the participants had to give a grade from 1 to 10, where 10 is the most significant, and (2) seven questions that measured efficiency, effectiveness, immersion, motivation, emotion, fluency. It had a 5 item Likert scale.

The first part of the GEQ included the following questions:

Q1: Did you find the game fun?

Q2: Was it difficult to adapt to the game control?

Q3: Did you find the game exciting?

Q4: How easy it was to fulfill the objective of the game?

Figure 4 shows the ratings obtained on this section of the evaluation.

In this part of the GEQ, participants found the game fun and exciting, with a low difficult to adapt with the control; but they believed that the game was slightly difficult to fulfill its objective. The four questions got an average grade of above 9.

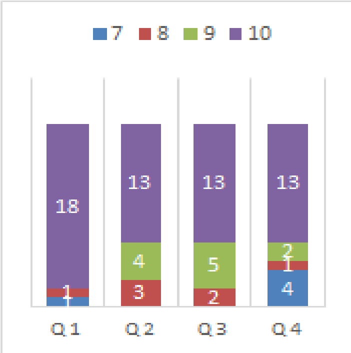

Fig. 4. GEQ first dimension.

As mentioned, the second part measured seven indicators. Figure 5 shows the results of this part. 90% of participants perceived the game as efficient, immersive and fluent; 85% thought it was effective; the game provided motivation and emotion to 80% of the users; and finally we found the weakness on the learning curve with a 75%, but it is still an acceptable percentage.

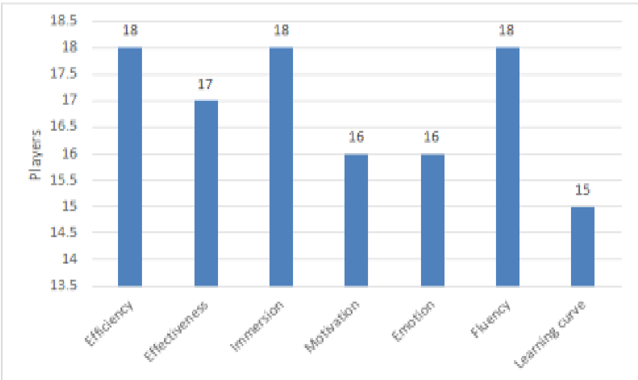

Fig. 5. GEQ second part.

5 Conclusions

Taking into account the participants' desire was always a good idea as our usability evaluation showed good intentions of using the game for educational purposes and thus we obtained good results on its usability. In addition, we spent great time working with children. We even learned from them aspects about usabitily that we have not had in mind first.

6 Future Work

We are going to improve the serious game thanks to the participants' feedback. After that, we are going to evaluate the educational part of the game, which means that we have to make sure that the game will effectively improve the reading comprehenion skills that we mentioned before.

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Coordinated Attention and Resuscitation in Code Blue Events through the CARES System: A Preliminary Evaluation

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Abstract. Code Blue refers to a medical situation in which a patient suffers cardiac or respiratory arrest and requires immediate cardiopulmonary resuscitation (CPR). A few systems have been developed to support these types of situations. In this paper, we present a preliminary evaluation of CARES, a system that employs mobile technology to support the coordination of response teams in Code Blue emergencies to minimize response times. The evaluation of the CARES system is aimed at exploring the usefulness and ease of use constructs in medical staff. From the data collected, participants agree that the system would be easy to use. Particularly, the Ease of Use factor was rated generally higher that the Usefulness construct by our participants.

Keywords: Code Blue Emergency, Medical Informatics, Preliminary evaluation.

1 Introduction

When a patient is hospitalized, a major concern of the medical system is to increase the chances of survival among patients suffering cardiopulmonary arrest, which occurs in the order of 10-20% [1, 2]. Code Blue refers to a medical situation in which a patient suffers cardiac or respiratory arrest and requires immediate cardiopulmonary resuscitation (CPR). In general, hospitals have a team of trained people to respond to this type of emergency. Particularly, the coordination of such response teams and the time during resuscitation are key aspects to increase the chances of survival among patients in Code Blue situations [1-3]. Code Blue situations require the coordination of an emergency team dedicated to providing cardiopulmonary resuscitation to patients. This type of medical emergency involves the mobilization of human and material resources towards a particular area of a hospital. Additionally, it is necessary the use of cardiopulmonary resuscitation equipment located in the emergency crash cart (also known as red cart or code cart). In many cases, in units where patient care is not critical, such as in intermediary care units[1], nurses or patient's family members notify of Code Blue emergencies when they observe a significant deterioration in the patient's condition. The literature reports that if a patient is treated within the first five minutes, chances of survival are greater and there is less risk of neurological damage [3, 4]. Since 2000, there has been significant progress in reducing mortality in cardiac arrests in hospitals. However, there are no structured and flexible systems that allow qualified personnel to respond promptly within hospitals [5].

According to [4], the most common errors in Code Blue emergencies are associated with the communication among response team members and with the algorithms of Advanced Cardiovascular Life Support (ACLS). Moreover, the literature reports that the human factor is essential for timely care in hospitals (e.g., direct supervision of nursing staff) [6]. In this context, in some research fields in which technology is used to address problems related to situations such as Code Blue emergencies, some research lines are focused on studying the automated monitoring of patients [7, 8] and the development of infrastructure to facilitate the communication among mobile nodes [9]. The literature also reports work to support the coordination of emergency teams [10-12]. For example, in [12] the authors designed a simulation to improve the coordination of firefighters. In [10], it is presented a model based on information technologies for crisis management. However, to the best of the authors' knowledge, there are no systems or models designed to facilitate the coordination of response teams in Code Blue emergencies. As mentioned above, this situation requires finding the location and the selection of human resources and the availability of cardiopulmonary resuscitation equipment and personnel.

This paper presents a preliminary evaluation of CARES (Coordinated Attention and Resuscitation in Emergency Situations), a system that employs mobile technology to support the coordination of emergency teams in Code Blue situations. The primary goal of the system is to minimize response times in attending Code Blue situations by improving the coordination of emergency teams. The evaluation is aimed at exploring the usefulness and ease of use constructs in medical staff.

1.1 The CARES System

The CARES system consists of four modules: Code Blue Event, Location, Coordination, and Notification modules (Figure 1). Once the Code Blue Event module initiates the process, the Location Module locates qualified personnel and material resources available for responding to the Code Blue emergency. Afterwards, using the output information from the Location Module, the Coordination Module selects the appropriate medical personnel to respond to the Code Blue emergency based on criteria such as their availability, the roles they can take, and their physical proximity to the event location. Finally, the Notification Module notifies the medical personnel required to participate in the Code Blue emergency.

[1] In intensive care units, patients usually are monitored by specialized equipment, besides personnel and family members.

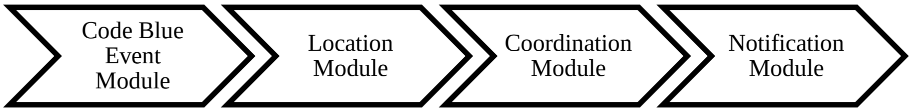

Fig. 1. Conceptual model implemented in CARES

2 Methods

We conducted a preliminary evaluation with medical personnel at a local hospital in northwest Mexico attending a total of 2,019 towns and villages (339,773 persons).

2.1 Participants

The participants of the evaluation session were 9 medical staff (Male=2, Female=7). The age of participants was 27 years old in average (SD=9.46 years), ranging from 22 to 46. Seven of them were interns. All of them were mobile phone users, and computer users. For the recruitment, we contacted the Head of the Training and Teaching department at the aforementioned hospital, who was in charge of inviting interns, residents, physicians and nurses. According to the number of people invited to participate, the turnout rate was around 30%.

2.2 Evaluation Session

The evaluation session lasted for about an hour and consisted of the following stages:

- Introduction (10 min): A 10-min introduction to the project and the research team was given.
- Presentation (20 min): The research team presented the overall goals of the project and the current status of the CARES system.
- Scenario (10 min): A scenario (audio only) was presented to the participants (Table 1).
- Video (5 min): A 2m 24s video was presented showing the main functionality of the system, based on the previous scenario.
- Evaluation instrument (10 min): Finally, a survey was answered by the participants based on the presentation, scenario, and video. This instrument consisted of a 16-item instrument based on the Technology Acceptance Model (TAM) [13]. The scale of the instrument was a 7-item likert-type scale, ranging from Strongly Agree (value=1) to Strongly Disagree (value=7). The questionnaire took around 5 minutes to complete.

Table 1. Scenario used during the evaluation session

Don Carlos is 42 years old. He was in the Intensive Care Unit (ICU) due to an acute inferior myocardial infarction, where a percutaneous transluminal coronary angioplasty (PTCA) of the right coronary artery was performed. Afterward, he was relocated to a less intensively monitored unit such as the Intermediate Care Unit where he has been stable, but under frequent medical care. Luisa, a 20-year experience nurse, who is in charge of taking care of Don Carlos observes that he is experiencing tachycardia and, given his clinical record, decides to raise the Code Blue alert through the recently-installed CARES system. The CARES system takes into account the location of nurses and physicians for deciding who are the most proximate for attending the emergency. In addition, the CARES system checks among the personnel those who are qualified for attending the emergence (e.g., experience, training, etc.). Moreover, the CARES system checks the staff's availability at that moment to attend the situation. Through the CARES system, Dr. Gonzalez, a resident, receives an alert in his smart wristband saying that there is an ongoing Code Blue situation. Dr. Gonzalez takes out his mobile phone from his pocket to receive further instructions. In his smartphone, Dr. Gonzalez is told that he will be in charge of taking the crash cart to the 322 bed (Don Carlos's bed), given that he is close to the cart at that moment. Meanwhile, Dr. Lopez, who was very close to Don Carlos's location at that time, is instructed to quickly move to Don Carlos's bed, where he is assigned the role of Team Leader in the emergency response team (ERT). Due to training the Dr. Lopez has previously received, he leads the selected nurses and physicians as they arrive. Luisa, who has been close to Don Carlos, received instructions from Dr. Lopez to be in charge of taking notes (e.g., medication administered, doses, time of day). In the same way, Dr. Bobadilla has been assigned the role of Respiratory (Airway), where she is in charge of managing the airway as directed by the Code Team Leader. After the arrival of Dr. Gonzalez, with the crash cart, the patient was stabilized and stayed in sinus rhythm.

3 Results

At this point, the evaluation of the CARES system focused on capturing the perception of potential users in the medical field. Opinion seemed to be divided regarding Q_8 "Using CARES in my job would increase my productivity." Many respondents (N=3, 33%) agreed only slightly with the statement. Still, almost an equal number of respondents (N=4, 44.44%) said they strongly agree with the statement. Also, opinion seemed divided regarding Q_10 "Using CARES would make it easier to do my job" in which a significant number of participants (N=4, 44.44%) strongly agreed with the statement, but two (N=2, 22.22%) participants only agreed, and the same number of participants slightly agreed. The same was for Q_13 "I would find it easy to get CARES to do what I want it to do." Still, it is noteworthy that none of the respondent disagreed at any level.

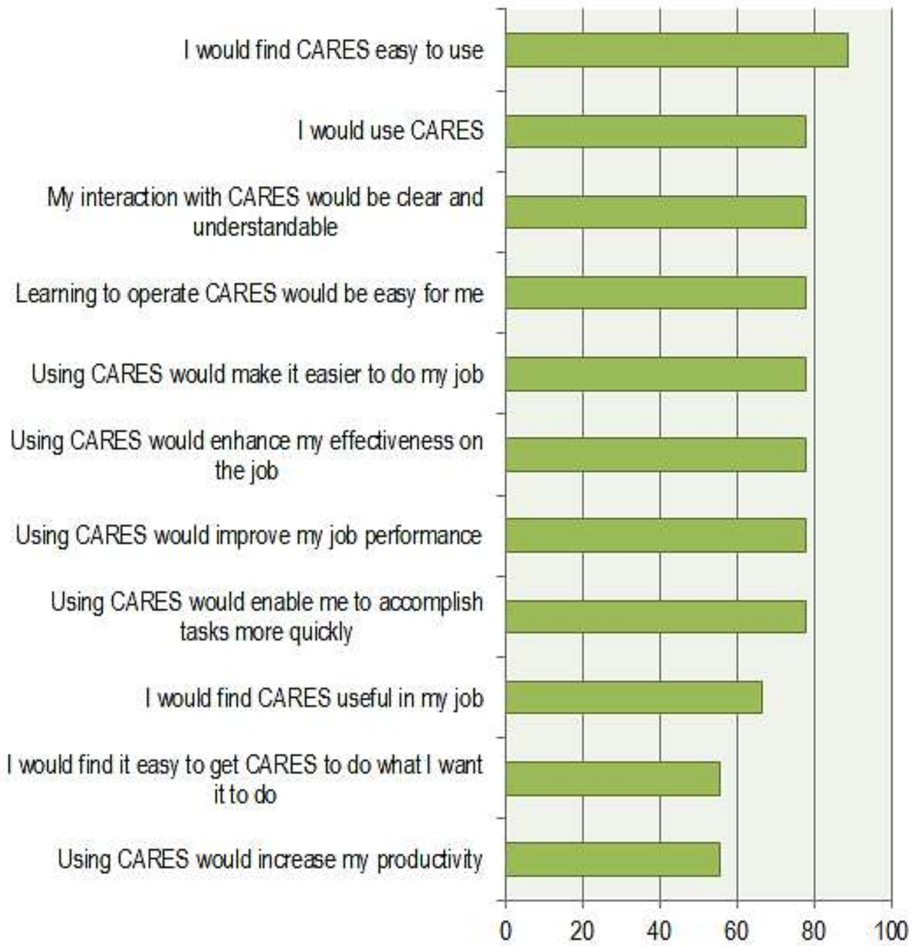

Fig. 2. The CARES system by first rating (strongly agree + agree) and ranked based on highest percentage of respondents' choice

Following Figure 2, it can be seen that the percentage of participants who recorded first rating (strongly agree + agree) was the highest for the item "I would find CARES easy to use", and the least for the item "Using CARES would increase my productivity". This means that our participants generally perceived the CARES system as easy to use, but it was difficult for them to foresee any increase in their productivity through system usage. As show in Figure 2, the items which were endorsed with first order ratings are related to the perceived ease of use construct, whereas the items related to usefulness, although positive, were generally rated second or third order ratings.

Table 2. Summary Statistics of the Computed Factors and Reliability estimates per construct

Construct	*Mean (SD)*	*Median*	*Mode*	*Percentiles*			*Cronbach's Alpha*
				25	50	75	
Usefulness	1.82 (0.23)	1.60	1	1.00	1.60	2.60	.953
Ease of Use	1.69 (0.25)	1.20	1	1.00	1.20	2.50	.891

Table 2 shows descriptive statistics regarding each of the constructs. Please note that those values refer to ordinal values assigned: Strongly agree=1, strongly disagree=7, meaning that lower ratings are in this case associated with positive endorsements. Notably, the Ease of Use construct received higher ratings than that of Usefulness, and this is reflected in the media and median. From the results obtained, the items related to ease of use, had the lower rating (i.e., strongly agree), following very close those related to effectiveness in their work duties and intention to use the system. The mode for all items was 1, meaning that Strongly Agree was the most common answer for all items.

Although some studies have emphasized the barriers for adoption of information systems in general, we carried out a preliminary evaluation to explore the perception of potential users in adopting the CARES system to help them in code blue emergency events in hospitals.

We found surprising that the Ease of Use factor was rated generally higher that the Usefulness construct. We believe there is an explanation for this, which may be related to an unintended sample bias. When carefully looking at the individual rating and comparing among the different backgrounds, interns generally rated lower those items related to usefulness. For instance, interns rated lower the CARES system in terms of ease of use (media=1.6, SD=0.8) as opposed to non-interns (media=1.0, SD=0.0). We believe that this may be due to the fact that the interns had very limited experience in code blue events, as reported by them in the survey. Therefore, it was difficult for them to see how they could benefit from using the CARES. The opposite seemed to happen to more experienced staff who chose first ratings generally for all items i.e., they were more optimistic as opposed to interns who seemed to be more skeptical or had no idea how the system could benefit them. Another explanation for this can be that the latter personnel are mainly devoted to administrative rather than operative duties like the interns.

It can be argued that this perception could change with experience as it has been reported that text-based communication systems in hospitals have improved efficiency [14]. On the other hand, other studies have evaluated usage and user perceptions on smartphone systems [15-17]. Each work reported positive outcomes and demonstrated user uptake and usage of the intervention during the study period. However, a deeper study is required to explore this issue.

Internal reliability was generally higher but there may be certain items that were not rated as high. Looking retrospectively, the writing of some of the items might not have been as straightforward as the others, and that could have been one of the reasons for the variance in their answers.

4 Conclusions and Future Work

From the data collected, participants seem to agree that the system would be easy to use. However, they were less convinced that the CARES system would be indeed useful in the workplaces. This study had several limitations, including the small number of participants, mainly interns. The age/experience difference could offer greater insights into this variation, but further studies are needed to corroborate this. For instance, having a greater sample from various hospitals could help consolidate these findings. Also, conducting qualitative studies such as semi-structured interviews could help better understand these results. Also, the CARES systems needs to address ethical concerns related to in-hospital practices, which certainly require careful consideration before a system like CARES can be implemented.

Acknowledgements
This work was funded by the Instituto Tecnológico de Sonora under grant No. PROFAPI_00302. We thank the medical personnel who participated in the evaluation as well as students who worked on this project.

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Impreso en los Talleres Gráficos
de la Dirección de Publicaciones
del Instituto Politécnico Nacional
Tresguerras 27, Centro Histórico, México, D.F.
abril de 2015
Printing 500 / Edición 500 ejemplares