Applying human-centered system design to the development of a tool for service innovation

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Abstract

According to the 2019 Revision of World Population Prospects, by 2050, people aged 65 and above will account for 25% of the population in Europe and Northern America. The number of people aged 80 or above is estimated to triple to 426 million by this time. Global aging has widespread implications for our society. With the emergence of technological and biomedical advances, people now hold higher expectations for their physical and mental health throughout their longer lifespans. People expect to live not only longer, but also better, calling for improved quality of living and working environments to support later adulthood (Coughlin, 2017). This new longevity presents complex opportunities for participatory and systems-oriented design thinking and processes (Nightingale & Rhodes, 2015; Lee, Zhu et al., 2020). It has become more important than ever for multidisciplinary teams of designers and engineers to contend with older age, including considering the role of immersive empathy and service tools in educating innovators on the importance of global aging and moving them towards collective action in making more inclusive decisions in their work. The purpose of our study is to rebuild and refine a current age empathy tool, AGNES (Age Gain Now Empathy System), through the application of a Human-Centered System Design (HCSD) framework (Lee et al., 2021; Lee, Rudnik et al., 2020).

This age empathy suit was originally developed by a team of social scientists, designers, engineers, and an occupational therapist to simulate the physical constraints associated with certain parts of the body and their possible functions in older age (Lavallière et al., 2017). For example, AGNES empathy suit can mimic common changes we may experience in an aging body such as changes to balance, stride length, joint mobility (e.g., wrist, elbow, shoulder, and cervical spine), muscle loss, tactile sensation, and vision and hearing loss. In this study, we propose a new age suit with modular components and a focus on service design to more accurately simulate various physical and cognitive functions associated with specific body conditions. HCSD consists of design thinking paired with systems engineering approaches; a focus on participatory design will be used to create a new age empathy suit. This case study will explore and prototype a more immersive simulation experience of older age for people and with people. This study intends to not only redesign a new AGNES suit, but also to examine the role of the HCSD framework and participatory design process in contributing to the development of empathy and service tools in pursuit of an age-inclusive society.

Keywords

Human-Centered System Design; AGNES; Service Design; System Design; Design Methodology

Introduction

A world of longevity is already here. By 2050, the U.S. Census Bureau has predicted that people aged 65 and older will outnumber people 18 and younger. Human beings' lifespans have become longer (Golden, 2022), which comes with huge potential business opportunities across industries (e.g., smart home, fintech) to reshape our society. We need to learn how to live meaningfully, not just survive, in the era of a longevity economy (Coughlin, 2017) and to re-frame and solve the complicated, systemic social-technological problems associated with population aging. Therefore, we introduce the AGNES (Age Gain Now Empathy System) age empathy suit, a learning tool to simulate common, chronic physical conditions that are associated with older age, build empathy, and provide education for younger generations, multidisciplinary teams and others to better understand the physical lived experiences of older adults.

AGNES was designed and developed by human factors engineers, health scientists, physical therapists, mechanical and electrical engineers, and product designers at the Massachusetts Institute of Technology's (MIT) AgeLab. In the following study, we explored service-related components embedded in the AGNES suit's design experience by considering four actions: 1. prepare, 2. transport, 3. engage, and 4. maintain, across the journey of service recipients (participants who wear the empathy suit) and service providers (MIT AgeLab

researchers who guide participants in their use of the AGNES suit). This study was driven by the desire to re-design and update the age empathy suit experience through a service innovation lens. A modified service blueprint approach based on the concept of Human-Centered System Design (HCSD) can be used to frame this study's approach to iterating on the immersive empathy-learning experience (Lee, 2022).

Literature Review

To build a more immersive empathy simulation and service-driven experience with AGNES, the suit's development history and existing features and the literature surrounding HCSD is reviewed.

The AGNES (Age Gain Now Empathy System) Suit

Empathy training originated from experiential learning theory (Kolb, 1984), which indicates that people can learn from transformational experiences. AGNES, as a suit, was designed for age and ability empathy training. The suit was designed to simulate physical limitations commonly experienced by older adults including impaired vision and hearing, increased muscle fatigue, postural imbalance, reduced joint range of motion, and limited dexterity (Lavallière et al., 2017). The suit becomes an impactful educational tool through engaging its users in an immediate total body experience of sensory loss through visual, auditory, olfactory, and tactile systems (Lavallière et al., 2017).

In addition to the AGNES suit, there are similar types of simulation tools that have been used similarly in educational contexts (e.g., pregnancy, impaired driving) (Empathy Resources LLC, 2019). Existing academic studies with AGNES have focused on measuring the effectiveness of the suit's specific simulation components: a rock-climbing harness, coverall suit, knee and elbow braces, resistance band straps for arms and legs, helmet, neck brace, yellow glasses, earplugs, shoes modified with foam, gloves and wrist braces (see Figure 1) (Gennis & Godfrey, 2011). In contrast to the functional focus of this work, we explored the design of the AGNES age empathy suit through the lens of HCSD to better understand the whole experience design of the suit from the perspective of its service providers and service recipients.

Our motivation to redesign the AGNES suit lies in considering the suit-wearing experience not only from the suit's participants or users' angles, such as its level of comfort or 'simulative realness', but also thinking through the lens of the suit's service providers, such as the experiences of lab scientists who guide participants through the journey of wearing an AGNES suit. In addition, we applied the service design process to help us gain a more comprehensive and in-depth view of all the service touchpoints across the user journey to better inform us of the potential parts (e.g., different product features or instruction design) of the AGNES suit that we can prototype and refine.

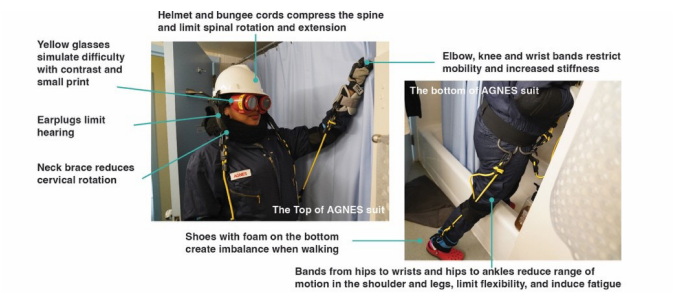

Figure 1. Explanation of an AGNES empathy suit (adapted from Lavallière et al., 2017)

Human-Centered Design, System Thinking and System Engineering

Human-centered design (HCD) is a creative problem-solving process for understanding target users' needs, brainstorming ideas, making physical and digital prototypes, testing selected concepts, and refining final design solutions to address target users' pain points (IDEO, 2022). Tim Brown, Executive Chair of IDEO (an international design consultancy) has said that HCD is a design-thinking approach to innovation (Brown & Katz, 2019). System theory, including system thinking and system engineering (SE), was established after World War II to solve complicated systemic engineering challenges that emerged from military, aeronautics and astronautics industries, and other relevant engineering fields (Leveson & Thomas, 2018). Crawley et al. (2016) has said that system thinking is not a call to think systemically, but rather to view each thing as a system to analyze. It also helps us understand and differentiate between systemic design, system design, and system thinking. De Weck, for example, has encouraged engineers, educators, and scholars facing hypercomplex and large-scale sociotechnical and economic systems to be aware of, consider, and learn system thinking and system engineering to address human needs to build a better world adapting to the requirements of digital and organizational transformation (De Weck, 2022; De Weck et al., 2012).

Human-Centered System Design (HCSD)

Human-Centered System Design (HCSD) is the intersection of HCD and SE to curate a set of problem-solving processes to give designers, engineers, and researchers guidance to understand which of the various selected methodologies to use, when and how (Lee et al., 2020). For example, one experimental study applied the 5E experience model (Sontag, 2018) integrated with Object-Process Method (OPM) from SE to solve campus tour experience design challenges (Lee et al., 2020). In another experimental case study, the researcher used user journeys combined with ConOps (Concept of Operation) to envision a moon-based conceptual space project hosted by NASA (Lee et al., 2020). MIT AgeLab designers have previously used HCSD to redesign smart footwear for an aging population, including initiating early concepts, product prototyping, and experience simulation as applied to innovative business models and platform design (Lee, 2022; Lee et al., 2022). The intention of applying HCSD is to help researchers have enough innovative capabilities to solve problems by zooming in and out while dealing with the various complexities of social-technological challenges. Therefore, in our study, we integrated HCSD with a modified service blueprint to model AGNES' service providers and service users' journeys across four critical experience actions: 1. prepare, 2. transport, 3. engage, and 4. maintain (Figure 2).

Adapted Human-Centered System Design (HCSD) Service Blueprint

A service blueprint is an informative mapping tool to help researchers visualize the participant journey from frontstage (user-facing side) to backstage (operational side) and organ-

ize the relationships between different service touchpoints including people, props, and process (Gibbons, 2017). A service blueprint can also be viewed as an advanced version of the journey map, which extends the scope from individual customers and users to other people in the experience ecosystem: businesses, operations, and other service providers. In this study, based on the structure and definition of HCSD and service blueprint, we modified the five terms: time, participant journey, frontstage, backstage, and support process and applied them to describe the subsystems and components in the journey of preparing, transporting, engaging with, and maintaining an AGNES age empathy suit. Further study can focus on how to improve the modified HCSD service blueprint in a more precise manner considering the dimension of time (e.g., pre, during, and after) and space (e.g., different environmental conditions or user scenarios) within various service touchpoints in the context beyond the four suggested experience actions: prepare, transport, engage and maintain (Figure 2).

Research Methods

The study's research approaches are based on the concept of HCSD, integrating the theory into a modified service blueprint to visualize an AGNES empathy suit experience through the lens of systems and subsystems. This section includes an overview of this approach, including: 1) identifying four actions of using the AGNES suit, and 2) modifying the definitions of five key terms from the service blueprint, which both significantly improve the research quality and its result.

Study Context and Interdisciplinary Research Team

We selected the retail (demo restroom) and home (dorm restroom) environment as two environments often the most relevant to people's lives. Two field studies were conducted in an in-store Kohler demo restroom and in a standard restroom in a three-bedroom apartment. Each study's testing process followed AGNES age empathy suit protocols, and each study was approximately three hours in length. We observed a five-person design team consisting of two product designers, one design strategist, one social worker, and one university lab researcher to see how the team interacted with the AGNES empathy suit to evaluate the users' experience of the restroom.

Four Actions of Using the AGNES Age Empathy Suit

We defined, observed, and documented the participant journey containing the four interconnected and non-linear actions: 1. prepare, 2. transport, 3. engage, 4. maintain (Table 1).

Five Modified Key Terms from Service Blueprint

Based on the structure and definition of the service blueprint, we modified five terms: time, participant journey, frontstage, backstage, and support process to make them relevant to the context of the AGNES age empathy suit (Table 2).

Table 2. Explanations and examples of five terms applied to AGNES.

Term	Modified definition in the context of using the AGNES age empathy suit
Time	Estimated time of each section that participants use an AGNES age empathy suit to interact, experience, and engage with people, activities, or services.
Participant Journey (Action)	Key engaging moments when participants wearing the AGNES age empathy suit interact, including different activities, decision-making, and reactions.
Frontstage	Incidents that happened directly in the view of the participants, including various types of interfaces: interacting with people or technology.
Backstage	Events or processes that operate behind the scenes to maintain and support the AGNES age empathy suit, services, and systems.
Support process	Internal activities that support participants using an AGNES age empathy suit to experience empathy simulation experiences and services.

In addition, we identified the participants' journey based on the two field studies and the four defined actions (Table 1) as a starting point to capture insight, summarize takeaways, and analyze opportunities to contribute to the suit's future re-design by using a modified service blueprint and HCSD.

Research Results

After synthesizing the available data, we propose an AGNES-related service blueprint that connects the service providers and service users' pain points and innovation opportunity areas (Figure 2). Visualizing the whole service of using the AGNES suit can effectively empower us to re-think some of the design aspects. For example, based on the four participants' journeys (actions), we can consider creating a new age suit with more adaptive and flexible modular components that cater to each action/touchpoint and focus on service design around the AGNES suit to more accurately simulate various physical and cognitive functions associated with specific body conditions.

Proposed AGNES Age Empathy Suit Service Blueprint

Based on the five terms in Table 2 and four actions from Table 1, we propose the AGNES empathy suit service blueprint depicted in Figure 2. In the study, the term "modified service

Table 1. Explanations and examples of four actions.

Action	Prepare	Transport	Engage	Maintain
Explanation	Focuses on under-standing partici-pants' learning objectives to better prepare to docu-ment and evaluate the process of expe-riencing the AGNES empathy suit.	Includes a discrete time period and way the research team packs, organ-izes, transports, and unpacks the AGNES empathy suit and its toolkits to the site for a study.	An interactive touch point when participants are using the AGNES empathy suit to experience aging, discussing their observations, and documenting their learnings.	Cleaning and organizing all components of the AGNES empathy suit before and after using it to maintain the principles and instructions of using the suit.

blueprint" means we simplified the original service blueprint structure by emphasizing five key elements for analysis: time, participant journey, frontstage, backstage, and supporting process. Arrows in the diagram indicate the relationships between components and subsystems to clarify their dependencies. We clustered these components and subsystems and mapped them into three lines by different interfaces: 1. interaction: the direct interactions between the participants and the AGNES suits, 2. visibility: what participants can see and experience from the frontstage apart from backstage, which is not visible, and 3. internal interaction: people who do not have direct contact with the participants.

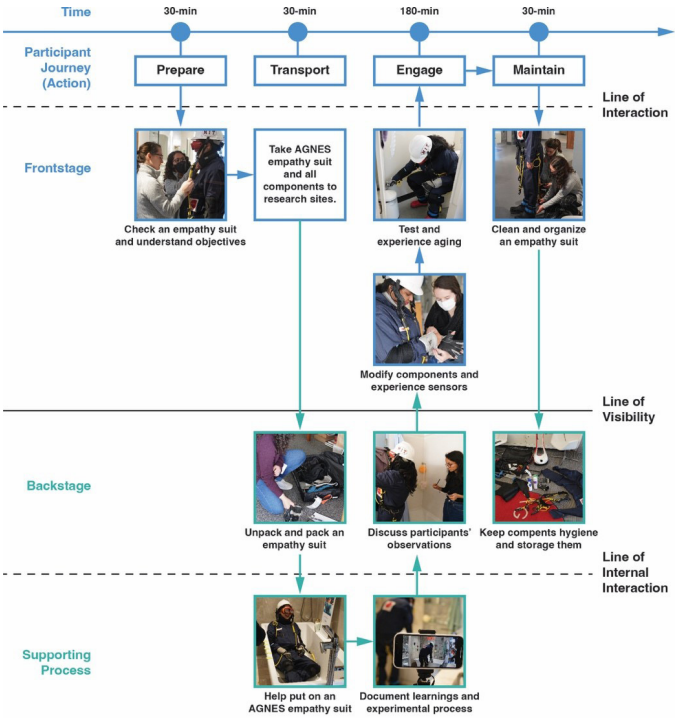

Figure 2. A modified service blueprint to describe AGNES empathy suit and services.

Further Research

Based on the research results and onsite observations, further research is needed to expand the current study's focus to diverse service experiences and service users. Leveraging mixed methodologies with the service providers might also be useful to gain a deeper understanding of these users' experiences with the four actions. Additional research will enable us to better shape a context-driven and human-centered system service model for the next iteration of AGNES.

Applying Materials Science to Make Fabrication Smarter and more Adaptable

The latest applications from materials science can provide more flexibility, adaptability, and accuracy to control, prototype, and simulate multiple scenarios with participants of different ages. For example, Tangible Media Group from the MIT Media Lab applied a reconfigurable fiber technology to control thin fluidic fiber actuators in a closed-loop strain design for movement-based interactions. The invention of artificial muscle-based devices, sensors, and research have demonstrated the potential application of these materials to empathy-learning tool design (Chandler & MIT Media Lab Tangible Media Group, 2021). The advances in materials science and its potential applications can offer us emerging opportunities to innovate the AGNES suit and even further encourage us to envision service strategies and business models to help not only improve the suit design but also promote the importance of the empathy suit globally and integrate it to various industries to make a positive social impact.

Suggested Research Directions

Three further research directions can be proposed from this study: 1. cognitive performance, 2. virtual tools, and 3. service design education. Although the field of cognitive science has already conducted many studies with older adults, we want to further understand how we can accurately simulate older adults' cognitive performance (e.g., stress, declining memory, emotional problems) in AGNES' embodied experience. How do we establish a matrix of measurement to evaluate the effectiveness of such a simulation? Emerging technologies like AR, VR, and IoT wearable smart devices have already transformed our lives. How can we re-think how to leverage AR or VR as useful simulation tools to help make experiences with AGNES even more technology-enabled, immersive and authentic? Ultimately, education has played a critical role in service design, and design generally. As a next step, we consider leveraging and emphasizing empathy-tool experiences and consider the modified design aspects from shifting the view of the AGNES age empathy suit as a *product-design* to an *experience-design* process considering the engaging moments of before, during, and after using the AGNES age empathy suit.

Discussion and Conclusion

The following three key takeaways: 1. product, 2. process, and 3. platform can be understood from this study to illustrate the future of empathy-learning tools and services. Future research approaches should leverage HCSD and systemic service innovation.

Product: An Age Empathy Suit as an Experience-Driven Service

In this study, four actions were applied—prepare, transport, engage, and maintain—across the journey of service providers and service receivers to review the AGNES age empathy suit design. This approach considers not only the physical product design, but also the service around the product that can benefit participants who put on the AGNES age empathy suit (service recipients) and the lab scientists who maintain and use the suit (service providers).

Process: A Modified Service Blueprint Approach Helps Identify Service Touchpoints

The service blueprint approach was modified by integrating the HCSD concept, which gave us more room to play with creative methodologies and system thinking. It has greatly benefited future AGNES empathy suit design since it blurred the boundary between service and product design. The methodology itself can involve more participants in the co-creation and co-development process of the AGNES age empathy suit. A modified service blueprint can help make future iterations of the empathy design process more interactive and engaging.

Platform: Service Innovation Takes Many Aspects to Consider

Re-designing the AGNES empathy suit through the layer of products, services, and experience considers many aspects. The platform can be considered a vehicle to the right conditions to deliver a full age empathy experience for participants. Platform thinking and awareness can equip designers and researchers with comprehensive views of creating immersive empathy product design, service innovation, and user experiences for an increasingly aging population.

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References

Brown, T., & Katz, B. (2019). Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation (Revised and updated edition). HarperBusiness, an imprint of HarperCollinsPublishers.

Chandler, D. L., & MIT Media Lab Tangible Media Group. (2021, October 15). New fibers can make breath-regulating garments. https://news.mit.edu/2021/fibers-breath-regulating-1015

Coughlin, J. F. (2017). The Longevity Economy: Unlocking the World's Fastest-Growing, Most Misunderstood Market (First edition). PublicAffairs.

De Weck, O. L. (2022). Technology Roadmapping and Development: A Quantitative Approach to the Management of Technology. Springer.

De Weck, O. L., Roos, D., & Magee, C. L. (2012). Engineering Systems: Meeting Human Needs in a Complex Technological World. MIT Press.

Empathy Resources LLC. (2019, June 4). About The "Belly." https://www.empathybelly.org/about-the-belly

Gennis, A., & Godfrey, K. (2011). AGNES Guidebook. MIT AgeLab Research Associates.

Gibbons, S. (2017, August 27). Service Blueprints: Definition. Nielsen Norman Group. https://www.nngroup.com/articles/service-blueprints-definition/

Golden, S. (2022). Stage (Not Age): How to Understand and Serve People Over 60 - the Fastest Growing, Most Dynamic Market in the World. Harvard Business Review Press.

IDEO. (2022). IDEO Design Thinking. https://designthinking.ideo.com/

Kolb, D. A. (1984). Experiential Learning: Experience As The Source Of Learning And Development. Prentice-Hall.

Lavallière, M., D'Ambrosio, L., Gennis, A., Burstein, A., Godfrey, K. M., Waerstad, H., Puleo, R. M., Lauenroth, A., & Coughlin, J. F. (2017). Walking a Mile in Another's Shoes: The Impact of Wearing an Age Suit. Gerontology & Geriatrics Education, 38(2), 171–187. https://doi.org/10.1080/02701960.2015.1079706

Lee, S.-H. (2022). Human-Centered System Design for an Aging Population: An Experimental Study of Footwear Design. Massachusetts Institute of Technology.

Lee, S.-H., de Weck, O. L., & Coughlin, J. F. (2021). Applying a System Engineering Approach to the Early Stage of Product Design. Embracing Future: Creative Industries for Environment and Advanced Society 5.0 in Post-Pandemic Era, 5. https://bcm.telkomuniversity.ac.id/

Lee, S.-H., Lee, C., Rudnik, J., de Weck, O. L., & Coughlin, J. F. (2020). Apply and Curate the Object-Process Methodology (OPM) and the Human-centered Design to Solve the Systemic Challenge – Use Campus Tour Experience Design as an Example. Impact the Future by Design, 16. https://www.dmi.org/page/ADMC2020Proceedings

Lee, S.-H., Lee, C., Yang, M. C., & Coughlin, J. F. (2022). Footwear Design Considerations for an Aging Population from User Experience, Service, and Technology Aspects. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 66(1), 1667–1672. https://doi.org/10.1177/1071181322661207

Lee, S.-H., Liu, J., Rudnik, J., de Weck, O. L., Coughlin, J. F., & Chapman, J. (2020). Experimenting with Design Thinking and System Engineering Methodologies: Using a Commercial Cislunar Space Development Project as an Example. 9. https://www.idsa.org/educationpaper/experimenting-design-thinking-and-system-engineering-methodologies

Lee, S.-H., Rudnik, J., Lee, C., Fakhrhosseini, S., de Weck, O. L., Coughlin, J. F., & Chapman, J. (2020, August 5). A Systematic Thinking Design Research Approach Combining the ConOps with Design Scenario – Use Commercial Cislunar Space Development Project as an Example. Impact the Future by Design. dmi: Academic Design Management Conference. https://www.dmi.org/page/ADMC2020Proceedings

Lee, S.-H., Rudnik, J., Lin, L., Tang, L., & Zhou, D. (2020). Apply Humanity-centered Design Process to Envision the Future Learning Experience of Public Area – Use "Redesign Shanghai Library Innovation Space Project" as an Example. Impact the Future by Design, 19.

Lee, S.-H., Zhu, Z., Rudnik, J., Lee, C., Coughlin, J. F., de Weck, O. L., & Chapman, J. (2020). Apply Funnel Model to Design Thinking Process. Impact the Future by Design, 17. https://www.dmi.org/page/ADMC2020Proceedings

Leveson, N., & Thomas, J. (2018). STPA Handbook. https://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf

Nightingale, D. J., & Rhodes, D. H. (2015). Architecting the Future Enterprise. The MIT Press.

Sontag, A. (2018, January 26). The 5E Experience Design Model: A step-by-step guide to designing meaningful experiences. Andy Sontag. https://medium.theuxblog.com/the-5e-experience-design-model-7852324d46c