Open innovation voices and choices: case studies of designing interactive virtual reality experiences in Australian public hospitals

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Abstract—Virtual reality (VR) can offer many advantages as an adjunct of care when end-user involvement and practical integration in clinical workflows are considered from the start. This paper describes open innovation approaches that can help the integration and sharing of knowledge between multiple stakeholder groups, creating a platform for meaningful engagement towards the design and integration of VR technology as a routine part of the patient care pathway. This paper presents two cases of VR design and use on a large Australian health precinct. Through the use of stakeholder interviews, this paper addresses the question: how can open innovation approaches facilitate meaningful stakeholder engagement for VR design in healthcare? Four portable principles are identified that summarise key learnings and may contribute to open innovation approaches for the design of VR for health services and human computer interaction practitioners engaging stakeholders at the ecosystem, health service, hospital department and patient level. Open innovation may also broaden the scope of Creative Connectivity beyond ideation and prototyping, by incorporating avenues for nontraditional approaches to dissemination.

CCS CONCEPTS • Interaction design • Life and medical sciences • Mixed/augmented reality

Additional Keywords and Phrases: open innovation, virtual reality, healthcare, codesign

1 INTRODUCTION

Creative Connectivity is a deliberate approach to creativity that gathers knowledge from different stakeholders and that has emerged in recent years [1]. It refers to platforms created by organisations to coordinate the generation, collection and management of external innovation impulses from the community, as well as from internal and external stakeholders. It is mostly related to design thinking around commercial products, such as the case of Porsche, where a B2C innovation platform was piloted. It was used to harness those creative impulses from the community and employees as a tool for product generation and for fostering a culture of creativity, proving particularly valuable for idea detection and market launch activities [2]. This speaks well to open innovation theory, that is examining how impulses are formed and travel outside-in and inside-out of an organisation [1], [3]. Through the lens of open innovation, this article brings together three health professionals and two design academics to discuss the scope of Creative Connectivity within two virtual reality (VR) case studies co-designed and translated into practice in a large public health service in the state of Queensland, Australia.

Health services are large knowledge warehouses, typically well connected to their ecosystem of knowledge, but where innovation processes can be hindered by system and organisational complexity and variability. As shown in Figure 1, Jones suggests that technology integration challenges in public health call for a disruption of traditional innovation processes at multiple, nested levels [4]:

- An ecosystem layer responsible for regulations policy and encompassing consumer engagement, industry actors, academic partners.
- A health service, organisational layer responsible for reporting, economics, and operations through the management of physical, digital, human and cultural capital.
- A department or work unit layer, responsible for the delivery of healthcare services through the governance processes established by the organisation.
- A human layer representing the end-user: the patient.

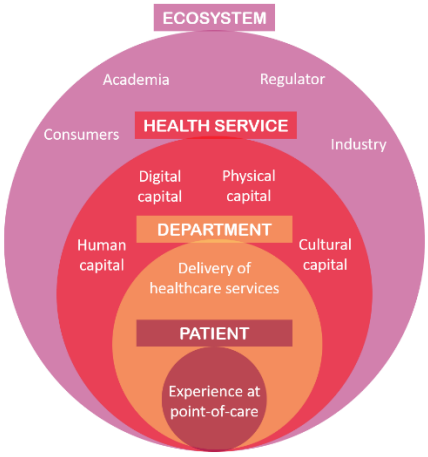

Figure 1. Nested levels of innovation, Adapted from Jones [4].

By empowering users from each layer and giving them a sense of control in both the creative and functional design and in the evaluation and dissemination of VR experiences, this paper utilises two case studies to explore how open innovation strategies to engage stakeholders at the different levels can enhance the design of VR experiences in public

health. The two cases brought together clinicians, consumers, researchers, software engineers, artists, and students across two hospitals and two universities. Consumer here is a term inclusive of the patients but also of family members, carers, and the community [5]. The first case, PARM-VR, consists in a co-designed, Australiana-themed immersive experience to aid in the management of procedural pain and anxiety in adult burns patients and in adolescents and young adults with cancer. The second case, Handy Juice, describes a co-designed virtual reality rehabilitation system with hand tracking that incorporates meaningful activities. Five interviews were conducted with key stakeholders within the case studies to explore the nature of their contributions and learnings throughout the creation of the VR experiences. Each case examines how stakeholders' knowledge and creativity was connected under the theoretical lens of open innovation. The goal is to identify a set of portable open innovation principles to support stakeholder engagement in the design of VR for health at the intra-, inter- and extra-organisational levels.

1.1 Open innovation

The theory of open innovation, introduced by Chesbrough in 2003, considers the knowledge flows of knowledge across the porous boundaries of an organization [3]. Gassmann and Enkel further qualify three processes for knowledge flows: 1. Inbound, or outside-in, that considers the integration of external knowledge, 2. Outbound, or inside out, which is the transfer of ideas to the market, and 3. A combination of both, called coupled process [6]. To visualise the outbound, inbound, and coupled flows of knowledge across those stages, Chesbrough's open innovation paradigm can be represented in a model shaped as a funnel, as shown in Figure 2. On the funnel, the organisation's porous boundary is represented with a dotted line to represent permeability, allowing ideas coming both from internal or external sources to contribute to the project. It stands in opposition to innovation that solely focusses on in-house ideas, creativity and capabilities.

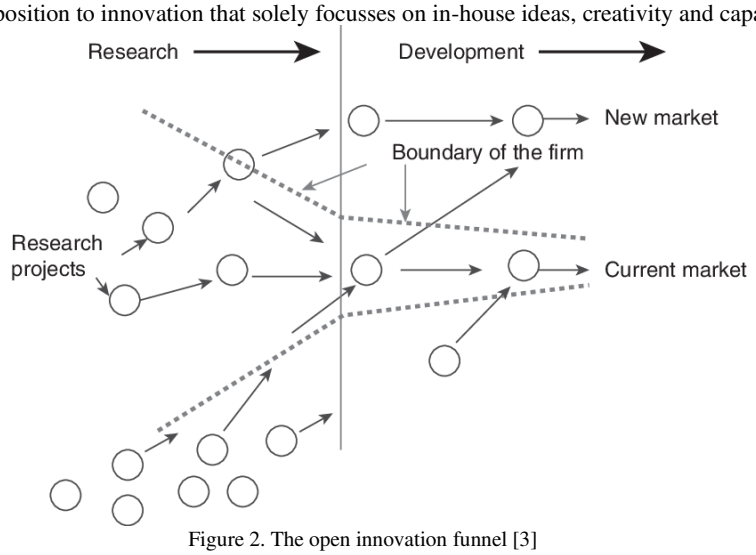

Figure 2. The open innovation funnel [3]

Open innovation research in the for-profit space is abundant, but it is only emerging in the government and non-profit space. New research is moving the primary focus of value creation away from profitability to adjust the lens on the positive social advances, and ultimately the systemic changes, generated by open innovation. For example, in their review of healthcare and open innovation literature, Wass and Vimarlund examine a number of collaboration platforms, often online, that provide products and health information on particular conditions, or a mean for people to contribute ideas for health improvement [7]. Their analysis suggests that open innovation acknowledges the knowledge brought in by the patient and

their relatives, increases the capacity of hospitals to innovate, and supports the development of new arenas for meaningful collaboration with external stakeholders [7].

The concept can be referred to as "open social innovation". Chesbrough and Di Mini, by examining case studies, established that open social innovation is characterised by diverse knowledge absorption capabilities and a willingness to shift attitudes towards sustainable business models. They suggest that open social innovation is particularly relevant to prototyping, sustaining innovation efforts and scaling-up activities [8]. Wass and Vimarlund's review found that efforts were centered on the knowledge integration at the start of projects [7]. Other scholars also argue that in the context of new product development in the public health space, projects have more to gain from inbound processes, external collaboration and from openness during early/ideation stages [9], [10]. It is worth noting that the research from these authors was conducted before the COVID-19 pandemic, that saw a rise in inbound, outbound and coupled open innovation processes in both the profit and non-profit sectors, opening up emerging pathways for the sharing of discovered knowledge and unused internal ideas. As a result of the pandemic, examples in knowledge dissemination range from companies, clinicians and citizens sharing open access designs for ventilators or personal protective equipment, to governments and journals releasing free to access COVID-19 literature [11]. Such examples serve to demonstrate that grand challenges in healthcare can enact a shift from knowledge ownership to knowledge openness when social benefits are at play.

A key challenge for further adoption of open innovation is the inherent organisational complexity of healthcare services, a complex regulatory system, and the lack of sustainable business models and platforms for stakeholder engagement, especially with patients and with external partners [10]. On the other hand, open social innovation offers opportunities for patients and carers to play an active role in innovation processes, and for further examination of the connections between the different actors and across the various stages of the open innovation process [7]. This is particularly relevant to technology-adoption challenges. Hospitals recognise the inherent importance of innovation and of digital technologies such as VR in improving the health of the population and are seeking avenues to integrate them into clinical practice. This is in conjunction with increasing consumer/healthcare system partnerships to increase inclusivity, growth, respect, safety and trust [5].

1.2 Designing VR for healthcare

VR is offering interactive and adaptable options as therapeutic adjuncts, and can lead to improved rehabilitation outcomes for people with traumatic injuries or neurological disorders, with demonstrated efficacy in terms of improvement in cognitive and motor responses [12]. VR technologies have yet to be introduced widely into health care but are rapidly evolving to cater for the specific demands of medicine. The transformative potential of VR lies both within but also outside of the hospital, enhancing patient and staff experiences with telehealth [13].

Many ways of accompanying individual journeys of care could benefit from new advances in VR by bringing in connecting historically ignored voices and creativity into the design and innovation process, namely patients and clinicians. For immersive technologies such as VR to find their way into clinical practice, the input of patients and clinicians is equally important to those of academia, policymakers, regulators and industry partners'. Indeed, accuracy, integration, efficiency and user adoption are not granted with a new technology. Limitations of VR include designing for the adequate level of human perception and interaction [14], which varies for each patient, and technical limitations, such as staff training and confidence [15]. Systems and experiences used in previously reported studies pertaining to VR also do not always cater

well to the specificities of the Australian public health system. VR hardware in use can be clunky, uncomfortable, and difficult to clean between patients, and generic apps in use also only sporadically include cultural or creative input from end-users, and have limited therapeutic benefits compared to injury-specific content [16].

Co-design offers an avenue for engaging consumers (patients and carers) and clinicians from the early stages of the development of VR. Sanders and Stappers define co-design as a process for the creation and diffusion of new knowledge, using tools and techniques allowing designers and users to actively engage in a collaborative creative process [17]. In the literature, co-design in healthcare is also referred to as "experience-based design" or EBD, as it primarily focuses on the care and emotional experiences of patients, carers and staff [18], [19]. The expertise of clinicians within a health system, along with the lived experience of patients as consumers in that health system, is coupled to the knowledge and resources brought in by the designers to create a new product or service [20], [21]. Some of the challenges associated with co-design in healthcare include:

- Readiness to embrace novelty and risk-taking in the public sector, where co-design approaches can contrast with conventional organisation cultures [20]
- Sustained engagement from patients and the increasingly diverse health workforce with co-design tools and platforms [7], [22].
- Hierarchical barriers between clinicians and power relationships between clinicians and patients [20].
- Meaningful engagement and tokenism: "Some services think they can invite a patient to sit on a committee and that's the 'involvement' box ticked" says John Pickles in the UK NHS EBD toolkit [19].
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Co-design is extensively used for creating VR experiences for patient care, including in the space of pain management and rehabilitation, where our case studies are situated. Specifically, previous collaborative research in this space has identified key interaction design principles that can be considered when designing VR environments for burns, a cohort of patients of particular relevance to our case studies. Whether for pain management or for rehabilitation, strong themes include choice or customisation in the experiences to provide agency to patients and treatment tailoring options to clinicians, interaction with trauma stimuli (such as hot and cold), and sensory familiarity with the VR environment [23], [24]. A successful example of end user involvement in health and of the application of those principles in the design of VR for burns is that of Hoffman and Patterson at the University of Washington. In 2003, they started Snow World, a virtual reality world for the management of procedural pain, specifically designed for use in hydrotherapy sessions with burns patients [25]. Over the following two decades, they continued collaborated with patients, software experts, scientists and other clinicians to build a body of literature documenting the safety and efficacy of the technique [26], expand their practice to other settings of care, and disseminate their VR systems through a company, Firsthand Technology. Hoffman, Patterson and colleagues have paved the way for the cases presented in this paper.

2 METHODS

This paper focuses on two cases of designing interactive VR experiences in 2020 and 2021 in a large, Australian health service. A qualitative case study methodology was selected to investigate observed phenomena driven by people, structures and processes within their specific context [27], [28]. Despite similarities between the two cases from a technology and target patient groups, the co-design process and outbound knowledge flow strategy in each case differ, allowing for drawing comparisons between the two cases. These comparisons, and our interpretation of the data, are inherently situated: some

of us are physically based on the healthcare precinct where the hospitals in the case studies are located. We are a part of the research setting, which directly challenges objectivity [29]. However, brought together, the findings from the two cases may generate learnings that can be applied to other settings of care. These transferrable learnings are defined by Gioia as "portable principles" [28], guided by first order (participant-centered) and second-ordered (theory-centered) findings. Research activities included in the cases are clinical observations to understand situated technology adoption challenges in clinical practice, review of meetings and co-design sessions notes, memos and minutes, and semi-directed interviews with key stakeholders to unpack the knowledge flows for VR design in each case.

Participants were selected through a purposive sampling strategy to seek a range of participants representative of diverse stakeholder roles in the case studies. Five 30-minute interviews were conducted face-to-face between March and May 2022 with 1 health service administrator (HSA), 2 clinicians (CLI), 1 consumer (CON), and 1 academic (ACA). Quotes are attributed accordingly, have been edited where identifying information was present, and acronyms have been defined in brackets. Each interview was audio-recorded and transcribed verbatim.

Although participants are situated within different nested layers of innovation, their insights may apply across the ecosystem, health service, hospital department and patient layers. Interviews were conducted with approval from the local human research ethics committee (reference HREC/2021/QRBW/78079) and questions included:

- How would you describe your role in the project?
- What specific knowledge do you think you contributed to the project?
- What new learnings do you think were created in the project?
- What did you learn through the project?
- If you had to this again, how could the collaboration between the different stakeholders be improved?

3 FINDINGS

3.1 Case 1: PARM-VR

VR can assist with reducing patients' reliance on opioid analgesics during acutely painful procedures by providing cognitive, behavioral learning, and neurological distraction mechanisms. It can help refocus attentional capacity to the distraction, away from pain perception, reduce anticipatory anxiety, and trick pain processing mechanisms [24], [26]. The Pain Augmented Relief Method – Virtual Reality project (PARM-VR) started in 2020 as a collaboration between a large tertiary hospital and an academic partner. The initial project aimed at engaging burns survivors in the co-design of a VR experience to provide distraction during painful burns baths and wound dressing changes. Initial research funding was secured, at the condition to collaborate with colleagues who wanted to do the same, but for the management of pain and anxiety in adolescents and young adults with cancer. Once priorities were aligned, the newly formed collaboration engaged groups of patients and clinicians from both cohorts in a series of co-design sessions, and the results formed a design brief that was utilised to inform the development of the interactive VR experience, named "A Wanderer's Tale" by an external provider. The experience is a treasure hunt where the user travels across several Australian bush landscapes to retrieve flowers, stones, and other natural resources. Subsequently to initial evaluations and an initial research publication [24], a license was drafted for release of the game on the Sidequest content platform for free, while the software is being evaluated for clinical safety and efficacy at the hospital. Figure 3 maps inbound and outbound knowledge flows on Chesbrough's funnel of open innovation [3], augmented by Piller and West's four phases of open innovation: (1) defining; (2) finding

participants; (3) collaborating; and (4) leveraging [30]. The funnel places the system boundary at the departmental level of the hospital's burns unit and distinguishes Jones' four layers of innovation (ecosystem, health service, department and patient) with icons.

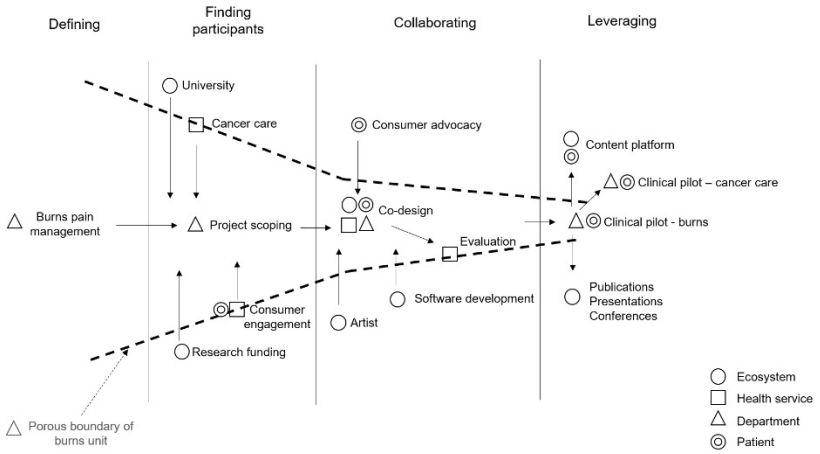

Figure 3. Open Innovation funnel for PARM-VR

The mapping of the knowledge flows clearly shows a majority of external knowledge integration flows from the ecosystem, the health service, and the patient, with outbound flows at the very end of the funnel. The funnel shows that Creative Connectivity did not necessarily happen at the ideation stage, but rather in the form of integration of consumer, academic and industry impulses to solve a clinical issue, and in the dissemination strategy. The following section presents some of the data from each part of the case study according to the phases of the Open Innovation funnel for PARM-VR.

- First, in the defining phase, ideation and problem definition were clinician-led, and included sharing the shortfalls of current approaches for pain management, and the need to build solutions with a bottom-up approach, centered on the patient and the reality of clinical care:

"You have engineers building beautiful elegant solutions to a problem that nobody has and just meeting in the middle and making sure that everything we've done... we do is focused and patient centric." (CLI).

- Second, when finding participants, the initial process of engagement was made purposefully transparent through extensive engagement with multiple clinical sub-specialties, ranging from surgery, anesthesia, nursing, physiotherapy and occupational therapy:

"I think it was everybody was invited and it was up to you whether you wanted to be involved or not" (CLI).

Engagement of specific occupational groups, especially nurses, was however deemed suboptimal due to already busy shifts. The response on being somewhat pushed to engage with the cancer care group to secure was however positive:

"It was really nice to have the opportunity to collaborate with people who wanted to not just use something that was out there, to design something specific for the consumers that we treat here and also use the Australian context." (CLI).

- Third, the collaborating phase was undoubtedly the richest phase, as it is when co-design, iterative software development and the gathering of initial usability and safety data was conducted with end-users:

"[the codesign] was structured enough so that, you know, you sort of got the answers that you needed from the consumer perspective, clinical perspective, design perspective, to actually go into the study and move forward with it." (CON).

The contributions from the participants supported the design of a useful and meaningful interactive experience. Participant engagement demonstrated that a middle-aged mechanic in their acute burns treatment phase undergoing staple removal has a vastly different experience at point-of-care than that of a teenager with cancer awaiting a bone marrow transplant while surrounded by elderly patients in a hospital situated 2,000 kilometers from their family and friends. This means that compromises had to be found to account for each patient's story and journey and for the specific procedural context of use. Example of resulting design choices are the incorporation of Australian wildlife and nature sounds from the BBC sound archive, and the experience being controller-free and gaze-controlled: some burns patients cannot hold controllers. This is because hand gestures are not desirable for patients with intravenous lines on their arms, or receiving wound care on their hands and arms. In addition to an interactive "treasure hunt" mode, a storytelling mode was also included in the design as a mean to modulate intensity. Providing agency to patients in the VR experience was a key component of the project [24], and one acknowledged by participants:

"I think in terms of VR, I think it's a great option to have. I mean we're not gonna just suddenly take all their pain meds away. […] I think that's what people…people forget about, patients have choice. I think their voices need to be allowed to be a little stronger." (CLI).

- Fourth, in leveraging the project, in addition to pilot studies within the burns unit, the cancer care unit, and dissemination via research publications and conferences, the experience was made freely available on a content platform. If we draw a parallel to the Porsche case study, Albers et al showed that Connecting Creativity platform are a good tool to develop market access strategy [2]. In our case study, it is interesting to note that because the VR software was intended to be free to access, the clinical team did not have a clear dissemination strategy of the software outside of direct translation in clinic and in publications and conferences, and the idea of licensing the software and making it available through a content platform came from the university and software development partners.

3.2 Case 2: Handy Juice

As extensively demonstrated in the literature, VR can offer interactive adjuncts to traditional rehabilitation therapy approaches, especially by stimulating patient engagement and motivation, resulting in increasing range of motion, pain reduction, and reduced levels of stress [23]. Handy Juice started in 2021 as a collaboration between two hospitals and an academic partner. Allied health professionals involved in PARM-VR identified the potential controller-free VR technologies could have in the rehabilitation of the upper-limbs, where the level of engagement of some patients with occupational therapy could be improved. The availability of meaningful rehabilitation activities is incredibly important to occupational therapists, as they should allow patients to engage in the daily life activities that are meaningful to them. A collaboration was set up with the university, and a collaboration between patients, multidisciplinary clinicians, engineering and design academics and students, led to the development of an interactive, virtual kitchen environment, "Handy Juice". The virtual kitchen environment was chosen as it allowed for universal activities to reach a wide range of patients across all settings and conditions. Key fingers, hand and arms motions were mapped and gamified: the user needs to grab and pinch different fruits and ingredients and use kitchen utensils to create a smoothie. End-user testing across two clinics

revealed high levels of patient engagement, and several student-led publications and conference presentations ensued. Within a year from project start, the VR software was able to be translated into routine use in a weekly upper-limb clinic. The project was awarded a prize from an accelerator, Bionics Queensland, to progress an expanded platform: Sensory Experiences in Occupational Therapy for Upper Limb (SEOUL). A trademarking strategy, led by the university, is underway. Figure 4 maps inbound and outbound knowledge flows on Chesbrough's funnel of open innovation [3]. Unlike the PARM-VR case study, it places the funnel boundary at the level of the occupational therapy discipline within the health service, as it took a health service wide approach across two hospitals rather an individual department approach.

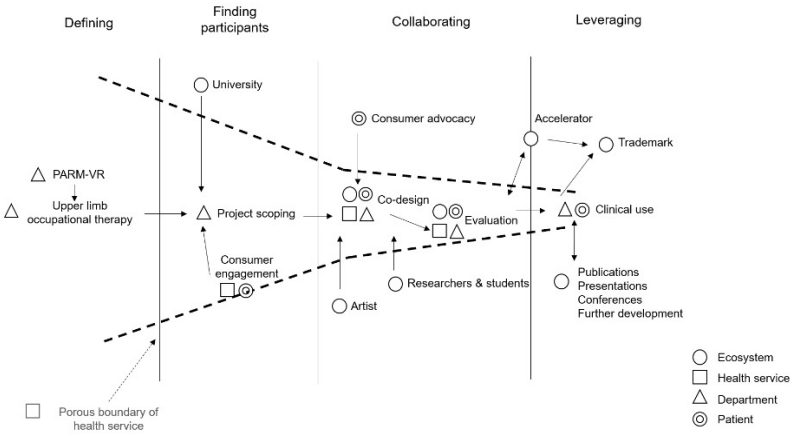

Figure 4. Open Innovation funnel for Handy Juice

Here, the mapping of the knowledge flows clearly shows a majority of external knowledge integration flows from the ecosystem and consumers, with coupled and outbound flows at the end of the funnel. In this case study, Creative Connectivity was further stimulated by engagement with the tech accelerator, that encouraged trademarking and expansion of the scope of the VR application. The following section presents some of the data from each part of the case study according to the phases of the Open Innovation funnel for PARM-VR.

- First, in the define phase and like in the PARM-VR case study, the idea for Handy Juice came from clinicians who believed that academics' concepts of the reality of clinical care on the ground and understanding of the regulatory framework was somewhat limited, but academia showed a strong appetite for being involved in clinically useful projects.

- Second, in finding participants, engagement from clinicians, academics and consumers from the very early stages of the project was essential to understand all parties' realities and priorities:

"the students and biomedical engineers are very keen to come on board and understand that how they can utilise their technical skills to help the clinicians out." (ACA)

- Third, in the collaborating phase, trust building and communication were recurrent topics in the interviews, which brought in interesting comments on project governance risks, and on who to engage and how many partners to

engage whilst remaining open and inclusive. It is also interesting to note that all types of entities think others are slow at making decisions.

"Well the issue is you could bring more stakeholders in so that if they change or drop out, it dilutes the impact of that […]. We could have brought in three academic partners and you'd have weaker commitment individually, but it also then doesn't matter if that commitment drops off." (HSA).

"Other projects that I've seen have never had such an MDT (multidisciplinary team) focus. (CLI)

- Fourth, in the leveraging phase, once validated, the experience was directly translated into clinical practice in one of the two hospitals, becoming an adjunct of care. For external dissemination and future work, the engagement with tech accelerator Bionics Queensland was led by the academic partners on the project, coordinating video and a live pitching session involving the clinicians. The trifecta of academia – hospital – consumer partnership was important to the accelerator, who helped putting the focus on a trademarking strategy and potential return on investment, which can be difficult to estimate:

"things like […] less time until they're back on their feet, able to mobilise, less time under anaesthesia, less complications, cosmetic result, all the... all the things that, all the things that need to be measured. […] And yes, yes you can put a price figure on them, but at the end of the day it's about providing the best possible service and the best possible care you can to a patient." (CLI)

"It's about the impact into healthcare that we're there for, not to try and make money out of IP (intellectual property)." (HSA).

The two cases highlight how open innovation approaches supported the design of VR experiences, resulting in clinical outputs, ultimately leading to improved healthcare outcomes. The consideration of inside out leveraging strategies helped create value for all partners, as it delivered on the research, education and translation priorities and objectives of external stakeholders engaged in the projects, creating connections and opening doors for future work. The learnings from the VR cases may be translated into other settings of care.

4 DISCUSSION

Connected Creativity ~~focuses on~~ requires the creation of platforms to integrate various types of knowledge and creative impulses for product innovation processes during ideation and prototyping [1]. Our experience with open social innovation approaches to designing VR for health experiences appear to broaden this scope, with opportunities to further engagement within and outside of the health system through evaluation and market access, ultimately facilitating adoption, translation and dissemination of the created VR experiences. Indeed, the VR experiences presented in this article were directly translated into clinical practice in a much shorter time frame than we had anticipated. The benefits of using open innovation with multiple parties being involved increased the speed of achieving the end goal for the health service, which was to improve patient experiences.

Although this paper focuses on two cases designing VR technology, and generalisation of the findings is limited, the identified set of portable open innovation principles ~~are identified that~~ may form transferrable learnings for other projects, technologies and settings of care. To develop those learnings, we first articulated the key impulses described by the participants. Secondly, because three of the authors were directly involved in the case studies, we were able to characterise

the associated key phenomena we observed within the case studies utilising some of Chesbrough and Bogers' levels of analysis for open innovation research [31]:

- Organisational, at the level of a firm or organisation
- Intra-organisational, focusing on teams, business units or projects
- Extra-organisational, involving external stakeholders and communities.

Table 1: Overview of key impulses, phenomena and open innovation portable principles

Layer	Key connected creativity impulses	Key phenomena	Open innovation portable principle
Ecosystem	VR technology advances Research and education priorities Economic drive	Extra-organisational collaboration with academia and industry drives dissemination and new business model	External engagement with academia and industry from the start can drive broader dissemination of outputs.
Health service	VR technology readiness Healthcare improvement Healthcare efficiencies Patient safety Governance Regulatory framework	Organisational collaboration between multiple hospitals requires fostering of a culture of creativity and innovation	Permeable governance models in place may need redesign to assist innovators in navigating dynamic relationships with internal and external partners.
Hospital department	On the ground knowledge Problem identification Usefulness of VR	Intra-organisational collaboration can accelerate implementation of the VR innovation in clinical practice	Open innovation requires a commitment from leadership to remove the barriers that slow down innovation champions.
Patient	Lived experiences of care Ideation Usability of VR	Extra-organisational benefits to society are actioned through patients who are willing to share their stories and be an actor of change for others	Structured processes are essential to gather useful patient knowledge and experiences.

First, at the ecosystem level, extra-organisational open innovation needs to account for possible differences in the external partners' motivation for engagement with hospitals [32]. In our case studies of designing interactive VR experiences, it proved to be an advantage: rapid translation into clinical practice took place, but strategies for dissemination back to the ecosystem were still able to be devised and actioned.

Second, the health service level is the orchestrator of organisational open innovation. This means understanding those motivations and encouraging collaboration while striking a balance between strict and self-organising, open governance [32], [33]. Governance models thus might need to be refined or redefined to become more permeable, establish new policies on the management of partnerships and intellectual property, as well as platforms to sustain a culture of creativity and connectivity between departments and for external partners [2].

Third, at the department level, the delivery of intra-organisational open innovation is reliant on individuals who focus on direct healthcare improvements for patients, are the guardians of clinical relevance and value, and also who bring their own vision, values and priorities to the project. Public healthcare is fueled by discretionary efforts from individuals and teams whose days are already over-subscribed and budget fully allocated. Change requires a commitment at the departmental head level to removing time and knowledge acquisition, integration and sharing obstacles for champions. In our cases, time from champions had to be freed up from clinical duties to support the projects [2]. In the cases, the inclusion of key department heads led to high levels of advocacy and support, ranging from approval of staff time, financial resources, communication on a large, busy ward, or extensive administrative support to manage university contracts.

Fourth, at the patient level, the power of safe, inclusive, meaningful platforms for consumer engagement with clinicians and researchers cannot be understated, but also with peers, resulting in extra-organisational benefits [7]. They are the ultimate beneficiaries of open social innovation in healthcare. Acknowledging the power imbalances between patients and clinicians [20], integrating knowledge from patients requires highly structured systems to ensure opinions are heard and debated, and ideas can be put forward with clarity on the objectives. The structured engagement process in the cases proved to be useful to consumer advocates engaged in the VR projects.

The knowledge flow processes investigated in the two cases documented in this paper suggest that open innovation approaches might facilitate meaningful stakeholder engagement and impulse integration and sharing for VR innovation in healthcare. The ecosystem, health service, hospital department and patients represent many voices and choices, and the designer's role is to connect their creativity to ensure they are all meaningfully contributing to projects across the various project phases.

5 CONCLUSION

This paper reflected on two cases of stakeholder engagement in the design of VR experiences for healthcare utilising open innovation strategies. The cases suggest that for open innovation to be used as a strategy to for Connected Creativity, porosity needs to be present at all stages of the design and innovation process and at the ecosystem, health service, hospital department and patient level. ~~This~~ Porosity allows for creative impulses to be considered while utilising a system design approach, within multilayered environments bound by patient safety, risk management, compliance with regulatory frameworks, and a limited vision for dissemination. In the described cases, the success of the open innovation approach for hospital-initiated VR innovation projects was directly influenced by external engagement in early stages to ensure all partners' priorities are accounted for, so dissemination can occur outside of the physical confines of the hospital. In addition, open governance models and a clear commitment to removing organisational, operational, and collaborative barriers for innovation champions are needed. Opportunities exist to restructure the collection and connection of patient knowledge, creativity, stories and experiences to continuously inform how experiences at point-of-care can be transformed. Collaboration is dynamic, and clinical problems, needs and priorities evolve. Open innovation offers a viable approach to Connected Creativity in healthcare innovation by offering improved ways of connecting stakeholders' voices and choices in the design, development, implementation and sharing of VR solutions. Ultimately, this approach may allow hospitals and human computer interaction practitioners to further action healthcare benefits for society.

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