UNIVERSIDAD AUTÓNOMA DE AGUASCALIENTES

CENTRO DE CIENCIAS BÁSICAS

TESIS

Metodología para la Generación de Ambientes de Realidad Mixta para el Trastorno Neurocognitivo en Adultos Mayores

PRESENTA

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PARA OBTENER EL GRADO DE

DOCTOR EN CIENCIAS APLICADAS Y TECNOLOGÍA

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Aguascalientes, Ags. noviembre 2025.

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Autores/as:

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Términos Índice:

Elderly;mixed reality;visuoconstructive ability;user experience

Resumen:

Nowadays, Senile Dementia is one of the most recurrent ailments related to aging as brain functions begin to deteriorate, making the elderly more dependent on others to take care of them. Using ecosystems with mixed reality allows them to have an easier way to their activities, have some independence, improve their quality of life and do exercise routines by themselves with the help of the Internet for remote control monitoring. This work proposes an architectural model for a mixed reality ecosystem to support older adults' daily activities. The work advocates the design of the ecosystem components, which are used in two scenarios for the rehabilitation of the visuo-constructive ability of patients, making a more adequate and detailed combination and implementation of connectivity, software and peripherals.

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Abstract and Figures

In the realm of digital ecosystems, the integration of Lean UX principles into virtual environments for older adults presents a promising avenue for enhancing cognitive health and addressing neurocognitive disorders. This research builds upon the foundation that virtual reality (VR) and augmented reality (AR) technologies can significantly improve the quality of life for the elderly, particularly in fostering social interaction and cognitive stimulation. Previous studies have demonstrated the efficacy of VR and AR in engaging older adults, yet there remains a gap in the application of Lean UX methodologies to optimize these digital experiences. This study investigates the incorporation of Lean UX into digital ecosystems for older adults, aiming to tailor virtual environments to their unique needs and preferences, thereby aiding in the treatment and management of neurocognitive disorders. Employing a user-centered design approach, iterative prototyping, and multidisciplinary collaboration, the research analyzes user engagement, adaptability, and satisfaction. The findings reveal that Lean UX can lead to more intuitive, accessible, and personalized VR interfaces, resulting in increased user satisfaction and potentially mitigating the effects of neurocognitive decline. The implications of this research underscore the importance of empathetic design in creating inclusive digital solutions that support the well-being of older adults.

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Arthur C. Clarke

Agradecimientos

Agradezco al Consejo Nacional de Humanidades, Ciencia y Tecnología (CONAHCYT) por permitirme continuar el camino de mi formación profesional a través del apoyo de beca desde mis estudios de maestría hasta la culminación de mis estudios de doctorado.

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Dedicatoria

A mi madre que siempre estuvo conmigo en las situaciones menos favorables de mi vida profesional y que nunca dejó de creer en mí hasta sus últimos momentos.

A mi padre que hizo siempre hasta lo imposible por ver a su Ingeniero titularse y que, aun sin palabras, siempre mostró su orgullo por mí.

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Índice General

Índice de Tablas

Índice de Figuras

Resumen

El envejecimiento poblacional ha incrementado la prevalencia de trastornos neurocognitivos que afectan memoria, habilidades visoconstructivas y autonomía funcional en adultos mayores. Este trabajo propone y valida un modelo de ecosistema digital de Realidad Mixta (VR/AR/MR) orientado a la asistencia geriátrica, integrando dispositivos de bajo costo, metodologías ágiles de diseño (Lean UX) y protocolos clínicos-analíticos para crear entornos virtuales adaptativos. La investigación se sustenta en dos artículos publicados: el primero describe una arquitectura por capas (interacción directa, indirecta, remota y análisis de datos) aplicada a la rehabilitación de la habilidad visoconstructiva; el segundo incorpora Lean UX y métricas de experiencia de usuario (UEQ, AttrakDiff, meCUE) junto con instrumentos clínicos (MMSE, ROSA, IQCODE) para evaluar impacto cognitivo y usabilidad. El modelo se complementa con un estudio de campo en instituciones del DIF estatal en Aguascalientes, México, donde se diseñaron protocolos de interacción y encuestas a terapistas, además de escenarios hipotéticos de aplicación con pacientes de Alzheimer. Los resultados muestran que la integración de ecosistemas digitales con Lean UX permite generar entornos más intuitivos, accesibles y reproducibles, favoreciendo la independencia de los adultos mayores y ofreciendo una ruta viable para la prevención y rehabilitación de trastornos neurocognitivos. La tesis concluye con una propuesta metodológica y arquitectónica escalable, lista para validaciones multicéntricas y aplicaciones en contextos clínicos reales.

Abstract

Population aging has increased the prevalence of neurocognitive disorders affecting memory, visuoconstructive abilities, and functional autonomy in older adults. This thesis proposes and validates a digital ecosystem model for Mixed Reality (VR/AR/MR) aimed at geriatric assistance, integrating low-cost devices, agile design methodologies (Lean UX), and clinical-analytical protocols to create adaptive virtual environments. The research builds upon two published articles: the first describes a layered architecture (direct, indirect, remote interaction and data analysis) applied to the rehabilitation of visuoconstructive skills; the second incorporates Lean UX and user experience metrics (UEQ, AttrakDiff, meCUE) along with clinical instruments (MMSE, ROSA, IQCODE) to assess cognitive impact and usability. The model is complemented by fieldwork in public nursing homes of the DIF institution in Aguascalientes, Mexico, where patient monitoring protocols and therapist surveys were designed, together with hypothetical scenarios involving Alzheimer's patients. Findings indicate that integrating digital ecosystems with Lean UX enables more intuitive, accessible, and reproducible environments, fostering independence in older adults and providing a viable pathway for prevention and rehabilitation of neurocognitive disorders. The thesis concludes with a scalable methodological and architectural proposal, ready for multicenter validation and application in real clinical contexts.

Capítulo 1. Introducción.

El envejecimiento poblacional incrementa la prevalencia de deterioros cognitivos que afectan memoria, percepción visoconstructiva y autonomía funcional. Los avances en Realidad Virtual, Realidad Aumentada y dispositivos conectados están transformando la manera de diseñar intervenciones tecnológicas para poblaciones vulnerables. Intervenciones basadas en entornos virtuales han mostrado capacidad para estimular funciones cognitivas, motivar la actividad física y reducir la monotonía de las rutinas terapéuticas. No obstante, su adopción queda limitada por barreras prácticas (ergonomía de dispositivos, alfabetización digital, privacidad) y de diseño (carga cognitiva, usabilidad específica para mayores).

1.1 Problemática.

El Trastorno Neurocognitivo constituye una de las afecciones más prevalentes en la población adulta mayor, dado que el deterioro progresivo de las funciones cerebrales incrementa la dependencia de estos individuos respecto al personal especializado para el desarrollo de sus actividades cotidianas. Se requiere implementar un proyecto que facilite la integración de las personas adultas mayores con la tecnología, permitiéndoles realizar sus actividades cotidianas de forma más sencilla y conservando, en la medida de lo posible, su independencia. Además, el objetivo es que puedan tomar sus terapias por sí mismas para mantener su salud y movilidad, minimizando la intervención del personal geriátrico especializado. Para ello, se contempla el monitoreo remoto, que permitirá detectar anomalías en los patrones de comportamiento y prevenir enfermedades relacionadas con la edad en etapas tempranas.

La Realidad Aumentada y Virtual es un área reciente en el tratamiento de trastornos neurocognitivos. Gracias a la disminución de costos y al avance tecnológico, los entornos virtuales son más accesibles y se emplean cada vez más para diversas enfermedades mentales.

La integración de un entorno virtual puede ayudar a facilitar la tarea de implementar múltiples tecnologías a la asistencia de adultos mayores en distintos escenarios, ahorrando tiempo y esfuerzo para adaptarlo a distintos padecimientos de una manera rápida y eficiente.

Este trabajo presenta el desarrollo de un entorno virtual orientado a la asistencia geriátrica, con especial atención al Trastorno Neurocognitivo. La metodología Lean UX se emplea como herramienta para adaptar eficientemente el entorno a los requerimientos específicos de los pacientes.

1.2 Objetivo.

Diseñar un modelo para adaptar de manera rápida un entorno virtual dirigido a la asistencia de adultos mayores con trastorno neurocognitivo.

1.2.1 Objetivos Específicos.

- Definir la problemática en la aplicación de Realidad Mixta y monitoreo para adultos mayores.
- Definir la relación entre los elementos que conformarán el entorno virtual.
- Determinar las necesidades terapéuticas del adulto mayor promedio y del personal de cuidado a cargo en un cuadro de Trastorno Neurocognitivo.
- Definir y crear entornos virtuales aplicando la realidad mixta para adecuar las terapias a pacientes geriátricos.
- Utilizar la metodología de desarrollo ágil Lean UX para definir el alcance de manera iterativa y orientada hacia el paciente.
- Comprobación de la viabilidad mediante pruebas de campo del diseño de entorno virtual

1.3 Hipótesis.

Reprogramando dispositivos de bajo coste y uso libre para llevar a cabo una interconexión entre el apartado de software y hardware adaptando técnicas de terapia ya existentes, es posible crear una metodología de Ingeniería de Software que permita generar eficientemente entornos de Realidad Mixta para ayudar a tratar el Trastorno Neurocognitivo en adultos mayores.

1.4 Preguntas de Investigación.

¿Es posible desarrollar una metodología eficiente para crear ecosistemas de realidad mixta que ayuden a mitigar/dar soporte a los trastornos neurocognitivos en adultos mayores?

1.5 Contribución.

En esta propuesta de investigación se espera producir los siguientes productos:

- Un modelo basado en Lean UX para las correspondientes iteraciones del proceso de desarrollo del proyecto de investigación.
- Una propuesta arquitectónica escalable que establezca la interacción entre dispositivos en relación con los entornos virtuales, dividida por nivel de interacción y los correspondientes actores involucrados.

1.6 Impacto.

Permitir a la población de adultos mayores continuar con sus respectivas terapias desde casa y asistiéndolos en sus actividades diarias para promover su independencia con respecto a sus cuidadores, mejorando su calidad de vida para una vejez digna.

Capítulo 2. Antecedentes.

La demencia es una condición que resulta en el deterioro del funcionamiento cognitivo a un grado que impide el desarrollo de la vida diaria. Una persona con demencia puede tener problemas de memoria, atención, lenguaje, etc., pero la demencia no es una enfermedad en sí, sino un conjunto de síntomas que tienen origen en una enfermedad (American Psychiatric Association, 2014).

La demencia senil es actualmente la tercera causa de muerte en adultos mayores, justo después de las enfermedades cardíacas y el cáncer (Ro et al., 2019).

La Asociación Americana de Psiquiatría estableció que el Trastorno Neurocognitivo puede variar entre leve, moderado y grave, siendo este último clasificado como Trastorno Neurocognitivo Mayor, nombre que reemplazó al término Demencia Senil en la quinta edición de la "Guía de consulta de los criterios diagnosticados de DSM-5" (American Psychiatric Association, 2014); este cambio permitió que el diagnóstico de la enfermedad ocurra en etapas más tempranas dentro de seis dominios:

- Lenguaje.
- Atención compleja.
- Habilidades ejecutivas.
- Habilidad visoconstructiva y perceptual.
- Aprendizaje y memoria.
- Cognición social.

Se establece que el Trastorno Neurocognitivo puede ser causado por alguno de los siguientes padecimientos:

- Traumatismo cerebral.
- Enfermedad de Alzheimer.
- Degeneración del lóbulo frontotemporal.
- Consumo de sustancias o medicamentos.
- Enfermedad de Huntington.
- Enfermedad por priones.

- Enfermedad de cuerpos de Lewy.
- Enfermedad vascular.
- Infección por VIH.
- Enfermedad de Parkinson.

La ejercitación aeróbica ayuda a mitigar las repercusiones del Trastorno Neurocognitivo en adultos mayores (Felipe Salech et al., 2012). Además, el uso de entornos virtuales para la actividad física diaria aumenta el interés por el ejercicio en personas mayores con baja interacción social, lo que mejora su estimulación cognitiva (Bruun-Pedersen et al., 2014).

La tecnología se ha integrado profundamente en nuestra vida cotidiana, ya sea de manera directa o indirecta, y desde una edad temprana hemos desarrollado la capacidad de interactuar con ella. Las generaciones más recientes demuestran una rápida adaptación a los avances tecnológicos, favorecida por el diseño de estos desarrollos, que busca facilitar la accesibilidad y el uso para todos los usuarios.

El diseño de experiencia de usuario (UX) constituye una disciplina relativamente reciente dentro del desarrollo de aplicaciones y dispositivos; resulta evidente la diferencia respecto a productos de hace dos décadas o más, tanto en su concepción como en la forma en que interactúan con los usuarios finales. Como ejemplo de un gran diseño de experiencia de usuario podemos mencionar a los Asistentes Inteligentes como Alexa, Google Home o Siri, que han demostrado una satisfacción del usuario muy prominente, permitiendo la comprensión de lenguaje natural incluso con distintos acentos en el mismo idioma (Pal et al., 2019).

Aunque la tecnología progresa rápidamente y cada vez más personas en todo el mundo la incorporan fácilmente a sus vidas (Hwangbo et al., 2013), la mayoría de los adultos mayores no experimentó de forma activa la evolución tecnológica hasta la actualidad.

Gracias a los procesos de miniaturización moderna es posible la creación de pequeños y poderosos dispositivos móviles y microcomputadoras como la Raspberry Pi, siendo la elección perfecta para dispositivos baratos de bajo consumo como unidad central de procesamiento para sistemas de automatización de hogares personalizados (Jamil & Ahmad, 2015), permitiendo así la conexión con dispositivos más pequeños como sensores, interruptores y otros dispositivos activos utilizando de interface dispositivos Arduino (Monk, 2016).

El cuerpo humano funciona como una interface con el mundo, existen sistemas interactivos que pueden sentirse parte de nosotros; los dispositivos portátiles modernos han comenzado a volverse parte de nuestra vida cotidiana en forma de pulseras, relojes, gafas y prendas de ropa que permiten monitorear nuestras actividades diarias o trasportarnos a mundos virtuales (Hartman et al., 2014), con un futuro bastante prometedor en las décadas por venir.

La Realidad Virtual consiste en entornos digitales que rodean al usuario con imágenes y sonidos, generando una sensación de presencia física (Moyle et al., 2018). Gracias a los motores de juegos actuales, estos entornos se desarrollan fácilmente y mejoran la experiencia del usuario en sus actividades cotidianas (Kritikos et al., 2021). Además, la interacción social virtual tiene potencial en áreas como la educación, simulación de decisiones, intervención en cambios de conducta y formación clínica, facilitando la comunicación y el alcance a audiencias específicas (Persky & McBride, 2009).

La Realidad Aumentada se refiere a tecnologías que permiten observar el entorno real mediante dispositivos tecnológicos e incorporar información visual adicional, superponiendo objetos virtuales sobre la imagen del mundo físico. La Realidad Aumentada facilita actividades cotidianas al resaltar objetos y mostrar notificaciones visuales, mejorando la precisión, eficiencia y seguridad de los usuarios en sus tareas (De Paolis & Bourdot, 2018).

La Realidad Mixta, como se muestra en la Figura 1 (Kishino & Milgram, 1994), combina los objetos reales con una capa de objetos virtuales sobrepuesta, brindando la posibilidad de mezclar objetos renderizados en 3D a través de un visor (Gamberini et al., 2009) con el uso de periféricos físicos permiten al usuario sentirse más cómodo con las representaciones 3D en conjunto con la retroalimentación presente en la vibración háptica de los controles y periféricos en uso.

Figura 1. Representación simplificada de la realidad mixta basado en la definición de (Kishino & Milgram, 1994)

2.1 Trastornos Neurocognitivos

Los trastornos neurocognitivos comprenden un grupo de entidades o condiciones con base neurobiológica, caracterizadas esencialmente por la afectación cognitiva con notorio déficit/deterioro en procesos atencionales, mnésicos, perceptivos y en funciones ejecutivas (Belloch et al., 2020).

Todos los criterios de los distintos trastornos neurocognitivos se basan en dominios cognitivos definidos por el DSM-5, y que, junto con directrices sobre umbrales clínicos, constituyen la base sobre la que diagnisticar los trastornos neurocognitivos, sus niveles y sus subtipos (American Psychiatric Association, 2014).

Dominios Neurocognitivos

a. Atención compleja.

- Atención continua: Mantener la concentración durante periodos prolongados, como responder a señales repetidas.
- Atención Selectiva: Mantener la atención a pesar de los estímulos externos o los factores de distracción (escuchar cifras y letras que se leen, pero que solo cuente las letras).
- Atención dividida: Consiste en ejecutar simultáneamente dos actividades independientes y cronometradas.

b. Función Ejecutiva.

- Planificación: Puede encontrar la salida de un laberinto, interpretar una secuencia de imágenes o disposición de objetos.
- Toma de decisiones: Realización de tareas que valoran el proceso de decisión ante alternativas diversas.
- Memoria de trabajo: Capacidad para retener la información durante un periodo de tiempo breve y manipularla (un memorama, sumar una lista de números o repetir una serie de números o palabras al revés).
- Retroalimentación/utilización de los errores: Capacidad de aprovechar la retroalimentación para deducir las reglas para resolver un problema.
- Inhibición y hábitos: Elegir una opción más difícil, como mirar en dirección opuesta a la flecha o decir el color de las letras en vez de la palabra.
- Flexibilidad mental: habilidad para cambiar entre distintos conceptos, tareas o reglas de respuesta.

c. Aprendizaje y memoria.

- Memoria Inmediata: Capacidad para repetir una lista de palabras o de números (relacionado con Memoria de Trabajo de la función ejecutiva).
- Memoria Reciente: Evalúa el proceso de codificación de información nueva, como una lista de palabras, una narración breve o un diagrama. Los aspectos que se pueden examinar en relación con la memoria reciente incluyen:

i) Recuerdo libre: solicitar a una persona el número máximo de palabras, diagramas o elementos de una narración.

ii) Recuerdo evocado: el examinador ayuda a recordar ofreciendo pistas (“señala los productos alimenticios de la lista” o “Nombra a todos los niños de la narración”).

iii) Memoria de reconocimiento: el examinador pregunta cosas concretas (¿Estaba la palabra ‘manzana’ en la lista? O ¿Has visto este diagrama o dibujo?)

- Semántica: recuerdos de hechos.
- Aprendizaje implícito: procedimientos, aprendizaje inconsciente de habilidades.

d. Lenguaje.

- Lenguaje expresivo: Identificación de nombres e imágenes y fluidez verbal (mencionar el mayor número de elementos de una categoría semántica o fonémica en un minuto).
- En las pruebas de denominación y fluidez verbal, se detectan errores relacionados con gramática y sintaxis, como omisión o uso incorrecto de artículos, preposiciones y verbos auxiliares. Estos errores se comparan con los valores estándar para analizar su frecuencia y diferenciarla de los lapsus linguae.
- Lenguaje receptivo: Capacidad de comprender, como entender definiciones de palabras y señalar objetos animados o inanimados, además de ejecutar tareas siguiendo instrucciones verbales.

e. Habilidades perceptuales motoras.

- Percepción visual: Es posible utilizar tareas de bisección de líneas para identificar deficiencias visuales elementales o déficit atencionales. También pueden emplearse pruebas de percepción estática, como el reconocimiento facial, que impliquen la identificación o comparación de imágenes —preferentemente no susceptibles de ser descritas verbalmente—, evitando que sean objetos reconocibles. Algunas pruebas exigen determinar si una figura resulta plausible o no a partir de sus proporciones.

- Habilidad visuoconstructiva: coordinación mano-ojo para tareas como dibujar, copiar o construir con bloques.
- Habilidades perceptual-motoras: Coordinar percepción y movimiento para tareas específicas, como insertar bloques en tableros o palitos en tableros perforados sin guía visual.
- Praxis: Se refiere a la integridad de los movimientos aprendidos, evidenciada por la capacidad para imitar gestos (por ejemplo, saludar con la mano) o emplear objetos según indicación (como demostrar el uso adecuado de un martillo).
- Gnosis: La capacidad de la conciencia para integrar percepciones y reconocer elementos como rostros y colores.

f. Reconocimiento social.

- Reconocimiento emocional: Consiste en detectar la emoción presente en imágenes que muestran rostros expresando diferentes emociones, ya sean positivas o negativas.
- La teoría de la mente es la habilidad para interpretar lo que otras personas piensan, sienten o desean, así como sus intenciones. Se ilustran situaciones con tarjetas que presentan preguntas diseñadas para averiguar el estado mental del personaje representado, por ejemplo: "¿Dónde cree la niña que está el bolso perdido?" o "¿Cuál es la razón de la tristeza del niño?".

2.1.1 Manifiesto Ágil

El *Manifiesto Ágil* (Pacagnella Junior & Da Silva, 2023) define las diferencias esenciales de las metodologías ágiles contra las metodologías de desarrollo de software tradicionales con especial énfasis en los siguientes puntos:

2.1.2 Individuos e Interacciones sobre Procesos y Herramientas.

Sin duda, este es uno de los principios clave del manifiesto. Es cierto que los procesos orientan el trabajo y funcionan como guía, así como las herramientas aumentan la eficiencia. Sin embargo, sin personas capacitadas y con una actitud adecuada, tanto los procesos como las herramientas pierden efectividad y no garantizan resultados.

Las organizaciones suelen afirmar que sus empleados son un recurso fundamental; sin embargo, en la década de los 90, la teoría de producción basada en procesos y la reingeniería adquirieron una relevancia significativa, especialmente en actividades cuyo valor depende del conocimiento y talento de quienes las ejecutan. Este enfoque destaca la importancia de los individuos, aunque considera que los roles pueden ser intercambiables.

Los procesos están diseñados para servir como guía y respaldo en el desarrollo del trabajo. Es fundamental que estos se adapten a las características de la organización, los equipos y las personas, en lugar de que sean estas quienes deban ajustarse a los procesos. Sostener que los procesos por sí solos pueden garantizar resultados sobresalientes independientemente de la calidad del personal puede ser riesgoso, especialmente en ámbitos donde la creatividad y la innovación son esenciales.

Ante los rápidos cambios, las organizaciones competitivas deben ajustar sus procesos y herramientas con agilidad. Es fundamental que el personal proponga iniciativas o se adapte rápidamente.

2.1.3 Producto funcional sobre Documentación comprehensiva.

La posibilidad de observar de forma anticipada el comportamiento de las funcionalidades esperadas, tanto en prototipos como en componentes desarrollados del sistema final, proporciona una retroalimentación valiosa que fomenta la generación de ideas innovadoras. Por lo general, resulta complejo elaborar un documento de requisitos detallados antes del inicio del proyecto.

El manifiesto no niega la necesidad de documentación. Los documentos facilitan la transferencia de conocimiento, registran información histórica y pueden ser requeridos legalmente, pero son menos relevantes que contar con productos funcionales y su valor es secundario frente al software operativo.

La documentación no puede igualar el valor ni la riqueza que se obtienen mediante la comunicación directa entre las personas y el trabajo práctico con prototipos. Por ello, siempre que sea posible, se debe priorizar el intercambio interpersonal y limitar la documentación solo a lo estrictamente necesario, ya que suele implicar tareas que no agregan un valor directo al producto.

Cuando la organización y sus equipos dependen principalmente de documentos para comunicarse, existe el riesgo de perder el valor que aporta la interacción directa con el producto. Además, estos documentos pueden llegar a utilizarse de manera defensiva, funcionando como barreras entre departamentos o personas.

2.1.4 Colaboración con el cliente sobre la negociación de un contrato.

Las prácticas ágiles son ideales para productos difíciles de definir al inicio o cuyos requisitos cambian con frecuencia, ya que permiten mejorar el valor mediante retroalimentación continua durante el desarrollo (Ming Huo et al., 2004). Son especialmente útiles cuando los requerimientos son volátiles debido a la dinámica empresarial acelerada.

En el desarrollo ágil, el valor del resultado surge de la implementación directa en el producto, no simplemente por cumplir procesos. Un contrato, en sí mismo, no genera valor al producto; solo actúa como una formalidad que define los límites de responsabilidad y establece las bases para resolver posibles disputas entre cliente y proveedor.

En el contexto del desarrollo ágil, el cliente participa activamente como integrante del equipo, colaborando de manera continua en el trabajo conjunto. Por este motivo, los modelos de contrato basados en entregas puntuales no resultan apropiados para esta metodología.

2.1.5 Respuesta al cambio sobre el seguir un plan.

Cuando los modelos de desarrollo se aplican en entornos inestables, donde todo cambia y evoluciona rápidamente, es más importante poder reaccionar con agilidad que seguir planes rígidos. La gestión ágil prioriza anticiparse y adaptarse al contexto, mientras que la gestión tradicional de proyectos pone el énfasis en la planificación y el control para limitar desviaciones respecto a lo planeado.

2.2 Lean UX

Debajo de los principios de Lean UX se encuentran los principios de Lean Startup, ayudando a remover lo que sobra del proceso de diseño de UX (Gothelf & Seiden, 2013). Se crean conversaciones mínimamente viables alejándose de documentación pesada y detallada; en lugar de eso, un proceso de Lean UX crea

Metodología	Design Thinking	Lean UX	Agile
Comprensión del Consumidor	+	+	
Ideación del bosquejo de producto	+	+	+
Definición de producto	+	+	+
Construcción de Producto		+	+
Modelo de Aprendizaje y mejora continua de Producto		+	+

Tabla 1. Características principales de las metodologías ágiles y su comparación entre sí.

solo los artefactos de diseño necesarios para que el equipo pueda continuar. Después los principios de Lean nos llevan a armonizar nuestro “sistema” de diseñadores, desarrolladores, ingenieros de calidad, mercadólogos y otros más en una colaboración transparente y funcional que incluye a los no diseñadores en el proceso de diseño. Finalmente, y quizás la parte más importante, es el conocimiento que obtenemos de adoptar un modelo basado en experimentación, en lugar de concentrar todo en un solo diseñador que sugiera la mejor solución desde un solo punto de vista, ya que la experimentación rápida y la medición nos ayuda a aprender qué tan rápido (o no) nuestras ideas llegarán a cumplir las metas.

A diferencia de Lean Startup, Lean UX (Gothelf & Seiden, 2013) parte de dos fundamentos: Design Thinking (que nos ayuda a ampliar el enfoque de nuestro trabajo más allá de interfaces y artefactos) y la filosofía de desarrollo Ágil (reenfoca el desarrollo de software en ciclos más cortos, entregando valor regularmente y un aprendizaje continuo). La Tabla 1 nos permite observar de una manera más clara

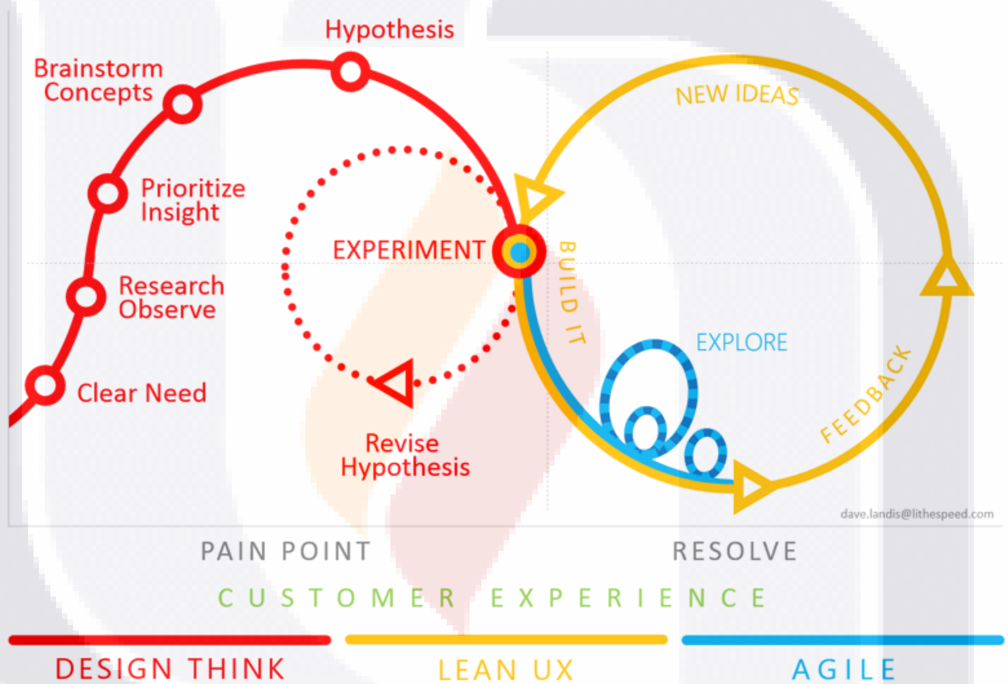

Figura 2. Comparación gráfica entre los procesos de metodologías ágiles más relevantes (Gotheff & Seiden, 2013).

las diferencias entre las metodologías ágiles más conocidas, comparando las características que ofrecen cada una de ellas; de igual manera, la Figura 2 nos ofrece una vista gráfica comparando estas mismas metodologías e identificar la forma en que se desarrollan sus procesos.

Una vez mencionadas las diferencias principales entre las metodologías ágiles podemos detallar el ciclo iterativo que involucra Lean UX como se muestra en la Figura 3, donde se observan los pasos a seguir en cada iteración y, una vez cumplidas las hipótesis y con un resultado satisfactorio, podemos llevar a cabo un nuevo ciclo de Lean UX para la siguiente etapa del proyecto.

Figura 3. Etapas de cada Iteración de la metodología ágil Lean UX (Gotheff & Seiden, 2013).

2.3 Realidad Mixta

Los entornos virtuales tienen un largo camino de desarrollo y perfeccionamiento gracias al desarrollo de videojuegos, que han inspirado el uso de sus mecánicas a experiencias en áreas tan variadas como la creación de perfiles psicológicos (van Lankveld et al., 2011), virtualización de entornos para ejercitación (Bruun-Pedersen et al., 2014), desarrollo de funciones cognitivas (Gamberini et al., 2009), rehabilitación motriz (Cardona Reyes & Muñoz Arteaga, 2016), tratamiento de la enfermedades cerebrales degenerativas como el Alzheimer (Tsao et al., 2019) e incluso la capacitación visual de usuarios en la industria con dispositivos de realidad aumentada y virtual (Ro et al., 2019).

La Realidad Virtual, conocida también como Entornos Virtuales, envuelve a las personas en imágenes y sonidos capaces de generar una sensación de presencia física dentro del mundo virtual (Moyle et al., 2018). Gracias a la versatilidad de los motores de juego modernos, hoy es más sencillo que nunca crear entornos virtuales, lo que los convierte en herramientas fiables para mejorar la experiencia de usuario en diversas actividades.

Capítulo 3. Artículo "Mixed Reality Ecosystem Architecture to Support Visuoconstructive Ability in Older Adults"

En este capítulo se incluye el primer artículo publicado derivado del proyecto doctoral, donde se propone un modelo arquitectónico por capas que integra realidad virtual, realidad aumentada, wearables y nodos locales para apoyar la rehabilitación y seguimiento de funciones visoconstructivas en personas mayores.

A partir de la revisión del estado del arte y de un caso aplicado en instituciones de cuidado (DIF), identifica problemas clave —ergonomía de dispositivos, alfabetización digital y diseño de software— y plantea una ruta práctica para desplegar escenarios de realidad mixta (interacción directa, indirecta, remota y análisis de datos) junto con instrumentos de evaluación de experiencia de usuario para facilitar la adopción, el monitoreo remoto y la detección temprana de deterioro cognitivo.

3.1 Artículo

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Mixed Reality Ecosystem Architecture to Support Visuoconstructive Ability in Older Adults

Erwin B. Montes Chaparro, Jaime Muñoz-Arteaga, Angel E. Muñoz Zavala, Héctor Cardona Reyes, Klinge Orlando Villalba Condori

***Abstract*— Nowadays, Senile Dementia is one of the most recurrent ailments related to aging as brain functions begin to deteriorate, making the elderly more dependent on others to take care of them. Using ecosystems with mixed reality allows them to have an easier way to their activities, have some independence, improve their quality of life and do exercise routines by themselves with the help of the Internet for remote control monitoring. This work proposes an architectural model for a mixed reality ecosystem to support older adults' daily activities. The work advocates the design of the ecosystem components, which are used in two scenarios for the rehabilitation of the visuo-constructive ability of patients, making a more adequate and detailed combination and implementation of connectivity, software and peripherals.**

***Index Terms*—Elderly, Mixed Reality, Visuoconstructive Ability, User Experience.**

I. Introduction

Even with the adoption of technological advances by more and more people worldwide[1], in many cases, the older population (over 60 years old) never had the opportunity to experience technological evolution as actively as later generations did.

Since the daily life of users considered in the classification of older adults, not to mention adapting user interfaces, it is more difficult for them to adapt to modern devices that can make their lives easier [2]. For this reason, training in the use of modern devices is provided, not only to older adults but also to family members and health professionals.

The goal is that older adults get a good experience and that the graphical interfaces are as simple as possible. Even if it is known that older adults tend to be technologically enthusiastic [1], [3], in training, it is important to keep in mind the generation gap so that they can adapt to new technologies with minimal assistance.

Older people may suffer from low self-esteem after retirement due to major changes in their daily routine, reducing their social interaction and physical activity drastically. A retired person should maintain his or her right to feel useful with dignity; each user should discover his or her own capabilities and limitations. Quality of life is a concept linked to physical, social, and mental well-being [4].

Visuo-perceptual skills refer to the processes involved in the analysis and identification of visual stimuli for object recognition; Visuospatial skills are those processes necessary to perceive spatial location, orientation, direction and distance; visuo-constructive skills refer to the skills necessary to put all the parts together as a whole [5]. These skills are often impaired in senile dementia because of conditions such as Alzheimer's disease [6] and Parkinson's disease [7].

Senile dementia is known as the third leading cause of death in older adults, just after heart disease and cancer [8], affecting memory, language use, different levels of perception, judgment, and reasoning [9], but it is possible to reduce its impact on mental health through aerobic exercise [10]. This combined with virtual environments in daily physical activity, has shown in older adults an increased interest in exercise routines due to their low or no social interaction with other people, making them improve their cognitive stimulation [3].

Due to the large presence of technology in our daily routine and being a big part of our lives directly or indirectly, new generations can quickly adapt to the technological evolution that has been created to be as easy as possible for end users. User Experience (UX) is a relatively new area in modern application and device development; there are visible differences between old and new devices and how they interact with the end user [11]. Great user experience design can be observed when talking about Intelligent Assistants, even when different accents are involved in the same language the user satisfaction is outstanding [12]. Amazon has created one of the most versatile voice assistance technologies with a realistic simulation that makes any user with little technological knowledge feel comfortable when making a request through the microphone, giving the user a universe of possibilities when designing an interface with voice recognition services in between, making the interaction more natural and easier to learn.

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In Mexico, the Sistema Nacional para el Desarrollo Integral de la Familia (SNDIF or simply DIF) is a Mexican public social welfare institution founded in 1977 (www.gob.mx/difnacional). This institution focuses on developing the welfare of Mexican families, which in its general activities includes: promoting family planning, care and protection of children, combating substance abuse, support for people with disabilities and assistance to the elderly.The openness of DIF to research projects is important for works oriented to the application of technologies in therapy programs, giving the opportunity to treat and live with patients with whom it is possible to adapt and test system proposals in real scenarios [13].

What this work asks is whether the use of current technologies in the routine of older adult patients can reduce the risk of suffering any decline in their visual-constructive skills, slowing cognitive decline to improve their quality of life in the long term through intuitive virtual environments and adapted with the use of Virtual and Augmented Reality devices (Mixed Reality).

The current paper is divided into the following sections: Section II is called Background and contains definitions of the related technologies to be used. Section III is formed by related works using Virtual Reality and treatment of patients with senile dementia. Section IV talks about the problem, including works using the technologies that integrate this proposal. Section V presents a Digital Ecosystem architecture to develop mixed reality environments, describing the general architecture for several possible scenarios and dividing it into layers of interaction to assist patients with dementia-related conditions. Section VI presents a case study applying several technologies to a real scenario. Section VII of the discussion provides a broader view of how this approach can be used beyond the specific study.

II. Background

Technological ecosystems count as the evolution of traditional information systems [14], [15]. A digital ecosystem, as a technological metaphor, is derived from the concept of a biological ecosystem as a community of living organisms whose vital processes are interrelated and whose development is based on the physical factors of the environment in which they live [16]. The definition of an architectural structure for technological ecosystems requires taking into consideration all aspects related to the integration, interoperability, and evolution of the components, as well as an appropriate definition of the underlying architecture [17]. In summary, a digital ecosystem can be defined as a set of low cohesion networks of interactive organization that are digitally connected and enabled based on modularity and that can affect and be affected by other devices [18].

To establish the ecosystem of this work it is necessary to mention the technologies that will be interrelated, such as Virtual Reality, Augmented Reality, Mixed Reality and their integration with multiple protocols and devices in the local network environment.

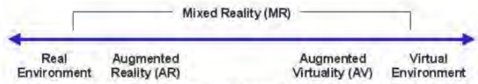

Fig. 1. Simplified representation of Mixed Reality by Milgram and Kishino (1994) [21].

Virtual Reality, also known as Virtual Environments, surrounds a person with images and sounds that can feel physically present in the virtual environment [19]. With the flexibility of modern Game Engines, virtual environments are easier to develop than ever, and act as a reliable tool to enhance the user experience combined with their daily activities [3], [19], [20]. Social interaction through virtual environments has a promising future as a tool for public health in areas such as education, simulation, decision making, behavior change intervention, clinical practice and specialized training [21], giving providers of this type of service, techniques to communicate ideas and the ability to focus on certain audiences to understand them.

Augmented Reality is a term to name the set of technologies that allow users to see part of their real environment through a technological device with extra graphical information, adding virtual objects to the real view [2]. Applied to daily life, Augmented Reality can facilitate some activities for people by coloring objects or displaying visual notifications, helping visually and hearing-impaired people complete their tasks with visual assistance and feedback with minimal intervention from the geriatric staff in charge.

Mixed Reality, as depicted by Milgram and Kishino [22] (Figure 1) combines real objects and virtual object interaction, giving the possibility to combine tangible objects and peripherals with 3D objects in a viewer [23]. The use of tangible peripherals can make the older adult feel more comfortable with 3D representations in combination with haptic vibration as feedback.

Figure 2 shows the traditional patient monitoring protocol in DIF [24], with the added layer of Mixed Reality scenario. In this representation, the Mixed Reality scenario is used as a complementary tool to the process that will be incorporated little by little with each new iteration of testing until it is organically integrated into the patient rehabilitation process.

Modern miniaturization has enabled the creation of small and powerful mobile devices such as the Raspberry Pi microcomputer, being the perfect choice for a low-power device to be used as the central processing unit of custom home automation systems [25] allowing connection between multiple small devices, actuators, sensors and other active electronic components using Arduino as the Hardware interface.

III. State of the Art

The use of Virtual and Augmented Reality in the treatment of conditions related to neurocognitive diseases is relatively new in practice. Due to the reduction of costs in virtual reality equipment and the increase in processing power for mobile

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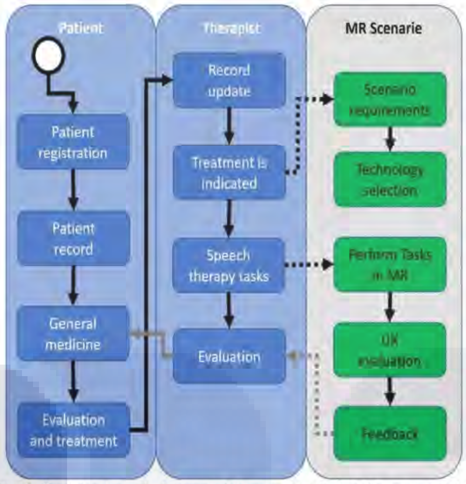

Fig 2. Traditional physical therapy follow-up protocol of the patient and his interaction with the therapist and its relation to the Mixed Reality scenario. The black lines represent the ordered sequence of the process, the gray lines represent the feedback to the previous layer of the sequence diagram. The dotted lines represent the connection to the Mixed Reality scenario with

devices, virtual reality has become much more affordable to the public than ever before [26].

The ease of use of modern game engines have shown exponential growth in the creation of virtual environment experiences when combined with game engines such as Unity [3], [19], [20] (free to use for non-commercial applications) and cell phones with Virtual and Augmented Reality attachments such as Google Cardboard [27], allowing users who are not up to date with technologies of this type to try out mixed reality technologies and developers to create experimental applications relatively free of charge.

Since 2012 an increase in Virtual Reality applications oriented to dementia conditions can be seen [28] in conjunction with the ease of creating virtual environments, taking geriatric patients out of their place of care virtually, allowing them to explore a variety of scenarios and studying their reactions to virtual natural environments [19]. There is a proposal in adaptive Virtual Reality environments that uses real-time feedback to change what the user can perceive in the environment while monitoring their brain activity [20].

The combination of virtual environments and exercise allows older adults to avoid routine activities by "visiting" other places outside the care center where they live virtually [3], obtaining a positive evaluation from the users and encouraging them to exercise for a longer time than usual; the same work focuses on the design of hardware adapting a leg and arm exerciser to a virtual environment using the Unity game engine.

The treatment of more specific conditions such as Alzheimer's have shown promising results in combination with Virtual Reality [29], with great benefits when integrated with theoretical models and Mixed Reality [30] through Reminiscence therapy.

The CogARC project [31] combines the use of virtual objects with real object detection to add an Augmented Reality layer in a Tablet application for older adults to play some mini games; even after obtaining positive results in user evaluation towards the system, negative evaluations show that there are still problems in the interaction aspect for some games.

The HalleyAssist system [32] involves a complex ecosystem that tries to prevent as many diseases related to geriatric patients as possible by combining sets of sensors of different types to achieve optimal detection of abnormal patterns according to the collected information.

The use of augmented reality devices such as HoloLens [33] have been shown to be a supportive device for memory loss therapies with a wide range of content available for this type of device. Panoramic 360° video experiences can improve patient care, but an interface design is needed to accommodate elderly users and ease of use, not to mention that poor device calibration can cause motion sickness (motion discomfort and viewpoint deformation).

The DCPAR Project [2] combines the use of a tablet application with a pico-projector hanging around the neck. Even with a good response from older adult users and the good interface design of the tablet application, there are problems with hanging the device from the neck causing discomfort scenarios. In cases where the user is using a wheelchair, the pico-projector often does not have the correct orientation to display information to the user on the wall.

The edlgergames project combines Mixed Reality with a board game to train cognitive functions [23]. The article analyzes the emotional aspects of the interaction between players and each player with the game, obtaining positive results of the platform with older adults, proving that a good user experience design oriented to older adults is feasible.

The European University of Madrid tested two Virtual Reality projects for simulation-based education [34]: the first involves the use of the RCSI Medical Training Application system to train students in the health field in case of an emergency involving a patient who has just suffered a car accident, allowing students to analyze the situation, establish priorities and carry out actions such as CPR and immobilization of the patient in addition to the importance of managing self-control in stressful situations; The second is carried out with the UE Risk Simulator training application, whose objective is to train students from the pharmaceutical sector in the management of accidents in a laboratory, learning basic rules and procedures for dangerous scenarios and finding the best way to solve the problem presented. Both virtual environments achieved positive results, providing knowledge to students at the same level of a real practice, with the difference that the virtual environment avoids putting the students' safety at risk, repeating the test as many times as necessary and stopping the test in case of any inconvenience in the virtual experience.

IV. Problem Outline

Many areas of opportunity can be found when dealing with the topic of Mixed Reality applied to elderly patients; some of the problems that this work tries to solve are:

- Mobility problems: it is one of the most frequent ailments in the elderly population due to muscular, cardiovascular, metabolic, muscular impairments and brain deterioration with advancing age [10]; it is known that the signs of some brain diseases are usually postponed when the elderly patient has a regular exercise routine. This mentioned article seeks to maintain a constant physical activity to maintain metal health and, if possible, using lightweight devices and virtual environments to catch the user's attention.
- Device ergonomics: Occupational therapy systems [13] show positive results for patient interaction in motor rehabilitation using virtual environments and peripherals. Finding the balance between ergonomic peripherals, comfortable body-worn electronic devices, intuitive user interfaces, and pleasant virtual environments is possible to increase interest in the target user, making therapy sessions a more enjoyable and user-friendly experience with external intervention and monitoring at a minimum.
- Software engineering approach: many research articles focused on Augmented Reality for geriatric patients are focused on the practical part, the physical device, the functionality and the design of experiments depending on the scenario [8], [23], [35], leaving the software design section aside.

V. Digital Ecosystem Architecture

The presence of different technologies to interact with each other using different communication protocols can produce confusion among all the interacting devices, which is why it is necessary to define a Digital Ecosystem architecture [15], [18] and be aware of the distribution and connectivity of devices. Developing a set of interactive environments will have to be different depending on each patient scenario.

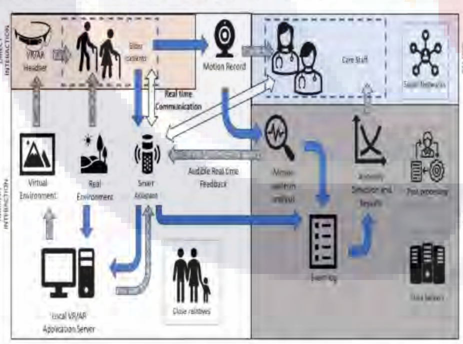

Fig 3. Digital Ecosystem Architecture for remote assistance for therapies of elderly patients with senile dementia in a healthcare institution.

This paper proposes a digital ecosystem architecture (see Figure 3) combining Augmented Reality, Virtual Environments (Mixed Reality), and the Software design tools that can be found in UML (Unified Modeling Language) [36] and SysML (System Modeling Language) [37], using Human-Computer Interaction (HCI) [38] to adapt the User Interface and User Experience. A way to easily adapt to as many disease scenarios as possible is sought, starting with the visuo-constructive ability, following the evolution of the patient's conditions.

Using Internet connectivity, a remote monitoring design is desirable to keep all parties involved in contact with the geriatric patient (family, friends, specialized care staff) even when they are not in the same building.

The proposed architecture is shown in Figure 3, divided by interaction layers and integrating different types of technological devices and their interaction with the different stakeholders. The description of each layer is detailed below.

A. Direct Interaction

In this paper we define Direct Interaction as all devices that interact with the patient at the closest level such as tablets, smartphones, Virtual and Augmented Reality devices and body-worn electronic devices including biometric sensors to monitor heart rate and step counters with the addition of smartphones for fall detection [39]. We are on the understanding that some types of dementia can cause patients to forget that they are wearing an electronic device, so the need for a non-intrusive device is a necessity for this type of application that is not to mention ergonomic design to make the experience more comfortable for the older adult.

Personal mobile devices such as tablets or smartphones, which patients can carry with them, allow them to keep track of their current medical situation as well as being a means to receive calls and notifications from family members and caregivers. Meanwhile the array of sensors found in smartphones can record accidental falls, movement patterns and daily activities for analysis of the daily routine.

Virtual and Augmented Reality (Mixed Reality) glasses can run some routines in virtual environments to allow the patient multiple therapies for physical exercise and mental illness, alternating a virtual scenario to make the experience less monotonous.

B. Indirect Interaction

The Indirect Interaction area will be composed of devices with which the patient can interact without being in direct proximity, but in a local network environment with an on-site server to process the data before sending it to the Internet. Usually wearable electronic devices (wearables) have a very small processing, storage, and battery capacity, so a more powerful device to collect all the information is indispensable.

Microcomputers such as the Raspberry Pi [25] can serve as powerful processors for data processing for readings received from wearables and other devices in the local network, such as:

- Cameras for pattern recognition and remote live

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monitoring.

- Smart assistants such as Google Home or Alexa [12] for direct user interaction and requests via voice commands (for assistance in using alarms, reminders, tips, and basic level conversations with Internet-connected voice services).
- Sensors for environment monitoring and to perform simple control actions with notifications to the user, in situations such as temperature or humidity level change.

After processing the patient's situation information, the Raspberry card will connect to the Internet to give live information to the staff and display alerts to the care staff in abnormal situations.

In this interaction layer, the patient can request simple voice commands from the voice assistant, and in case more complex commands or interactions are required, on-site family members can perform the task of digital inclusion for the senior, after training in the use of the digital ecosystem by the care staff, as well as being connected to a system of notifications about the patient's status.

C. *Remote Interaction*

This interaction layer is carried out through Internet connection, allowing specialized care personnel and interested family members to maintain contact through audio and video and receive notifications of the patient's physical condition by making calls using an intelligent assistant or mobile devices.

The participation of the medical staff in this layer focuses on remote patient consultation, in addition to the verification of the collected follow-up data, validating the completion of therapies at designated times. Specialized care staff can perform live monitoring of the patient during their routines and provide feedback comments on therapies in real time via voice and/or video calls.

D. *Data Analysis*

The data obtained during the constant monitoring of elderly patients represent an important source of information for the recognition of biometric patterns when performing a specific activity, since it is possible to detect variations and abnormalities in the patient according to the patient's historical data and to automate procedures that allow detecting improvements over time and with a level of periodicity according to the type of variable.

Fig 4. Older adult user using a Xiaomi Mi Band 3 bracelet, a device with a compact and simple design. Own source.

With an in-depth analysis it is possible to detect changes that represent symptoms of conditions that affect the visual-constructive ability in early stages. To carry out the data capture and storage, a tunnel connection is required to protect the data collected from the different patients as it travels to the data servers, where all the big data processing will take place.

The server infrastructure must be scalable, in order to be prepared for the time when the ecosystem starts to allow more and more users in different locations, including nursing homes, ranches, patients' homes and classify them by type of disease and condition. The scalability of the ecosystem must contemplate big data processing methods and algorithms that can automatically classify the data.

VI. Field Research

The target audience is the population of older adults in public nursing homes belonging to the institution "Desarrollo Integral para la Familia" (DIF estatal, www.aguascalientes.gob.mx/dif/) in the city of Aguascalientes, Mexico. An interview with the specialized assistance personnel is needed to study the procedures of physical therapies, recreational activities and sleep schedules for geriatric patients. Interviews with patients will also be necessary to learn their general preferences and openness to using technological devices and wearing certain devices.

The scenario described below involves an older adult with Alzheimer's disease conditions, impaired visuo-constructive skills and how he or she relates to each layer of interaction.

A. *Direct Interaction*

The patient, having memory difficulties, cannot remember where he leaves his keys and is beginning to have difficulty finding his medications for his chronic conditions. His spatial perception has been affected and he is sometimes unable to perceive how far away he is from objects or in which room he is in his home.

The Xiaomi Mi Band (Figure 4) is an especially useful device for monitoring a user's number of steps per day, blood oxygenation level, and heart rate of a patient, depending on the device version. It is characterized by a low cost with an acceptable reading quality and a good battery performance that can range from one to three weeks, depending on the device version and the functions being used. This device can allow receiving notifications with a slight vibration to the wrist that reminds you to check your smartphone to remind you of useful information. The Mi Band device brings readings for one to two weeks until the battery runs out, avoiding the need for attention to the device for a relatively long period.

In addition to a smartphone connecting each Mi Band device to store patient information via Bluetooth connection, it will also be necessary to know if the patient has a visual impairment to choose the device according to the required screen size.

The readings will give us an idea of how many steps the patient walks daily and adjust their exercise routines when

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Fig.5. Older adult using an Oculus Rift viewer in a virtual environment. Virtual reality is considered a first stage in the development of the mixed reality ecosystem. Source: Own source.

necessary. The heart rate monitor can help the specialized care staff to have more frequent heart rate readings without having to be with the patient on site.

For the first part of the project, the first commercial version of the Oculus Rift viewer will be the Virtual Reality device to be used (Figure 5) as part of the initial prototype for testing virtual environments. Through the Oculus Rift viewer the patient will have the possibility to "visit" virtual environments with a level of immersion provided by an intuitive way of interacting with that environment, where the patient will be able to learn to become familiar with the activities and objects found in the virtual environment. It is possible for the older adult patient to gain new knowledge through virtual interaction according to the suggested routines and the patient's motor skills, modifying the levels of interactivity as needed.

For future stages of the project, the goal is to use the Cardboard viewer with a mobile device, such as virtual and augmented reality glasses with low cost and easy replication of spare parts. The integration of Augmented Reality into the daily routine can allow the patient to detect objects in front of him and place text on screen to orient him and help him avoid accidents when he is alone at home.

B. Indirect Interaction

Google Home and Amazon Alexa are low-cost voice-controlled devices with agile voice-processing algorithms [12] to provide almost immediate response to commands. These devices can provide information to the patient about the weather, the time, or their therapy schedule; they can also provide virtual interactions including singing songs, requesting information, playing voice games, telling jokes, and solving puzzles making the patient's daily routine more enjoyable.

Installation of cameras with motion pattern recognition from a Raspberry Pi [25] will allow the ecosystem to locate the patient within the property and notify his mixed reality viewer of his location with respect to objects around him.

In the operation within the ecosystem, the Intelligent

TABLE I
USER EXPERIENCE EVALUATIONS PROPOSED FOR THE DESIGN OF MIXED REALITY SCENARIOS.

UX Evaluation	Measures
UEQ (User Experience Questionnaire) [39]	Attractiveness Efficiency Perspicuity Dependability Stimulation Novelty
SUS (System Usability Scale) [39]	Perceived Usability Effectiveness Efficiency Satisfaction
UMUX (Usability Metric for User Experience) [40]	Reliability Concurrent Validity Sensitivity
CSUQ (Computer system Usability Questionnaire) [40]	Overall System Usefulness Information Quality Interface Quality
AttrakDif [41]	Pragmatic quality Hedonic Quality (identity) Hedonic Quality (stimulation) Attractiveness

Assistant can deploy voice alerts in case problems are detected from the patient when moving around his home and as reinforcement in alerts and notifications from the smartphone he is carrying.

C. Remote Interaction

Using the APIs of popular social networks such as Facebook, Twitter and some instant messaging services such as Telegram, notifications can be sent to all friends and family members interested in the patient's condition; similarly, medical and geriatric care staff can receive specialized notifications (biometric information, patient activity log, reading anomalies and routine log) instead of social network oriented interactions, to know the patient's status in a more real-time oriented communication. This type of alerts will give medical staff a live status of the patient's situation or conduct a consultation without the need to make an on-site visit.

D. Data Analysis

The first step of data analysis is to build a knowledge base with all the information collected from the devices with which the patient interacts. With all the data received from the patient's routines, data mining routines will be run to detect patterns using statistical analysis and heuristics. If the patient is incorrectly executing one of his or her routines, the system should be prepared to detect alterations concerning historical data that the medical care staff can verify. The patient needs to know as early as possible when a routine is being executed incorrectly to avoid physical injury.

In later stages it is expected to be able to detect abnormalities in the patient's movement and certain conditions at an early stage, allowing medical staff to treat certain diseases in a timely manner.

E. User Experience

Measuring user experience is of great importance due to the difficulties of adaptation of the average older adult to state-of-the-art technologies [2], so it is necessary to measure user experience using some of the most representative evaluations available in the literature [40]-[42] and in detail in Table I. With these evaluation instruments, we can know the perception of older adults of Mixed Reality environments in their therapy activities, the ease of use and adaptation and the effort required to carry out such activities.

VII. Discussion

The present work responds to the question of how the proposed architectural model will help older adults improve their quality of life through Mixed Reality routines and environments to reduce the cognitive deterioration that affects their visual-constructive skills with the supervision and advice of therapists and physicians specialized in geriatric care.

The definition of a digital ecosystem can facilitate the schematization at hardware and software level that will allow us to have a more concrete vision of all the elements involved in monitoring the patient and their corresponding therapies. The resulting architecture can serve as a "mold" of a general approach in order to identify the main blocks and quickly adapt it to multiple technologies for the treatment of different conditions in the specific situation of each geriatric patient in an efficient way.

Once the functioning of the ecosystem architecture is validated and a positive evolution in older adult patients is obtained, it will be possible to expand the target population allowing therapy for a wider variety of conditions and in different age ranges, as well as allowing the inclusion of a more diverse range of biometric devices to have a more accurate and complete tracking of the status of users using the ecosystem.

Modeling a digital ecosystem is necessary for the interconnection between all types of devices and the type of interaction with the stakeholders involved. Each device in the ecosystem has an essential role to play in maintaining consistent connectivity across all layers. Understanding the specific situation of each end user will give us a broader view of the needs for the conditions being discussed with the patient.

VIII. Conclusion

The creation of virtual environments allows us to have applications to which traditional therapy mechanics can be agilely adapted, with the option of high scalability and even hybridization of therapies if the patient requires multiple exercises in case of suffering from different ailments. Interactions between older adults and virtual environments through mixed reality can offer a huge expansion in their daily interaction without leaving their homes, allowing them to avoid monotony and make their therapy sessions more attractive. The augmented reality section can help geriatric patients better perceive their environment when they do not have company on site.

An intuitive user experience designed especially for older adults can work as an incentive to perform their daily therapies in a more pleasant way, causing the elderly patient to have a greater interest in carrying out their exercise sessions without the obligation set by the geriatric care staff.

The patient's smartphone is very important as a tool for connectivity to the ecosystem, view of notifications, voice/video calls and basic monitoring of the user's condition, as well as functioning as a screen for the Cardboard viewer. A device with a balance between cost and performance is required, this to carry out a more affordable implementation, but with enough capacity to display the 3D graphics that will be rendered in the virtual environment developed for the user's therapy.

The future work of this research is very broad in an agile methodological approach to optimally carry out the implementation of the proposed model. Also, it is required to carry out the design of the User Experience that allows more and more older adults to have a more intuitive experience in order to address the ailments that affect their visual-constructive ability. Virtual environments are tools that, in conjunction with Virtual and Augmented Reality viewers, allow the ecosystem to be attractive to users. It is our duty as a society to bring to the elderly technologies that have been ignored for years and can make their daily lives more enjoyable at a relatively low cost and without completely losing their independence as individuals, thus improving their quality of life.

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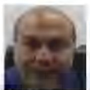

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3.2 Conclusiones del Artículo

La propuesta de una arquitectura de ecosistema de Realidad Mixta orientada a la rehabilitación de la habilidad visoconstructiva en adultos mayores demuestra que es posible integrar dispositivos accesibles, protocolos de interacción y herramientas de software en un modelo modular y escalable. El diseño por capas —interacción directa, indirecta, remota y análisis de datos— facilita la incorporación progresiva de tecnologías en entornos institucionales como el DIF, garantizando que la experiencia del paciente sea intuitiva y que el personal de cuidado pueda monitorear y ajustar las terapias de manera eficiente. Los resultados preliminares, junto con la encuesta a terapistas y los escenarios hipotéticos, evidencian que la combinación de realidad virtual, aumentada y mixta puede mejorar la estimulación cognitiva y la independencia funcional de los adultos mayores. En conjunto, este trabajo sienta las bases para futuras validaciones clínicas y abre la posibilidad de extender el ecosistema a otros dominios de rehabilitación neurocognitiva, consolidando la Realidad Mixta como una herramienta viable y transformadora en el cuidado geriátrico.

Capítulo 4. Artículo "Digital Ecosystem Model to Produce Mixed Reality Environments to assist Neurocognitive Disorder"

En este capítulo se incluye el segundo artículo publicado derivado del proyecto doctoral, el cual propone un modelo de ecosistema digital que integra Realidad Mixta (VR/AR), dispositivos IoT (wearables, asistentes de voz, microcomputadoras locales) y prácticas de Lean UX para diseñar, iterar y personalizar entornos terapéuticos dirigidos a adultos mayores con trastornos neurocognitivos.

A partir de una revisión del estado del arte y de requisitos técnicos y humanos, el trabajo describe una arquitectura por capas (interacción directa, indirecta, remota y análisis de datos), un flujo de adquisición y procesamiento de señales, y la combinación de instrumentos clínicos (MMSE, NPI, IQCODE, ROSA) con cuestionarios de experiencia de usuario (UEQ, AttrakDiff, meCUE) para evaluar simultáneamente efectos cognitivos, usabilidad y aceptación en ciclos de prototipado iterativo.

4.1 Artículo

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Digital Ecosystem Model to Produce Mixed Reality Environments to assist Neurocognitive Disorder

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Abstract

In the realm of digital ecosystems, integrating Lean UX principles into virtual environments for older adults presents a promising avenue for enhancing cognitive health and addressing neurocognitive disorders. This research builds on the foundation that virtual reality (VR) and augmented reality (AR) technologies can significantly improve the quality of life for the elderly, fostering social interaction and cognitive stimulation. Despite the proven efficacy of VR and AR in engaging older adults, there remains a gap in applying Lean UX methodologies to optimize these digital experiences. This study investigates the incorporation of Lean UX into digital ecosystems for older adults, tailoring virtual environments to their unique needs and preferences, thereby aiding in the treatment and management of neurocognitive disorders such as Alzheimer's disease. Employing a user-centered design approach, iterative prototyping, and multidisciplinary collaboration, the research analyzes variables such as user engagement, adaptability, cognitive load, accessibility metrics, and user satisfaction. Findings reveal that Lean UX leads to more intuitive, accessible, and personalized VR interfaces, increasing user satisfaction and potentially mitigating neurocognitive decline effects. The implications underscore empathetic design in creating inclusive digital solutions that support older adults' well-being and independence. Future work involves fieldwork to validate and refine the digital ecosystem model in real-world settings.

Keywords: Mixed Reality, Internet of Things, Neurocognitive Disorder, LeanUX, Digital Ecosystem.

1 Introduction

The integration of technology into the lives of older adults is an ever-evolving field of study. Hwangbo et al. [1] highlighted the importance of adapting smartphone interfaces to enhance the experience of older users, while Saracchini et al. [2] explored how mobile augmented reality can serve as assistive technology for this demographic. Virtual and augmented reality, in particular, have shown promise in supporting physical therapy in retirement homes[3].

Quality of life and dignity in aging are crucial issues [4], and technology can play a vital role in this regard. Ro et al. [5] presented a projection-based augmented reality for older adults with dementia, suggesting that technological solutions can be adapted to meet specific needs.

Physiological changes associated with aging [6] also pose unique challenges for the design of assistive technologies. User experience with smart voice assistants shows how technology can be personalized to improve accessibility and usability for older adults [7].

The effectiveness of virtual environments, such as the virtual forest for people with dementia [8], and personalized human-computer interaction for psychiatric and neurological illnesses [9] highlight the potential of these technologies to improve cognition and emotional well-being. Persky and McBride [10] argue that immersive virtual environment technology is a promising tool for research and practice in social and behavioral genomics.

The discussion by Garcia et al. [11] on the use of virtual reality in dementia and the systematic review by Clay et al. [12] on the use of immersive virtual reality in the assessment and treatment of Alzheimer's disease underscore the clinical relevance of these technologies. Tsao et al. [13] and Boletsis and McCallum [14] explore how augmented reality and cognitive games can be used to support cognitive therapy and gamification.

Internet of Things (IoT) technology, as seen in HalleyAssist [15], can assist the elderly in their daily lives, while Cardona Reyes and Muñoz Arteaga [16] highlight the multidisciplinary production of interactive environments to support occupational therapies. The perception of hazards in elderly drivers enhanced by augmented reality cues shows how AR can improve safety and independence [17].

The design of concurrent, distributed, and real-time applications with UML [18], and system and simulation modeling using SYSML [19] are fundamental for the development of these assistive technologies. Dillon and Watson [20] provide historical lessons on user analysis in HCI, which are relevant for user-centered design.

Smartphone-based fall detection for the elderly [21], and the understanding of Alzheimer's disease by Bucciarelli [22], are examples of how technology can be adapted to address specific aging-related issues.

To this foundation are added the findings of Park et al. [23], who investigated the impact of virtual reality-based cognitive-motor rehabilitation on motivation and cognitive function in older adults with MCI, finding significant improvements compared to conventional methods. Bevilacqua et al. [24] conducted a systematic review on the efficacy and effectiveness of non-immersive virtual reality in the rehabilitation of older people, highlighting its acceptance and potential benefits.

Mikhailova et al. [25] explored the requirements of older adults for an augmented reality communication system, emphasizing the need to consider the preferences and emotional needs of this group to encourage the adoption of immersive technologies. Tian et al. [26] provided experimental evidence on the impact of virtual reality-based products on older subjects with MCI, using multiple sources of data to analyze brain activity and behavioral conditions.

These studies underscore the importance of designing technological interventions that are not only effective from a clinical standpoint but also motivating and appealing to end-users. The integration of these technologies into care plans can offer new avenues for improving the quality of life and independence of older adults, while addressing the challenges associated with aging and cognitive decline.

This work has been formed in seven sections: Second section, named Background, contains basic definitions of the technologies related, Third section contains some work with VR devices for treating neurocognitive disorder patients, Fourth section contains the problem outline, with other works using the integrated technologies of this approach, Fifth section describes a Digital Ecosystem Model for the development of Mixed Reality Environments, showing a general architecture for possible scenarios and organizing the model by interaction layers in order to assist the patients with neurocognitive disorders; A case study is presented in section six, applying several technologies in a real scenario. Finally, the conclusions are described in section seven.

2 Background

Virtual Reality (VR), also referred to as virtual environments, creates an immersive atmosphere by surrounding an individual with sound and visuals, simulating the sensation of physical presence within that virtual space [8]. The versatility of modern game engines has made the development of virtual environments significantly more accessible and efficient compared to previous generations of game engines. This advancement has transformed VR into a reliable tool to enhance user experience (UX) and integrate seamlessly into daily routines [3], [8], [9]. The application of virtual environments in social interaction holds great potential for advancing education, decision-making simulations, training, healthcare, and clinical practices [10], enabling innovative methods to convey ideas.

Augmented Reality (AR) encompasses a set of technologies that allow users to view their real-world environment through a device that overlays additional graphical information onto real objects, effectively adding virtual layers to the real-world view. AR can simplify various daily activities by highlighting objects with colors or displaying notifications.

Mixed Reality (MR), as illustrated in Figure 1, combines real objects with interactions involving virtual ones, allowing users to engage with physical objects enhanced by 3D virtual objects rendered on an MR headset [27]. The use of physical peripherals can be more suitable for elder users, providing them with haptic feedback that makes them feel more comfortable and engaged.

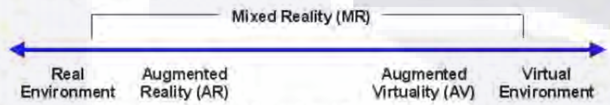

Fig. 1. Simplified representation of Mixed reality by Milgram and Kishino (1994) [28].

Recent advancements in electronic miniaturization have resulted in the development of reliable and powerful mobile microcomputers such as the Raspberry Pi. These devices are perfectly suited to act as the central hub in custom and open-source home automation systems [29]. They are capable of controlling a range of electronic devices, including sensors, electric motors, and actuators, with Arduino serving as the low-level hardware interface.

Lean UX is a design methodology that focuses on rapid iteration, collaboration, and user feedback to create user-centered products efficiently. Rooted in the principles of Lean Startup, Lean UX emphasizes minimizing waste and maximizing learning by developing only what is necessary to test hypotheses and gather insights. This approach fosters a culture of experimentation and flexibility, allowing design teams to adapt quickly to changing user needs and market conditions [30]. Unlike conventional UX practices, which regularly depend on massive documentation and long task cycles, Lean UX prioritizes lightweight, shareable artifacts and pass-useful teamwork to boost up the layout method. By integrating continuous feedback loops and real-time user checking out, Lean UX helps make sure that the very last product aligns closely with user expectancies and promises maximum price [31]. This methodology has proven particularly effective in environments where speed and adaptability are crucial, such as startups and agile development teams.

The concept of a Digital Ecosystem involves loosely connected networks of interacting organizations that are digitally linked and facilitated by modularity. These ecosystems mutually influence each other's offerings [32]. In this context, a digital ecosystem can be established through interactions among various components, including the Internet of Things (IoT), virtual environments, AR/VR headsets, and wearable devices. Moreover, smartphones, tablets, and smart assistants act as intermediaries, connecting these technologies with elderly patients.

Digital Ecosystems:

- Connectivity and Modularity: Leverage the connectivity and modularity of digital ecosystems to integrate various technologies such as IoT, virtual environments, and portable devices.
- Interaction with Emerging Technologies: Incorporate AR and MR to enrich the user experience, allowing for a more natural and comfortable interaction with the virtual environment.
- Personalization and Scalability: Use mobile microcomputers like Raspberry Pi to customize and scale home automation solutions that integrate with the virtual environment and improve the quality of life for older adults.

- Data Analysis and Feedback: Collect and analyze data on user behavior and preferences to continuously adapt the virtual environment to their needs.

3 Related Work

The application of AR/VR to neurocognitive disorders is a relatively new area in the treatment of mental diseases. With the reduction in costs of virtual reality headsets and the increase in power of mobile devices, VR applications have become more accessible than ever before.

The development of virtual environments has experienced exponential growth, leveraging modern engines like Unity [3], [5], [9] (which are free for non-commercial applications) and mobile phones with AR/VR accessories such as cardboard headsets. These tools enable users who are unfamiliar with virtual environments to experience mixed reality technology and allow developers to create experimental AR/VR apps at relatively low costs.

Since 2012, there has been a noticeable growth in VR apps designed for various neurocognitive disorders [11]. Without needing to take patients out of nursing homes, these apps allow the exploration of diverse scenarios and the study of elders' reactions to virtual nature environments like forests [8]. An adaptive VR environment proposal uses real-time feedback from users to modify the virtual environment based on what the user sees and interacts with, while monitoring brain activity [9].

The combination of virtual environments and physical exercise allows the elderly to avoid routine and "visit" (virtually) other places outside their living environments [3]. This approach has received positive feedback from users, who express a desire to exercise for longer periods. One such project focuses on a virtual environment using Unity and includes hardware design for an arm and leg exerciser machine.

Diseases as Alzheimer's have promising results when combined with virtual reality [12], [26]. Studies have demonstrated the benefits of integrating VR and MR with theoretical models [13], such as using reminiscence therapy.

Research directly addressing mild cognitive impairment (MCI) through virtual environments shows that VR can assist in identifying, intervening, and treating this condition by analyzing brain activity and behavioral conditions using near-infrared functional spectroscopy and behavioral recording devices, supported by the Microsoft Kinect device [26].

Ji-Su Park et. al [26] explored the impact of virtual reality-based cognitive–motor rehabilitation (VRCMR) on motivation and cognitive function in older adults with mild cognitive impairment (MCI). Forty participants were divided into a VRCMR group, which used a computer recognition program called MOTOcog, and a conventional cognitive rehabilitation (CCR) group, engaging in traditional activities like puzzles and card games. Both groups underwent 30 minutes of daily rehabilitation for six weeks. The VRCMR group showed significant improvements in cognitive assessments, including the Montreal Cognitive Assessment (MoCA) and Trail Making Tests (TMT-A/B), and reported higher interest and motivation levels compared to the CCR group.

The use of non-immersive virtual reality (VR) in rehabilitation, is well-received by older adults due to minimal cybersickness. A systematic review of the last decade's literature from databases like Cochrane and PubMed was conducted, focusing on randomized controlled trials [24]. The studies showed clinical heterogeneity and varied in quality based on the Physiotherapy Evidence Database (PEDro) scale. VR was found to enhance cognitive and motor abilities, positively affecting patients' emotional states and compliance. It has been effective in treating symptoms of various neurological disorders.

The study "Like a Virtual Family Reunión" [25] explores the attitudes and requirements of older adults regarding augmented reality (AR) communication systems. Through interviews with 30 participants from Germany, the research identified key technological, emotional, social, and administrative requirements for AR systems. The study emphasizes the importance of addressing the emotional needs of older adults, particularly the perceived intimacy of AR-based communication, to encourage the adoption of immersive technologies.

Project CogARC [14] integrates real objects with AR add-ons and visual detection software installed on a tablet, enabling elderly patients to engage in small games. Although the project yielded positive results, there was negative feedback concerning certain interactive aspects of the games.

HalleyAssist [15] utilizes a sophisticated ecosystem to prevent various health-related issues in elderly patients by combining sensor sets to more accurately detect anomalies in movement patterns stored in a knowledge base. However, this work also highlights the importance of software and user interface design to make these devices and applications more accessible and user-friendly for older adults [2], [3], [5].

The DCPAR project [2] employs a combination of a pico-projector worn around the neck and a tablet app for the user. While the tablet app design received positive feedback from elderly users, the weight and bulkiness of the pico-projector around the neck presented challenges.

The Eldergames Project created a mixed reality environment with tabletop games to train cognitive functions [27]. This project explores the emotional aspects of player interactions, demonstrating positive results and proving that a well-designed UX for elderly patients is achievable.

Most current design practices either fail to specifically address the needs of aging individuals or view these needs negatively as problems to be solved [33]. Given the growing aging population worldwide, it is crucial to design better for older adults by considering their wants, needs, desires, and expectations as foundational elements. This necessitates modifying existing design practices and methodologies to be more effective for aging user populations. The workshop aims to gather researchers, designers, and developers interested in designing, developing, evaluating, and deploying digital products, technologies, tools, and services for older adults. It will serve as a platform for sharing experiences from various perspectives through presentations, discussions, and a hands-on design activity, generating innovative ideas for future directions in designing for aging people.

Cardozo et al. [34] proposes improving older adults experience with social networks on tablets using Lean UX. The study proposed 23 design recommendations aimed at enhancing the user experience for older adults on social networks, focusing on simplicity, intuitive design, and addressing vision and motor skill challenges. An iterative and incremental prototyping cycle based on Lean UX methodology was applied, which was guided by the design recommendations and centered on the needs of older adults. The alternative social network design for tablets resulted in a significant reduction in the difficulties experienced by older adults when using the social network Facebook. There was an increase in the number of tasks and actions successfully executed by older adults using the prototype. Due to the improvements in usability and task success, there was an increase in the degree of satisfaction among older adults, contributing to a better overall user experience. These findings suggest that a user-centered approach, combined with Lean UX principles, can lead to significant improvements in how older adults interact with and benefit from social networks on mobile devices, particularly tablets. The study lays the groundwork for further customization and application of these methods to other products aimed at the older adult population.

These references provide a solid foundation for understanding how technology, particularly virtual and augmented reality, can be used to improve the quality of life of older adults, addressing both their cognitive and emotional needs. With the integration of Lean UX and digital ecosystems, a robust framework is offered for the development of virtual environments that can prevent or mitigate the effects of neurocognitive disorder in older adults, improving their quality of life and autonomy.

4 Problem Outline

Implementing Lean UX and digital ecosystems for older adults presents several challenges that need to be addressed to ensure successful adoption and usage:

- Digital Literacy: Many older adults may not have the digital skills required to navigate new technologies. This can lead to difficulties in understanding and using digital solutions effectively [35].
- User-Friendly Design: Complex interfaces, lack of intuitive design, or an overload of features can overwhelm older users. It’s crucial to design user-friendly solutions with clear instructions to help seniors overcome initial hurdles[36].
- Accessibility: Physical limitations such as reduced vision, hearing, or motor skills can make it challenging for older adults to interact with digital devices. Solutions must be designed with these considerations in mind [37].
- Personalization: Older adults have diverse needs and preferences. Personalization is key to ensuring that digital solutions cater to individual requirements [38].
- Trust and Privacy: Concerns about data privacy and security can make older adults hesitant to use digital solutions. Building trust through transparent practices is essential [39].
- Affordability: Cost can be a barrier. Ensuring that digital solutions are affordable and offer value for money is important for wider acceptance [40].
- Technical Support: Providing ongoing support and assistance is necessary to help older adults troubleshoot issues and feel confident in using the technology [41].
- Integration with Existing Systems: Digital solutions must be able to integrate seamlessly with existing healthcare and support systems to provide a holistic experience [42].
- Cultural Sensitivity: Solutions must be culturally sensitive and considerate of the diverse backgrounds and values of older adults [43].

- Continuous Feedback and Improvement: Implementing a system for continuous feedback and iterative improvement is crucial to adapt to the changing needs of older adults [44].

Addressing these challenges requires a multidisciplinary approach that combines expertise in technology, design, healthcare, and gerontology. By focusing on these areas, developers and designers can create digital ecosystems that are not only technologically advanced but also deeply attuned to the needs of older adults.

Despite VR devices have the potential to allow non-experienced users the ease of use for Virtual Environments, there are things to consider with elderly users like the cybersickness [24] and physical risks like falls [21] we can find ways to monitor the elderly combining the use of cameras and/or sensors, using non-immersive peripherals or lower immersion experiences like AR environments .

It is essential for the elderly to understand the importance of the feedback they can provide in the use of the ecosystem, as knowing their well-being at any given time will allow for the adjustment of parameters on the fly with the help of the LeanUX agile methodology to adapt the user experience in a simple and direct manner.

This work aims to encourage elderly individuals to engage in consistent physical activity to maintain brain health through the use of virtual environments and lightweight devices that promote user engagement.

Systems Design for occupational therapy [16] has demonstrated positive outcomes in motor rehabilitation using virtual environments and peripherals. This approach strikes a balance between ergonomics, intuitive interfaces, and pleasant environments to enhance elderly user engagement, making therapy sessions enjoyable.

Many research articles related to AR for the elderly focus on practical applications, device functionality, and experiment design based on specific scenarios [5], [17], [27], often neglecting the software design aspect.

Integrating Lean UX and digital ecosystems in the creation of virtual environments for the prevention of neurocognitive disorder in older adults could be approached in the following way:

Lean UX:

- Rapid and Continuous Iteration: Adopt an iterative and agile approach that allows for short development cycles and constant user feedback. This facilitates the quick incorporation of comments to improve the design of virtual environments.
- User-Centered Development: Maintain a constant focus on the needs and preferences of older adults with neurocognitive disorders. Conduct research to understand specific challenges and adapt the design of virtual environments accordingly.
- Early Testing and Validation: Use low-fidelity prototypes to quickly test different ideas and concepts with users. Conduct usability tests frequently to proactively identify and resolve issues.
- Waste Elimination: Prioritize features and functionalities of the virtual environment that add real value for older adults with neurocognitive disorder. Remove complicated elements that may hinder the user experience or increase cognitive load.
- Multidisciplinary Collaboration: Encourage collaboration among designers, developers, healthcare professionals, and older adults with neurocognitive disorder to ensure an inclusive, accessible, and effective virtual environment.
- Flexibility and Adaptability: Maintain flexibility to adjust the design of the virtual environment based on user feedback and evolving needs over time. Be prepared to make changes at any stage of the development process to continually improve the user experience.
- Focus on Simplicity and Clarity: Design a virtual environment that is intuitive and easy to use for older adults with neurocognitive disorder. Prioritize simplicity, consistency, and clarity in the user interface and interactions.

The combination of Lean UX and digital ecosystems provides a robust framework for the development of virtual environments that can prevent or mitigate the effects of neurocognitive disorder in older adults, improving their quality of life and autonomy.

5 Digital Ecosystem Model

Defining a digital ecosystem architecture is essential due to the presence of various technologies interacting through multiple communication protocols, which can cause confusion among the interconnected devices [32]. Different patient scenarios will require the use of multiple distinct environments. This work proposes a digital ecosystem architecture that combines AR, VR, MR, and software design tools such as the Unified Modeling Language (UML) [18] and System Modeling Language (SysML) [19]. It leverages the Human-Computer Interface [20] to adapt User Interfaces (UI) and User Experience (UX).

We are looking for a way to easily adapt to the most possible kinds of mental diseases starting from a generic architecture and following the evolution of the participants' conditions. Our focus lies on Alzheimer's disease [22]. Alzheimer's disease is a progressive neurodegenerative disorder characterized by memory loss, cognitive decline, and personality changes [45]. It is the most common cause of dementia in the elderly, affecting over 24 million people worldwide. The disease poses significant challenges for both patients and caregivers, as it leads to a gradual loss of independence and increased care needs.

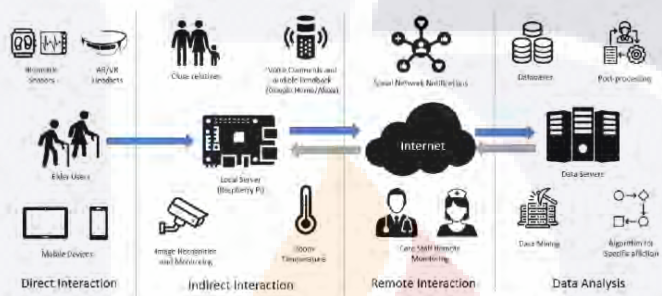

Fig. 2. **Digital Ecosystem Model for the Production of Mixed Reality Environments to Assist Neurocognitive Disorder Patients**

The descriptive model proposal is shown in Figure 2 divided by Interaction Layers involving the different kinds of devices and the relation with various actors. A description of each layer is provided below:

5.1 Direct Interaction

We define Direct Interaction as the engagement between patients and physical devices, including tablets, smartphones, AR/VR headsets, and body-attached wearable devices. These devices serve as conduits for various interactions, including monitoring biometric data such as heart rate and step count. For instance, smartphones can assist in fall detection [21].

However, certain neurocognitive disorders may cause patients to forget that they are wearing a VR headset or other wearable devices. To ensure a comfortable experience for the elderly, it is essential to provide non-intrusive gadgets.

Tablets and smartphones play a crucial role in keeping elderly users informed about their medical condition. They also serve as a medium for receiving calls and notifications from relatives and care staff, maintaining constant interpersonal contact. Additionally, the sensor suite within smartphones can detect accidental falls, movement patterns, and daily activities for further analysis.

AR/VR headsets, when used in virtual environments, offer a diverse range of therapies for physical workouts. By alternating virtual scenarios, we aim to make the experience less monotonous for patients.

5.2 Indirect Interaction

The Indirect Interaction layer encompasses devices that patients can engage with, connected to a local network server for localized data processing. Typically, wearables possess limited processing power, battery life, and storage capacity. Therefore, a more robust device is necessary to aggregate all local information.

Microcomputers, such as the Raspberry Pi [29], have demonstrated powerful processors suitable for collecting data from wearables and other locally networked devices. These include:

- **Cameras**: Used for pattern recognition and live remote monitoring.
- **Smart Assistants**: Devices like Google Home or Alexa [7], which provide direct user feedback and respond to voice commands.
- **Room Ambiance Monitoring**: These systems record data and inform decisions regarding simple actions, such as adjusting air cooling systems and ceiling fans, or notifying users based on changing temperature conditions. Adjustments may also extend to related devices, such as room lights.

Once the basic patient situation is processed, the Raspberry Pi connects to the internet, providing real-time information to care staff and deploying alerts during anomalous situations.

In this interaction layer, patients can trigger straightforward commands via the voice assistant to modify lighting or adjust room temperature. If these parameters are not patient-dependent, nearby relatives can make the necessary room control adjustments.

5.3 Remote Interaction

Remote interaction is facilitated through an internet connection, serving as the primary channel for care staff and distant relatives to stay connected with elderly patients. This connectivity enables:

- Care staff to monitor the patient's condition using audio and video communication.
- Relatives remain informed and engaged through social network notifications.

Such remote interactions allow all parties to be apprised of the patient's physical status and to initiate direct communication using smart assistant speakers or mobile devices.

Additionally, medical staff are alerted to any anomalies detected in the patient's condition. They can promptly respond by making audio calls directly to the patient's mobile phone, tablet, or smart assistant speaker. This immediate feedback loop enables swift action to be taken in response to the patient's needs.

5.4 Data Analysis

To safeguard the data collected from patients, an encrypted connection is essential when storing information on application servers. This is the stage where big data processing occurs, enabling the identification of behavioral anomalies by analyzing variations in movement and voice patterns. Such analysis facilitates the early detection of diseases commonly associated with aging.

A robust server infrastructure is necessary to accommodate an increasing number of users from diverse locations, such as hospitals, nursing homes, or private residences. This infrastructure will categorize users based on their specific diseases and conditions, enhancing the ability to identify anomalous patterns and early symptoms among patients with similar ailments.

The data analysis process involves several steps [46]:

- Data Collection: Using wearables and smart devices, continuous data collection on biometric signals (e.g., heart rate, step count), environmental conditions (e.g., room temperature, lighting), and interaction patterns (e.g., usage of AR/VR applications) will be conducted.
- Data Preprocessing: This step involves cleaning and transforming raw data to ensure quality and consistency. Noise reduction techniques will be applied, and missing values will be addressed through imputation methods.

- Feature Extraction: Key features relevant to neurocognitive health will be extracted from the data. This includes metrics like activity levels, sleep patterns, and cognitive performance indicators gathered from VR interactions.
- Anomaly Detection: Machine learning algorithms, such as anomaly detection models, will be employed to identify deviations from normal behavior. This facilitates the early identification of potential health problems.
- Pattern Recognition: Advanced pattern recognition techniques will analyze trends and patterns in the data, identifying common factors associated with cognitive decline or improvement.
- Statistical Analysis: Statistical tests will be conducted to validate the significance of the findings. Comparative analyses, such as pre- and post-intervention assessments, will help determine the efficacy of the interventions.
- Visualization: Data visualization tools will be used to present the analysis results in an understandable format for healthcare professionals and caregivers. Interactive dashboards will allow for real-time monitoring and decision-making.
- Feedback Loop: A continuous feedback loop will be established where insights from the data analysis inform iterative improvements in the digital ecosystem. User feedback will be incorporated to refine and enhance the system.
- Evaluation Instruments: Instruments, semi-structured interviews, and cognitive assessment tools will be utilized to evaluate user engagement, satisfaction, and cognitive performance.

To comprehensively understand the state and progression of Alzheimer's patients, it is crucial to utilize well-established assessment tools that evaluate various cognitive, functional, and behavioral domains [47]. These instruments provide valuable insights into the severity and impact of the disease, allowing for effective monitoring and tailored interventions. Below are four key tools commonly used for this purpose:

- Mini-Mental State Examination (MMSE): The Mini-Mental State Examination (MMSE) is a brief test that evaluates various cognitive functions, including memory, attention, language, and visuospatial skills. It is commonly used to detect cognitive impairment and follow the progression of neurocognitive disorders such as Alzheimer's disease. The test includes simple questions and tasks that help assess temporal and spatial orientation, word registration and recall, calculation, and language.
- Neuropsychiatric Inventory (NPI): The Neuropsychiatric Inventory (NPI) measures neuropsychiatric symptoms in patients with dementia, including changes in behavior and mood. This inventory covers areas such as agitation, depression, anxiety, apathy, and hallucinations. It is useful for assessing the frequency and severity of these symptoms, as well as the impact they have on the caregiver.
- Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE): The IQCODE (Informant Questionnaire on Cognitive Decline in the Elderly) is a questionnaire that allows caregivers to evaluate the cognitive decline of patients over time. It is based on the caregiver's observation of changes in the patient's cognitive abilities compared to their previous level of functioning. It is useful for detecting cognitive decline without requiring the patient to directly perform a test.
- Relevant Outcomes Scale for Alzheimer's Disease (ROSA): The Relevant Outcomes Scale for Alzheimer's Disease (ROSA) is a brief, multidimensional instrument that evaluates cognitive, functional, and behavioral manifestations in patients with Alzheimer's disease. ROSA is used for periodic evaluations and monitoring the patient's progress over time. Like Lean UX, ROSA follows an iterative approach, providing constant feedback that allows for continuous adjustments to interventions, thereby improving the patient's quality of life.

By integrating these instruments into the data analysis, we can obtain a comprehensive understanding of the state and progress of patients with Alzheimer's disease.

For the measurement of users interaction with applications, User Experience (UX) evaluation questionnaires are quantitative tools used to collect data on user satisfaction, ease of use, and design preferences [48]. These questionnaires allow researchers to get an overall picture of how users perceive a product or system, helping to identify areas for improvement and validate whether the design meets the users' expectations and needs. They are a quick and cost-effective way to detect patterns and gain valuable insights into the user experience. Some known tools for UX evaluation are:

- AttrakDiff: Measures user perception in terms of attractiveness and usability, covering both pragmatic and hedonic aspects [49].
- UEQ (User Experience Questionnaire): Evaluates user experience across various dimensions, including usability, aesthetics, and emotion [50].
- meCUE (Modular Questionnaire for Measuring User Experience): A modular questionnaire that includes separate modules to assess instrumental and non-instrumental product perceptions, user emotions, consequences of use, and general attractiveness judgment [51].

Utilizing these UX evaluation instruments can provide valuable insights into user satisfaction, usability, and emotional responses.

6 Case Study

The primary audience for our study comprises elderly patients residing in public nursing homes under the auspices of the "Integral Development for the Family" institute (DIF) in Aguascalientes, Mexico. This study presents a theoretical case, designed to explore and propose a digital ecosystem model tailored to the needs of elderly patients. Conducting interviews with the care staff is crucial to gain insights into the elders' exercise routines, recreational activities, sleep patterns, main interests, and other aging-related ailments that are not directly linked to neurocognitive disorders [52] It's also important to understand their general preferences, as well as their willingness to adopt technological gadgets and wearable devices.

Figure 3 presents the mixed reality infrastructure scenario, offering a detailed view of the information management process. It illustrates the various methods through which care staff can receive updates and monitor the patients effectively.

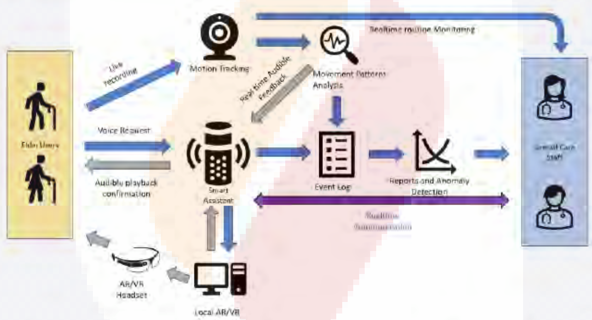

Fig. 3. Digital Ecosystem for the Assistant of Patient with neurocognitive disorders from DIF Institute.

We aim to adapt virtual environments using therapeutic techniques to track the progress of patients participating in the project. In cases where patients have physical or mental limitations, device adaptations will be necessary. However, the overarching goal is to have devices prepared for a wide range of scenarios.

6.1 Direct Interaction

The Xiaomi Mi Band (Figure 4) is a particularly valuable wearable device for monitoring daily step count and heart rate in patients. It offers a cost-effective solution with prices ranging from 15 to 40 USD, delivering satisfactory quality readings. The device's battery life is impressive, lasting between one to three weeks, varying by the generation of the wearable and the active features.

Each Mi Band requires a smartphone to store the data collected from patients through a Bluetooth connection. The device can gather data for one to two weeks before the battery is fully drained.

The data retrieved provides insights into the patient's daily activity levels, enabling adjustments to their exercise routines as needed. Additionally, the Mi Band includes a straightforward heart rate monitor, which can facilitate more frequent heart rate checks by care staff without the need for in-person visits.

Fig. 4. Elder user wearing the Xiaomi Mi Band 3, a great wearable with simple and compact design.

In the initial stage of the project, we have chosen the Oculus Rift (Figure 5) as the VR headset to serve as the interface between patients and the virtual environment. As we progress to subsequent stages, our objective is to utilize the Cardboard headset paired with a smartphone. The Cardboard headset offers a cost-effective VR solution and is easily replicable, making it convenient for maintenance and spare parts replacement.

Fig. 5. Elder user with the first retail version of Oculus Rift, that will be used in the first stage of the project.

6.2 Indirect Interaction

Amazon Alexa and Google Home (Figure 6) are voice-controlled Smart Assistants that use cloud voice processing algorithms [7] to respond quickly to natural language commands. This device can provide the patient with weather, time, or therapy schedule information; also, this device can offer the patients a virtual interaction with the Smart assistant that includes asking for any information, hearing jokes, playing voice games and solving riddles to make their routine more fun.

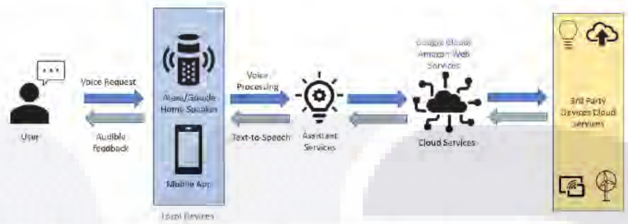

Fig. 6. General Smart Assistant Architecture view, showing how Alexa and Google Home work with their respective online services.

6.3 Remote Interaction

APIs from popular social networks such as Facebook, Instagram, and X (formerly known as Twitter), as well as instant messaging applications like Telegram, can be utilized to keep relatives and friends informed about the patient's condition. Additionally, medical staff will receive special notifications containing biometric data, rather than social network interactions, to monitor the patient's status in a more timely manner.

6.4 Data Analysis

The initial step for data analysis involves creating a knowledge base with all the data gathered from devices near the patient. The data obtained from the patients' routines will be used for data mining to identify patterns using statistical and heuristic methods. In a later stage, this will enable the detection of anomalies in movement and early signs of ailments, providing medical staff with the opportunity to treat conditions promptly.

Given the need for a comprehensive evaluation of the user experience (UX) tailored to older adults, the User Experience Questionnaire (UEQ) was selected as the primary instrument for measuring UX. The UEQ was chosen due to its versatility, ability to measure a wide range of UX dimensions, and its efficiency in gathering user feedback. Its broad applicability and ease of interpretation make it a valuable tool for iterating and refining digital ecosystems to better suit the needs and preferences of elderly users.

The iterative use of ROSA allows for continuous and personalized adjustments, similar to how Lean UX adapts user experiences based on feedback and collected data, in comparison we can find:

- Continuous Iteration and Evaluation: Both methods are based on iterative cycles and periodic evaluations to continuously improve.
- User/Patient Focus: Lean UX and ROSA prioritize the needs and experiences of the user/patient.
- Multidisciplinary Collaboration: Both methods encourage collaboration across different disciplines to gain a comprehensive view.
- Validation and Adjustments: Lean UX and ROSA use feedback and collected data to make adjustments and improvements.

This combined approach ensures that both the medical and user experience aspects are thoroughly assessed, enhancing the overall effectiveness and personalization of interventions.

7 Conclusion

Mixed reality enables elder users to interact with virtual environments and enhance their daily social interactions from home, breaking boredom and making their daily therapy sessions more manageable. The AR component can assist elders in perceiving their home environment better when they are alone.

Integrating Lean UX principles into the design of digital ecosystems can significantly improve the rehabilitation and daily life of older patients in nursing homes by breaking their routine. Virtual environments with AR/VR headsets are excellent tools to engage users with the ecosystem. Introducing the elder population to the technologies they have missed for many years can improve their daily activities at a low cost while preserving their autonomy as much as possible.

To connect devices and interact with involved actors, it is necessary to model the digital ecosystem. Each device's role is crucial to maintaining a steady connection between layers. Understanding each user's specific case will help address the needs of different neurocognitive disorders in the elderly.

Integrating Lean UX into digital ecosystems with a VR interface for older adults offers several benefits. Lean UX focuses on creating intuitive and user-friendly products, crucial for older adults who may not be as familiar with digital interfaces. The iterative nature of Lean UX, combined with the use of the User Experience Questionnaire (UEQ), allows for quick prototyping and testing, ensuring that VR interfaces can be adapted based on real feedback from older users. This approach helps reduce the cognitive load on older adults by prioritizing simplicity and clarity, making digital ecosystems more accessible to them.

The principles of Lean UX, reflected in the continuous assessment and personalization provided by the ROSA method, ensure that the design accommodates various limitations that may come with aging, such as reduced vision or motor skills. This alignment between Lean UX and ROSA methodologies enhances the comfort and satisfaction of older adults, leading to products that truly meet their needs and preferences.

A critical area of research will be the analysis of variables that influence the successful implementation of Lean UX in virtual environments tailored for older adults. This involves:

- User Engagement: Measuring the engagement and interaction levels of older adults with virtual environments using ROSA and UEQ.
- Adaptability: Assessing how well older adults adapt to changes in the virtual environment resulting from iterative design processes.
- Cognitive Load: Evaluating the cognitive demands placed on older adults by the virtual environment to ensure that Lean UX principles effectively minimize complexity.
- Accessibility Metrics: Establishing quantitative measures for accessibility to ensure that virtual environments are usable by older adults with varying degrees of physical and cognitive abilities.
- User Satisfaction: Utilizing ROSA, UEQ, AttrakDiff, and meCUE to gauge the satisfaction of older adults with the virtual environment, providing insights into areas for improvement.
- Learning Curves: Analyzing the time and effort required for older adults to become proficient in using the virtual environment, aiming to streamline the learning process.
- Technology Acceptance: Understanding the factors that affect the acceptance of new technologies by older adults to enhance the adoption rates of virtual environments.
- Personalization Effectiveness: Measuring the impact of personalized features on user experience and how they contribute to the overall usability of the virtual environment.

By focusing on these variables, we can refine Lean UX methodologies to create virtual environments that are not only technologically advanced but also deeply attuned to the needs and preferences of older adults. This ensures that the solutions developed are not only functional but also enjoyable and empowering for this demographic. The goal is to foster an inclusive digital ecosystem that supports the well-being and independence of older adults through thoughtful design and continuous innovation.

Future Work: As part of our ongoing efforts, we plan to conduct fieldwork to validate and refine our digital ecosystem model. This future work will involve the implementation and testing of the selected instruments (UEQ for Lean UX and ROSA for Alzheimer's) in real-world settings, collaborating with public nursing homes and other care facilities. Gathering real-world data and feedback from elderly users and care staff will further enhance the effectiveness and usability of digital ecosystems tailored for older adults.

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4.2 Conclusiones del Artículo

El estudio concluye que la convergencia entre un diseño ecosistémico modular y la adopción de Lean UX facilita la creación de entornos mixtos más intuitivos, accesibles y adaptables para población geriátrica, permitiendo además la instrumentación sistemática para monitoreo y detección temprana de anomalías mediante análisis de datos. Como resultado, se plantea que la combinación de evaluaciones clínicas (p. ej. ROSA) y métricas UX (UEQ, AttrakDiff) genera un ciclo de retroalimentación efectivo para ajustar intervenciones; el trabajo recomienda avanzar hacia validaciones de campo y la apertura de artefactos reproducibles para confirmar viabilidad, impacto y escalabilidad en contextos reales.

Capítulo 5. Conclusiones

Los resultados obtenidos a lo largo de este trabajo permiten afirmar que sí es posible desarrollar una metodología eficiente para crear ecosistemas de realidad mixta orientados a mitigar y dar soporte a los trastornos neurocognitivos en adultos mayores. La integración de arquitecturas digitales por capas, dispositivos accesibles de bajo costo y metodologías ágiles como Lean UX demuestra que se pueden diseñar entornos virtuales adaptativos, reproducibles y centrados en el usuario. Además, la incorporación de instrumentos clínicos y métricas de experiencia de usuario asegura que la propuesta no solo sea técnicamente viable, sino también clínicamente relevante y aceptada por pacientes y personal de cuidado. En conjunto, la evidencia teórica, los artículos publicados y la investigación de campo validan la hipótesis de que un ecosistema digital de realidad mixta puede convertirse en una herramienta efectiva para promover la independencia, mejorar la calidad de vida y apoyar la rehabilitación cognitiva de la población geriátrica.

- **Contexto y Protocolo**: Se realizaron entrevistas con personal de asistencia y con pacientes para identificar necesidades, hábitos y apertura hacia el uso de dispositivos tecnológicos. El protocolo tradicional de seguimiento del DIF se complementó con una capa de escenarios de realidad mixta, incorporada progresivamente en las rutinas de rehabilitación. Este enfoque busca que la tecnología se integre de forma natural en los procesos clínicos y sociales.

- **Encuesta a terapistas**: Siguiendo el ciclo Lean UX, se diseñó un instrumento de encuesta con 40 preguntas (Anexo A), aplicado en instituciones públicas y privadas. Tras tres iteraciones de diseño y una de aplicación, se obtuvieron resultados preliminares que permiten evaluar la pertinencia del instrumento y decidir si se requieren nuevas iteraciones. El objetivo es medir la percepción de los profesionales sobre la utilidad y usabilidad de los entornos de realidad mixta en terapias geriátricas.

- **Experiencia de usuario**: La medición de la experiencia de usuario resulta esencial para evaluar la adaptación de los adultos mayores a tecnologías emergentes. Se emplean instrumentos reconocidos en la literatura (UEQ, SUS, UMUX, CSUQ, AttrakDiff) para conocer percepción, facilidad de uso y esfuerzo requerido en actividades de terapia. Estos resultados permiten ajustar la interfaz y los escenarios virtuales, garantizando que la tecnología sea inclusiva y efectiva.

- **Integración tecnológica y metodológica:** La tesis demuestra que es posible articular dispositivos de bajo costo, arquitecturas digitales por capas y metodologías ágiles (Lean UX) para diseñar entornos de realidad mixta orientados a la asistencia geriátrica.
- **Aportes clínico analíticos:** La combinación de instrumentos clínicos (MMSE, ROSA, IQCODE) con métricas de experiencia de usuario (UEQ, AttrakDiff, meCUE) ofrece un marco robusto para evaluar simultáneamente impacto cognitivo y usabilidad, asegurando que las soluciones sean efectivas y aceptadas por los usuarios.
- Validación contextual: El estudio de campo en instituciones del DIF y la encuesta a terapistas evidencian la viabilidad de integrar estas tecnologías en protocolos reales de rehabilitación, aunque aún se requiere ampliar la muestra y realizar pruebas longitudinales.
- Escenarios hipotéticos: Los casos descritos muestran cómo las capas de interacción (directa, indirecta, remota y análisis de datos) pueden aplicarse en situaciones concretas de pacientes con Alzheimer, anticipando beneficios y retos en la implementación práctica.
- Impacto social: El modelo propuesto contribuye a preservar la independencia y dignidad de los adultos mayores, ofreciendo herramientas tecnológicas que complementan la labor del personal de cuidado y reducen la carga asistencial.
- Limitaciones: La investigación se centra en prototipos y escenarios hipotéticos; aún falta validar empíricamente los resultados con pruebas clínicas extensas y multicéntricas.

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ANEXO A.
ENCUESTA A TERAPISTAS V 1.3

CENTRO DE CIENCIAS BÁSICAS DE LA UNIVERSIDAD AUTÓNOMA DE AGUASCALIENTES
DEPARTAMENTO DE SISTEMAS DE INFORMACIÓN E INGENIERÍA DE SOFTWARE
DOCTORADO EN CIENCIAS APLICADAS Y TECNOLOGÍAS
Equipo de trabajo: MCC Erwin Brian Montes Chaparro, Dr. Jaime Muñoz Arteaga, Dr. Ángel Eduardo Muñoz Zavala

Las Tecnologías de la Información y Comunicación (TIC) son herramientas a través de las cuales se pueden diseñar y desarrollar contenidos de cursos en línea, que han resultado clave para ciertas áreas en forma de teletrabajo dado la pandemia del COVID-19. Es por esta razón es que la Universidad Autónoma de Aguascalientes propone la presente encuesta a manera de sondeo para conocer el estado de trabajo con modalidad a distancia de pacientes por parte de Centros de Rehabilitación públicos o privados. El objetivo es vislumbrar las habilidades y las necesidades de uso de los profesionales de Centros de Rehabilitación, así como educadores, terapeutas, psicólogos, médicos y administradores al aplicar las nuevas TIC en su labor, así como identificar algunas de sus experiencias frente a los nuevos retos que ha presentado la sociedad durante la pandemia de COVID-19.

I. Preguntas sobre trabajo a distancia.

III. ¿Había trabajado usted bajo la modalidad a distancia previamente a la pandemia de COVID-19?
- Sí
- No

IV. ¿Se ha visto usted en la necesidad de trabajar a distancia durante la crisis del COVID-19?
- Sí
- No

V. ¿Se encuentra actualmente trabajando en modalidad a distancia?
- Sí
- No

II. Preguntas sobre trabajo realizado a distancia durante la crisis de COVID-19

1. ¿En qué lugar realiza usted del trabajo a distancia?
   a. Domicilio
   b. Centro de Rehabilitación
   c. Oficina
   d. Otros
2. ¿Cómo calificaría usted el equipo tecnológico con el que cuenta para trabajar a distancia?
   a. Destacado
   b. Suficiente
   c. Mínimo necesario
   d. Desactualizado
   e. Obsoleto

3. ¿Alguien más en casa usa el equipo que usted requiere para trabajar desde casa?
    a. Sí
    b. No
4. ¿Tiene usted lugar específico para trabajar desde casa?
    a. Sí
    b. No
5. ¿Tiene usted un horario establecido por la institución para trabajar a distancia?
    a. Sí
    b. No, yo administro mi tiempo.
6. Marque el grado de cada uno de los retos a los que se enfrenta a trabajar a distancia debido a la pandemia de COVID-19. La opción **Totalmente de acuerdo** representaría un reto mayor y la opción de **Totalmente en desacuerdo** representaría un reto meno o nulo.

(Totalmente De acuerdo, De acuerdo, Indiferente, En Desacuerdo, Totalmente en Desacuerdo)	TDA	DA	I	ED	TED
a. Aislamiento Social					
b. Cuidado de niños, adultos mayores o personas con padecimientos que requieren asistencia.					
c. Demasiadas distracciones en el hogar.					
d. Fallos en el servicio de Internet.					
e. Capacidad del servicio de Internet Insuficiente.					
f. No tener acceso en casa a herramientas y archivos necesarios para realizar el trabajo.					
g. Dificultades de comunicación con colegas de trabajo durante la jornada laboral desde casa.					
h. Tener un horario irregular.					
i. Impacto en mi rutina a causa de la pandemia de COVID-19.					

7. ¿Considera usted que hay un incremento en salidas de aprendizaje-logros alcanzados con un trabajo de forma remota o a distancia?
    a. SIEMPRE
    b. FRECUENTEMENTE
    c. REGULARMENTE
    d. OCASIONALMENTE
    e. NUNCA
8. ¿Cómo lleva a cabo sus sesiones a distancia? (Marque todas las necesarias)
    a. Videollamada individual (Zoom, Google Meet, Microsoft Teams, Whatsapp, Messenger, Telegram)
    b. Videollamada Grupal (Zoom, Google Meet, Microsoft Teams, Whatsapp, Telegram, Messenger)
    c. Envío de sesiones pregrabadas (Whastapp, Telegram, Messenger)
        i. ¿Dónde sube sus sesiones pregrabadas?

1) Almacenamiento en Nube (Google Drive, Dropbox, OneDrive, Mega, etc.)
2) Youtube
3) Portal de plataforma de cursos en línea (Aulas Virtuales).
4) ¿De qué duración son sus sesiones pregrabadas? (minutos)
5) ¿Edita sus sesiones pregrabadas? (Sí, No)
    a. ¿Cuánto tiempo invierte en edición por sesión pregrabada? (campo libre)

III. Preguntas sobre autoevaluación al trabajo realizado a distancia durante la crisis de COVID-19 utilizando las tecnologías de la información.

1. ¿Considera que tiene usted las habilidades para proporcionar un servicio de rehabilitación-enseñanza de forma remota?
    a. Sí.
    b. No.
    c. En caso de respuesta negativa, ¿Qué considera que le hace falta? Especifique:
2. ¿Qué método considera que sería más viable para proporcionar el servicio de forma remota?
    a. Videollamada individual.
    b. Videollamada grupal.
    c. Sesiones subidas a Youtube.
    d. Sesiones subidas a Almacenamiento en la nube (Google Drive, Dropbox, Onedrive, Mega, etc.).
    e. Sesiones subidas a plataformas de curso en línea (Moodle).
3. ¿Considera usted que el centro donde trabaja tiene una estrategia de trabajo a distancia para la entrega de servicios de Rehabilitación?
    a. Sí.
    b. No.
4. De la siguiente lista de plataformas tecnológicas, indique la frecuencia en que las utiliza para comunicarse en su entorno personal.

	Siempre	Frecuentemente	Regularmente	Ocasionalmente	Nunca
a. Whatsapp					
b. Telegram					
c. Correo Electrónico					
d. Google Meet					
e. Zoom					
f. Chat Messenger					
g. Facebook					
h. Plataformas educativas					

5. ¿Entre qué rango de porcentajes considera usted que utiliza las Tecnologías de la información (Computadoras, Laptops, Smartphone, Tablet, Cámara de video) en su tiempo libre?
    a. Entre 80 y 100%
    b. Entre 60 y 80%
    c. Entre 40 y 60%
    d. Entre 20 y 40%
    e. Entre 0 y 20%

6. ¿Entre qué rango de porcentajes considera usted que utiliza las Tecnologías de la información (Computadoras, Laptops, Smartphone, Tablet, Cámara de video) durante las sesiones de terapia?
    f. Entre 80 y 100%
    g. Entre 60 y 80%
    h. Entre 40 y 60%
    i. Entre 20 y 40%
    j. Entre 0 y 20%
7. Marque el grado de afinidad para las siguientes afirmaciones con respecto al uso de Tecnologías de la información para sesiones de terapia.

(Totalmente De acuerdo, De acuerdo, Indiferente, En Desacuerdo, Totalmente en Desacuerdo)	TDA	DA	I	ED	TED
a. Es un factor determinante en la evolución de los pacientes.					
b. Es una moda, dada la era tecnológica en que vivimos.					
c. Es una herramienta de apoyo alternativa para la rehabilitación sin necesidad de asistir presencialmente.					
d. Es una herramienta totalmente innecesaria.					
e. Es una alternativa que no necesariamente influye en el desarrollo de la rehabilitación					
f. Es un recurso importante para mejorar las habilidades psicomotoras en los pacientes.					
g. Promueve el interés y la motivación en los pacientes.					
h. Facilita el trabajo grupal, la colaboración y la inclusión con pacientes y sus familiares.					
i. Ninguno de los anteriores.					

8. Clasifique los siguientes puntos según su nivel de ventajas y desventajas del uso de las Tecnologías de la información en el centro de rehabilitación (Ventaja Total, Ventaja Parcial, Indistinto, Desventaja Parcial, Desventaja Total).

(Ventaja Total, Ventaja Pacial, Indistinto, Desventaja Parcial, Desventaja Total)	VT	VP	I	DP	DT
a. Disponibilidad de equipos y materiales.					
b. Capacitación.					
c. Personal especializado en el uso de tecnologías.					
d. Comunicación.					
e. Optimización de tiempo.					
f. Distracciones.					
g. Información.					
h. Apoyos visuales.					
i. Motivación.					

IV. Preguntas sobre educación de las tecnologías de la Información.

1. ¿Considera usted necesario que se oferten cursos especiales de formación en el uso de las Tecnologías de la información para los Terapeutas/Docentes?
   a. Sí.
   b. No.

2. Especifique cuáles de las siguientes Tecnologías de la Información que se enlistan estaría de acuerdo en conocer y aprender. (Totalmente de acuerdo, De acuerdo, Ni en acuerdo ni en desacuerdo, en desacuerdo, Totalmente en desacuerdo).

(Totalmente De acuerdo, De acuerdo, Indiferente, En Desacuerdo, Totalmente en Desacuerdo)	TDA	DA	I	ED	TED
a. Plataformas de ambientes colaborativos.					
b. Uso de plataformas educativas.					
c. Uso de simuladores.					
d. Aplicaciones móviles educativas.					
e. Juegos Educativos.					
f. Uso de software específico (.					
g. Uso de software de edición multimedia (Audio, Video, Imagen).					
h. Uso de software ofimático (Excel, Word, Powerpoint, etc.).					
i. Elementos básicos de la computadora.					
j. Uso avanzado del teléfono móvil (correo, calendario, recordatorios, notificaciones, envío de archivos, navegación web, etc.).					
k. Uso básico de la computadora.					
l. Seguridad de datos personales.					
m. Uso avanzado de aplicaciones de comunicación (Whatsapp, Telegram, Microsoft Teams, Google Meet, Facebook Messenger).					
n. Uso y manejo de Redes sociales.					
o. Plataformas de gestión de equipos.					
p. Realidad Virtual / Realidad Aumentada.					

3. Especifique con cuáles de las siguientes afirmaciones estaría de acuerdo para una colaboración con asesores en Tecnologías de la Información de la Universidad Autónoma de Aguascalientes para apoyar la actividad terapéutica.

(Totalmente De acuerdo, De acuerdo, Indiferente, En Desacuerdo, Totalmente en Desacuerdo)	TDA	DA	I	ED	TED
a. Dispositivos móviles (Smartphones, Tablets).					
b. Computadoras personales Windows (PC de escritorio, Laptop).					
c. Computadoras personales Mac (iMac, Macbook, Mac Mini, iPad).					
d. Microsoft Word.					
e. Microsoft Excel.					
f. Microsoft PowerPoint.					
g. Microsoft Teams.					
h. Microsoft Publisher.					
i. Microsoft One Note					
j. Almacenamiento en la Nube (Google Drive, Microsoft Onedrive, Dropbox, Mega, etc.).					
k. Plataformas de aula virtual (Moodle, Google Classroom).					
l. Plataformas de reuniones a distancia (Google Meet, Microsoft Teams, Zoom, Skype, etc.).					
m. Programas de edición de audio (Adobe Audition, Sony Soundforge, Audacity, etc.).					
n. Programas de edición de imagen (Photoshop, Corel, Inkscape, GIMP, etc.).					
o. Programas de edición de video (Adobe Premiere, Sony Vegas, Pinnacle Studio, Filmora, DaVinci, Final Cut, etc.).					
p. Realidad Virtual.					
q. Realidad Aumentada					
r. Realidad Mixta.					
s. Videojuegos educativos.					
t. Videojuegos orientados a terapia física.					
u. Videojuegos orientados a Terapia psicológica					
v. Impresión 3D.					
w. Prótesis impresas en 3D.					

V. Preguntas sobre la interacción con pacientes y familiares.

1. ¿Cree usted que los familiares están motivados para apoyar la rehabilitación de los pacientes?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
2. ¿Se cuenta con horarios disponibles para que los terapeutas atiendan a los familiares de los pacientes?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
3. ¿Cree usted que los familiares dedican tiempo para apoyar a la rehabilitación de los pacientes?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
4. ¿En el Centro de rehabilitación se brinda información a los familiares sobre los recursos o herramientas disponibles para apoyar la rehabilitación de los pacientes?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
5. ¿Cree usted que los familiares cuentan con experiencia en el uso de las Tecnologías de la Información apoyando la rehabilitación de los pacientes en casa?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
6. ¿El personal terapéutico informa a los familiares lo que los pacientes están aprendiendo y/o desarrollando?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
7. ¿Cree que los pacientes con condición neuromotora mostrarán disposición en la rehabilitación a distancia?
    a. Siempre
    b. Frecuentemente
    c. Regularmente
    d. Ocasionalmente
    e. Nunca
8. ¿Cree que la tecnología disponible en el hogar de los pacientes con condición neuromotora será suficiente?
    a. Siempre

b. Frecuentemente
c. Regularmente
d. Ocasionalmente
e. Nunca

9. ¿Las herramientas y materiales disponibles en el hogar de los pacientes con condición neuromotora suelen ser suficientes?
   a. Siempre
   b. Frecuentemente
   c. Regularmente
   d. Ocasionalmente
   e. Nunca
10. ¿Considera usted que en los pacientes con condición neuromotora ha habido un estancamiento o incluso un retroceso debido a la modalidad a distancia?
   a. Siempre
   b. Frecuentemente
   c. Regularmente
   d. Ocasionalmente
   e. Nunca
11. ¿Utiliza usted alguna aplicación (software), plataforma (espacio virtual) o página web como apoyo en la rehabilitación a distancia de los pacientes con condición neuromotora?
   a. Siempre
   b. Frecuentemente
   c. Regularmente
   d. Ocasionalmente
   e. Nunca
12. Independientemente de su utilización, ¿considera que las aplicaciones, plataformas o páginas web pueden ser adecuadas para los pacientes con condición neuromotora?
   a. Siempre
   b. Frecuentemente
   c. Regularmente
   d. Ocasionalmente
   e. Nunca
13. ¿Estaría usted de acuerdo en probar nuevas aplicaciones, plataformas o páginas web que sean desarrolladas pensando en pacientes con necesidades especiales?
   a. Siempre
   b. Frecuentemente
   c. Regularmente
   d. Ocasionalmente
   e. Nunca