ITERATIVE CO-CREATION IN HEALTHCARE MOBILE APP DEVELOPMENT

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ABSTRACT

The diffusion of mobile phone applications offers healthcare professionals innovative digital channels to support their patients beyond the confines of the hospital. The clinician-patient relationship typically reflects a sensitive and personal interaction between service provider and service user. As such, creating relevant mobile app healthcare that respond to individual patient needs and requirements can be challenging. The co-creation literature suggests that service users can contribute their resources, including knowledge, to improve service design and delivery. However, few studies in this area demonstrate the precise mechanisms by which knowledge is exchanged and combined, particularly in an innovation context. Additionally, co-creation studies typically focus on relationships between service users and service providers. Mobile healthcare app development introduces an additional actor in the shape of software developers. To examine the resultant complexity and explain collaboration across knowledge boundaries, we draw on theory from boundary objects. We examine the triadic relationship between service providers (clinicians), service users (patients) and app developers in the co-creation of a mobile app for healthcare provision. Analysis of empirical data suggests that apps act as boundary objects, which serve to overcome boundaries in an iterative co-creation approach. This research contributes to understanding of co-creation processes in innovative service development by focusing on the exchange of knowledge across knowledge boundaries. It offers implications for practice and policy, while enhancing understanding of digital innovation.

Key words: Co-creation; Digital; Mobile App; Healthcare; Service Innovation; Boundary Objects

INTRODUCTION

Patient-clinician relationships require interaction in that each actor contributes information to allow diagnosis and treatment (Chen, Wen, & Yang, 2014). Healthcare service is co-created in the sense that the patient must participate and therefore welcomes a deeper level of engagement and interaction in contributing to effective care. Traditionally, these interactions take place within the confines of a hospital or medical practice, which affords co-location, facilitates scheduling and ensures access to required equipment and personnel. However, limitations also arise where patients may be hampered by mobility challenges, schedule conflicts, or late and missed appointments (Hull et al., 2002). Beyond these issues, there is also the requirement for patients to attend clinics in order to interact with clinicians and receive updated care review. This not only limits the patient clinician access dynamics, but also encroaches on the

limited time allocated per session. Patients now increasingly seek greater choice and technology can help clinicians to offer it (Coulter, 2005).As such, healthcare organisations such as the UK National Health Service (NHS) have been seeking greater efficiencies, coupled with increased patient support beyond the confines and structural setting of traditional hospitals (Silvestro & Silvestro, 2003). One such novel approach has emerged through the development and implementation of mobile phone applications, commonly referred to as apps (Neubeck et al., 2015). For example, in 2013 the NHS in England launched its online Health Apps Library, a pilot project to guide clinicians and patients to approved mobile apps to be downloaded and used on mobile phones (Boulos et al., 2014). During this period, the platform remained in operation for approximately two years until 2015, when data security concerns identified by researchers forced its closure (Huckvale et al., 2015). Despite this, more recently the NHS has opted to further engage in the digitalization process of healthcare support by reintroducing the availability of digital health tools for patient care and support (Ahmed et al., 2017). The NHS seeks to transform the patient experience through a combination of digital health tools and mobile services towards ensuring individuals receive the support and guidance required at their own pace and choosing (Bauer & Murphy, 2017). These healthcare mobile apps are filtered across a number of categories, ranging from oncology based support to keep track of breast cancer treatment, and mental health apps that support a range of treatment and support options (NHS, 2017). The phased reintroduction of these digital services for patient healthcare illustrates how healthcare service providers and app developers harness emerging technologies to more efficiently and effectively respond to patient needs (Chen et al., 2014) (Bauer & Murphy, 2017). However, developing relevant mobile healthcare apps is both challenging and fraught with uncertainty for clinicians, developers, and patients (Armstrong, 2015; Boulos et al., 2014; Maciver, Beltagui, & Dacre, 2016). For example, concerns over patient safety, the untested nature of digital mobile technologies in healthcare, and context and forms of usage contribute to perceptions of usefulness and non-usefulness of mobile healthcare applications (Wu, Li, & Fu, 2011).

The ubiquity of mobile phones has led to rapid growth in m-commerce, which involves consumers accessing services using their phones, through web browsers or dedicated apps (Chong, 2013). The issues faced by the NHS, however, cast doubt on the extent to which professional services, such as healthcare, are as easily translated into mobile apps (Ahmed et al., 2017; Armstrong, 2015). This requires greater attention in service innovation research and practice. For example, healthcare is considered an important but underdeveloped context for researchers of service innovation (Berry & Bendapudi, 2007; Chen et al., 2014). In particular, innovations involving the use of information systems provide opportunities and challenges that demand further study (Chao et al., 2007; Romanow, Cho, & Straub, 2012; Yang & Hsiao, 2009).

Digital technologies can assist with diagnosis, patient monitoring and interpretation of medical data. They can also provide opportunities to change the traditional paradigm of face-to-face, doctor-patient relations to reduce costs and improve outcomes (Berry & Mirabito, 2010; Chen et al., 2014; Fichman, Kohli, &

Krishnan, 2011). As such, ongoing innovative technological developments with increased access to smartphones and the use of mobile apps, offer medical professionals opportunities to promote greater healthcare support (Bauer & Murphy, 2017; Luxton et al., 2011). Research suggests that mobile technology has been adopted across a range of support services to facilitate clinicians' care of patients (Car et al., 2008; Klasnja & Pratt, 2012; Lee et al., 2009). However, despite this adoption, the literature suggests that there is a greater need to understand how patients may participate in the co-creation development process of mobile health apps across knowledge boundaries (Boulos et al., 2011). Prior studies suggest that patients offer a rich source of knowledge, which can be accessed by engaging in co-creation for product and service development services (Edvardsson et al., 2012). The co-creation literature suggests that customers contribute their resources, including knowledge, to value creation (Vargo & Lusch, 2008). Additionally, co-creation studies typically focus on relationships between customers and service providers (Cui & Wu, 2016; Edvardsson et al., 2012). Mobile healthcare development relies on both healthcare and software knowledge that increases the complexity of relationships (Boulos et al., 2011; Chen et al., 2014; Free et al., 2013). Furthermore, the transfer of knowledge between groups of actors can be facilitated across boundary objects, representing an embodiment of knowledge capture and exchange (Carlile, 2002; Le Dain & Merminod, 2014; Star & Griesemer, 1989). However, few studies in the co-creation field demonstrate the precise mechanisms and relationships by which knowledge is exchanged and combined (Perks, Gruber, & Edvardsson, 2012) and few studies have applied the concept of boundary objects, from information systems and organisational behaviour, to innovation (e.g. Moultrie, 2015). This paper addresses these gaps by understanding innovative healthcare mobile co-creation through the theoretical lens of boundary objects (Carlile, 2002; Star & Griesemer, 1989). We focus on understanding how the use of boundary objects supports the co-creation process in service innovation by allowing knowledge transfer across boundaries. We specifically examine the triadic relationship between the patients as service users, clinicians as service providers, and app developers as innovators and the knowledge transfer across both professional and user knowledge boundaries in the development of innovative healthcare mobile applications.

This research adopts the following structure. First we review existing literature to develop a foundation for our research approach. We focus on concepts of co-creation and boundary objects. We then introduce the empirical setting and research methods which support our research approach. Our empirical data was collected across the development of healthcare mobile app services. The findings lead to insights on the role that boundary objects play in co-creation, which contributes to knowledge in both innovation management and service management. Finally we discuss the implications for theory and practice in mobile healthcare app development.

THEORETICAL BACKGROUND

Healthcare Mobile Apps

Professional services, and healthcare services in particular, are under pressure to innovate and reduce costs while delivering more value to a population growing in size, average age and care requirements (Chen et al., 2014; Lin & Hsieh, 2014). A promising avenue for achieving these conflicting goals is through the use of mobile phone based software applications to transform some services into standardised products for download (Armstrong, 2015; Bauer & Murphy, 2017; Chen et al., 2014). The mobile phone is the most rapidly diffused technological artefact in history, leading to its rapid adoption for service delivery (Kumar & Zahn, 2003; Wajcman, 2008), Chong, 2013). In combination with the benefit of internet access that current smartphones provide, barriers to communication can be removed allowing unprecedented opportunities for service user contact and service innovation (Chen et al., 2014). These apps also fit with two wider trends that affect healthcare as much as other services: firstly the digital transformation of healthcare services (Bauer & Murphy, 2017), and secondly, the recognition that services are co-created through customer participation (Edvardsson et al., 2012). Healthcare providers and developers recognise digital technologies as a possible means of making healthcare services safer, cheaper and more widely accessible to patients (Agarwal et al., 2010; Fichman et al., 2011; Romanow et al., 2012). For example, through the advent of mobile technologies, traditional healthcare as an “inside-out” practice is being reshaped as an “outside-in” service (Chen et al., 2014, p. 514). Rather than requiring patients be present in hospitals, this means healthcare professionals can reach out to patients. This approach is not only more proactive and effective, but facilitates an experience-centric approach to service design that allows users’ needs to be better accommodated (Beltagui, Candi, & Riedel, 2016). These nascent approaches create opportunities for researchers to investigate both the design of healthcare information systems, and the patient’s perspective as a user of these systems (Romanow et al., 2012).

According to Chen et al. (2014), nascent digital healthcare reflects service innovation. For example, healthcare approaches that exhibit service innovation with the introduction of new processes, such as with novel diagnostic technologies, surgical technique development, the evolution of medical knowledge, or the application of mobile approaches for patient safety, reflect innovations in types of services (Chao et al., 2007; Consoli, 2007). The literature in this field has gained prominence in investigating and understanding innovative healthcare services (Chen et al., 2014). Furthermore, the service innovation literature identifies the role of customers in service development and the success of service delivery in professional services such as healthcare, often dependent on customers’ actions, rather than those of service providers (Chen et al., 2014; Edvardsson et al., 2012; Perks et al., 2012; Seiders et al., 2015). However, developing healthcare mobile apps as service innovations is challenging (Maciver, Beltagui, et al., 2016). Developers are faced with not only the regular IT challenges of user acceptance (Venkatesh et al., 2003) but also the professional service challenges such as opacity and external control of

knowledge (Von Nordenflycht, 2010). This suggests a level of complexity that spans multiple knowledge boundaries. Further challenges highlighted by Boulos et al. (2014) stipulate that mobile health app developers generally focus on the aesthetics of their medical apps, without taking into consideration the digital literacy of patients and clinicians alongside cognitive accessibility dimension. Ahmed et al. (2017) highlight that apps vary in quality of design, appropriateness, and suitability for their intended target audience. This leads to clinicians limiting the extent of their recommendations of app usage with patients, where these are deemed to exhibit low levels of patient value. Furthermore, there is a myriad of health related apps, with estimates suggesting as many as 150,000 across Europe resulting in 102 billion downloads, however despite these figures there is a stark contrast on how these apps should be used and how relevant they are for their users (Armstrong, 2015). These salient points raise significant questions as to the validity and value of healthcare mobile app development as innovations within the realms of value added services for medical organisations and their patients. Thus, a proposed approach in ensuring higher levels of mobile app relevance for medical professionals and patients, is by engaging service users and service providers in the co-creation of healthcare service innovations (Ramaswamy & Ozcan, 2014).

Co-Creation

Although empirical evidence of co-creation remains limited (Gemser & Perks, 2015), the co-creation perspective has been conceptually outlined over the last decade (Perks et al., 2012). Co-creation asserts that service innovations are enhanced through the interrelationship and exchange of knowledge between service providers and service users towards value added outcomes (Gemser & Perks, 2015). Mainly, that input from stakeholders typically centred on firms and customers, are inherently beneficial to the development of innovative services or products (Edvardsson et al., 2012). Perks et al. (2012, p. 935) define co-creation as “the joint creation of value by the firm and its network of various entities”. These entities generally refer to customers, and companies as suppliers of product and services. Innovations thus emerges through the behaviours, interactions, and sharing of knowledge with consumer and business stakeholders. This perspective rejects the binary division of producers and consumers of value. Instead, it views all actors as resource integrators, whose knowledge provides the basis for interactions that co-create value (Vargo & Lusch, 2008). Edvardsson et al. (2012) suggest that the value proposition of co-creation emerges through the development of service innovation, in that value reflects the activities and knowledge input from service users and the interrelationship with service providers. The authors conceptualised the knowledge input capture and customer integration practices across four dimensions, being insitu, exsitu, incontext, and excontext. Insitu refers to knowledge that is captured in the service user’s usage situation. Conversely, exsitu denotes data capture beyond the use situation of actors. Incontext and excontext reflect the actual direct engagement or non-engagement of resources pertinent to the co-creation process. The result of their findings suggest that

actor integration in co-creation may differentiate between how experiences manifest and are captured (i.e. insitu or exsitu). This leads to a typology of correspondents (report from the situation), reflective practitioners (in context but exsitu), testers (insitu but excontext), and dreamers (excontext and exsitu) in the integration of customers in co-creation. The framework provides a salient approach to understanding and interpreting various modes of customer integration and how these add value in co-creation practice.

Gemser and Perks (2015) suggest firms gain greater value from co-creation in fulfilling customer expectations by proactively engaging with their consumers across innovation processes. For example, by entertaining stakeholder engagement in new product development, firms can maximise innovation and value outputs by focusing on product specificity which relate to their intended audience and intended usage. Co-creation in these circumstances alleviate inherent challenges in translating customer needs into relevant services and products. Gemser and Perks (2015, p. 664) suggest “there is a need for a better understanding of the conditions under which customer co-creation leads to successful innovations”. Specifically, further empirical insights are required by examining stages of customer involvement with co-creation processes in developing service or product innovations. One of the suggested stages of consumer involvement lies at the fuzzy front end, in that stakeholders can engage, communicate and share insights at the idea generation of new products and services. Cui and Wu (2017) suggest a differentiation of co-creation from alternative forms of consumer innovation at the idea generation stage. For example, in their research they adopt the premise that co-creation enables consumer involvement in the design of products, unlike crowdsourcing which relies on acquiring new ideas. This is salient in understanding co-creation as a process of product and service development in concert with firms, rather than solely stimulating ideas where companies develop products independently from their customers.

Within the realm of healthcare, Prahalad and Ramaswamy (2004) conceptualised the process of co-creation value focused on cardiac pacemakers. They suggest that traditionally, pacemaker manufacturers gain value at the point of sale, in that when the exchange from a manufactured product to a purchased product, this entails value through the transaction exchange from consumer to company (Prahalad, 2004). However the inherent value embedded in the pacemaker itself can be enhanced further. For example, Prahalad and Ramaswamy (2004) outline a scenario where the function of patient pacemakers are improved to include remote monitoring towards increasing medical support when away from the hospital. This enables mobile monitoring of patient requirements with greater health benefits and early diagnosis of potential issues. They suggest that this can be achieved through the concept of users’ experiential context in adding value to the co-creation process. Essentially, sharing user experiences through communication across stakeholders illustrates the value of co-creation by adapting existing technology to novel implementations , in that “the co-creation experience originates in the patient’s interactions” (Prahalad & Ramaswamy, 2004, p. 10). Additionally, Ramaswamy and Ozcan (2014, p. 157) suggest that

emergent technologies and novel patient engagement processes can “transform healthcare experiences through co-creation”. However, in both the delivery of healthcare services and design of healthcare apps, there is asymmetry in the knowledge of professionals and their customers that makes interaction and co-creation difficult across a range of dimensions (Løwendahl, 2005). Furthermore, there are considerable knowledge boundaries between groups of software professionals, healthcare professionals and patients/users of these services (Carlile, 2002).

Effectively capturing the breadth of patient experiences (Prahalad & Ramaswamy, 2004), whether insitu or exsitu (Edvardsson et al., 2012), to enhance the creation of value in healthcare (Perks et al., 2012), by translating stakeholder requirements and expectations (Gemser & Perks, 2015) across professional interactions (Vargo & Lusch, 2008), from fuzzy front end to product and service development (Cui & Wu, 2017) suggests a complex multiparty co-creation process of service innovations across knowledge boundaries (Carlile, 2002). For example, recent service management theory considers service as the integration of knowledge by customers and service providers (Vargo and Lusch, 2008). With a few exceptions (e.g. Perks et al., 2012), the service innovation literature rarely shows empirically how the knowledge of customers and suppliers is integrated. How the knowledge boundaries can be overcome in service development and delivery is not well understood, which limits the contributions that service innovation scholars can make to practitioners. In contrast, the information systems literature offers the concept of boundary objects (Carlile, 2002), which may be physical artefacts or abstract concepts that facilitate the transfer of knowledge between groups of experts.

Knowledge and Boundary Objects

Carlile (2002) suggests that knowledge embodies both the premise of an enabler and barrier for innovation. Individual internalised expertise which has been gained through exposure of practice and academic knowledge, serves as a source to generate ideas and build upon these through the development of new products and services, but also hampers the interchange and communication of shared understanding. Developing new products and innovative services generally necessitates collaborative practice across teams of individuals with various levels of expertise, experiences, and ideologies which underpin knowledge creation (Carlile, 2004). Engaging actors in development activities, thus requires the exchange and sharing of knowledge, whilst overcoming boundaries of disparate understanding and varied interpretations (Ewenstein & Whyte, 2009). For example, in professional services, such as in software development, the collaborative effort of an interdisciplinary group of professionals is required (Barrett & Oborn, 2010). Their educational, professional and social backgrounds result in a body of knowledge and shared working practices that allow them to collaborate with peers (Nandhakumar, Panourgias, & Scarbrough, 2013). However, these backgrounds also result in knowledge boundaries that make collaboration difficult between different groups (Star & Griesemer, 1989). Software development may require collaboration between

technically oriented programmers and user oriented designers (Dacre, Constantinides, & Nandhakumar, 2014; Maciver, Beltagui, et al., 2016). The former will define and solve problems by building upon their technical knowledge and see challenges as opportunities to further develop this technical knowledge. The latter, on the other hand, will define problems in terms of their knowledge of design and of user experience, with projects helping to enhance their design knowledge. Furthermore, engaging individuals to collaborate and participate in knowledge sharing and idea generation can be challenging without the right context of motivation (Dacre, Constantinides, & Nandhakumar, 2015). However, the difficulties in collaboration may be avoided rather than addressed through modular project management that limits interactions (Maciver, Malins, et al., 2016). This avoids the problem of knowledge boundaries, but fails to take advantage of the potential for knowledge combination. Examples of these challenges in practice are illustrated through the seminal work of Carlile (2002) in studying new product development with an automotive parts manufacturer. Different practices with individuals embedded with levels of expertise, elicited boundaries across areas of knowledge in collaborative processes. In order to manage these boundaries, teams undertook to find and develop commonality in their approaches as a foundation for shared understanding. As such, in this case the common adoption and reliance on technical drawings between designers and engineers within the automotive parts manufacturer, enabled the interchange of knowledge as an instantiation of an object of knowledge. This reflects to the concept of boundary objects developed by Star and Griesemer (1989), in that Carlile (2002, p. 451) suggests that these objects establish “a shared syntax or language for individuals to represent their knowledge”.

The concept of boundary objects originally emerged from research undertaken by Star and Griesemer (1989) in their study of multidisciplinary teams at Berkeley’s Museum of Vertebrate Zoology. They identified that levels of expertise varied between individuals, for example academics, scientists and enthusiasts. To overcome the boundaries in their knowledge, boundary objects such as maps and field notes allowed actors from differing backgrounds, but with related objectives, to effectively exchange knowledge (Ewenstein & Whyte, 2009). Boundary objects can also be related to the concept of reflective practice in design (Schön, 2017), whereby an actor’s knowledge is developed through a process of interaction with objects. Schön (2017) describes an architecture student’s conversation with her tutor in which a drawing is used to exchange knowledge between the individuals. More than simply communicating, the drawing allows both to share their ideas and overcome boundaries in their knowledge Carlile (2002). While such explicit boundary objects have been studied extensively, more recently information systems scholars have looked at the role of conceptual boundary objects. Allhutter and Hofmann (2010) demonstrate a reflective practice of negotiation between actors in which the differences between their perspectives are deconstructed to uncover conceptual boundaries between them. Conversely, boundary objects described by Carlile (2002) in the study of an automotive parts manufacturer, focus on clearly defined objects, such as diagrams, which inherently embody parameters and

borders. However, Ewenstein and Whyte (2009) have sought to differentiate between boundary objects which may be closed, and open. Nandhakumar et al. (2013, p. 935) suggested that open boundary objects may take the form of a vision or concept that helps to overcome boundaries between individuals, whereas closed objects are "stable representations of expert knowledge across existing and well-defined boundaries of expertise". Essentially, open boundary objects may be interpreted as a conduit to *opening-up* conversations towards developing further knowledge through the development of shared perceptions and understanding. This is salient in enabling open discussions instead of surmising solutions during development of products and service innovations. Accordingly, whether open or closed, boundary objects suggest the opportunity for engaged collaboration between stakeholders across knowledge boundaries in co-creation processes. This is particularly salient, in that as previously outlined co-creation processes rely on a number of dimensions where communication and the exchange of knowledge are pivotal to new product and service innovations across teams, firms, and customers with different experiences and knowledge.

Research Focus

Through the review of existing literature, associate concepts, and by establishing the context of the study we focus our empirical research on the following premise. First, the context of study is defined as the development of healthcare mobile apps as service innovations. We have established that this can be challenging in dint of the complex nature of developing systems for intended audiences, and ensuring adoption, usage, and value for patients and clinicians. Second, the literature suggests that co-creation processes offer a foundation upon which stakeholders are engaged during the development of novel services. In turn use the concepts of insitu and exsitu as sensitizing devices to explore experiences and knowledge that emerge from situated and non-situated use. This enables our study to examine the relationship between active and reflective users during co-creation. Third, boundary objects offer a focal point of analysis, and as such adopt this as our unit of analysis in interpreting the exchange and embodiment of knowledge during co-creation between stakeholders. In this case the identified parties are the service users, as in the patients, the service providers which are the clinicians, and the developers responsible for the practice of coding, interface design and user experience. Fourth, the key research questions addressed in this paper relate to whether and how high contact, high variety and high volume service can be simultaneously achieved through the use of apps for healthcare services. Drawing on theories of co-creation and boundary objects, we are able to examine the knowledge boundaries, and the complex interactions required to overcome them, in development and use of healthcare mobile apps.

EMPIRICAL APPROACH

Our study draws from a largely exploratory approach in examining phenomena of co-creation across boundary objects in the development of healthcare mobile apps. As such we adopt appropriate qualitative methods of empirical data

collection and analysis to review our findings and uncover emergent themes. We thus employed suitable methods of data collection to support our main research aims. This entailed identifying relevant examples of co-creation practice in the development of mobile apps within a healthcare context. We were also mindful of the sensitive nature of our research within a healthcare context, and undertook to ensure that our research adhered to ethical guidelines. This ensured that high levels of rich data were acquired whilst limiting exposure to potential sensitive individual issues.

Empirical Setting

To examine the development of healthcare mobile apps, we gained access to a software and application development company based in England. This company was founded by a digital entrepreneur who has grown the company from its early inception to form part of a much larger organisation through equity funding. The firm employs a number of technical experts, software developers, designers and illustrators, user experience, and project managers. Teams are primarily situated in the UK, with some off-shore capacity. Employees are responsible for different areas of development, for example front-end design, back-end technical development, data security, and graphic design and administrator roles. The company was experienced in developing a range of mobile apps and online website portals for large multinational companies. The firm also had a portfolio of mobile apps focused on healthcare support. One of their main active projects, was commissioned by clinicians in the NHS to help support their patients.

Data Collection

Data collection mainly relied on semi-structured and in-depth interviews. We initially engaged with the company through the adoption of unstructured interviews, this enabled us to understand the context of the field site, the projects, and the company's context. During this stage we used a combination of telephone, and skype meetings to explore the processes adopted by the company in creating mobile apps. This was ensued by further in-depth engagement through a combination of site visit and further interviews. Having already explored the initial context of study through unstructured interviews, the ensuing semi-structured approach enabled us to refine our understanding of the co-creation processes, limitations, and challenges. This approach offered the majority of insights. Where early themes emerged we then revisited pertinent data through further in-depth interviews. This enabled us to refine our initial findings and re-assess data where required. For example, during ensuing interviews we followed a pre-defined set of questions to uncover details on the purpose of the apps, the interviewees' roles, and in particular to probe the development process and the interactions between developers, clinicians and patients. During the site visit we were also able to observe practice in action, the context of development, and team interactions. Within the company we interviewed all members of the team, which included the MD (Managing Director/Founder), FE (the Front-End developers and user experience designers) and BE (Back-End developers and technical experts). Documentation was

provided to further support our understanding of the development process and communications between clinical, patient, and software teams. Videos produced by the hospital to promote the apps were also used to uncover the client and user's perspective. These videos present comments by end users who were involved in the development process. Finally, we downloaded and reviewed the apps to better understand their functionalities.

Data Analysis

The interviews were transcribed and then coded collaboratively by the research team, using regular coding meetings to control the reliability of interpretations (Miles & Huberman, 1994). Coding focused on resource integration and knowledge boundaries, examining how actors contributed through their specialised or professional knowledge base, and the extent to which co-creation was required. Thus, we first ascribed descriptive codes to chunks of text relevant to the development process and development context. This approach consigned relevant segments of interviews, archival material and observations to pertinent actions, activities, and practices associated with co-creation processes. We relied on theoretical elements of co-creation and boundary objects to contextualise our codes. Ensuing this approach, we were then able to coalesce these codes into emergent themes. As such, our findings and remarks are presented in the following sections.

FINDINGS

This study examines co-creation and knowledge boundaries by examining the interaction between actors in the development of a digital professional service-product, i.e. a healthcare mobile app. This section presents a narrative of the development process, from kick-off to launch, and identifies the knowledge boundaries between the actors involved. The following description focuses on two key aspects: 1) the knowledge boundaries and between actors and 2) the approaches taken to mediate these knowledge boundaries, find resolution and co-create the app.

Problem identification / Briefing

The app was developed following identification by clinicians of the problem, namely the need for early intervention to support teenagers with mental health. The clinicians faced limitations to their ability to provide the service due to resource constraints. A particular issue is the length of time that passes between appointments. This makes it difficult for the clinician to detect and address symptoms, but also limits the patient's ability to report symptoms. For example, asking a patient to recall how they felt in the four to six weeks since the last appointment presents both a recall challenge and risks losing details. However, an app, downloaded to the patient's mobile phone, allows opportunities for continuous, if indirect, contact.

The project began by developing understanding of the challenge in transforming clinical services into a product. As with most design projects, there was a need to

define the problem and solution simultaneously. The first knowledge boundary was revealed from the initial brief, which amounted to “about half a page” (BE) of text. The clinicians, with little previous experience of software development, had delivered a very loosely defined brief, and their understanding of both the process and the outcome of development were vague. In general, the clinicians lacked knowledge of the technical possibilities. The developers, on the other hand, lacked knowledge of users, which is not unusual since most software developers have little direct contact with end users. They also lacked knowledge of the service to be delivered, due to the specialised subject specific knowledge required to deliver healthcare services. This necessitated an unusual development process in which clinicians were given considerable time to provide inputs and developers were made to wait due to the clinicians’ busy schedules. However, the delays were seen positively because they allowed time and freedom to explore possible approaches.

“We would actually explain stuff to the clients and they were really friendly to approve stuff and that's very good interaction. So the more freedom they give to the developers, the better the app is” (BE)

Understanding of the problem and potential solution was co-evolved by the clinician and developer using a process of knowledge sharing, and demanding a high level of in-depth communication between those stakeholders. Yet while the design brief remained as a sketchy, half-page document, the ideas and discussions between clinician and developer left the app company in an autonomous position, able to lead, innovate and make propositions in the course of the development process.

Problem Framing

Interdisciplinary teams are regarded as crucial in developing solutions to complex, multi-faceted design problems. In this case, a workshop attended by social workers, clinical teams and patients was mediated by the developer, whose aim was to gather knowledge, insights and perspectives, and arrange this data “into some sort of structure that could work within the software” (MD), later articulating it visually in a diagram to inform the development of the app.

The developer’s role was proactive in propelling the project forward by filling the knowledge gaps between stakeholders involved in the app development. Using their experience of user requirements capture, the MD managed the wealth of information, by creating a framework to collate, filter and interpret knowledge:

“I created a framework document which I asked them to fill out the purpose of the app, what were the outcomes they were looking for, also what was the target audience. And what were certain stakeholders that were involved on the project. So we started to fill this information” (MD)

This was evidently a strategic move for the firm: bringing the project to a successful completion would enhance their portfolio, and therefore the likelihood of further projects and business.

Solution Development / Content Development

Due to the nature of the apps and the origin of the knowledge used to develop them, the software solution and the clinical content were separated. For example, the developers suggested the use of menus, providing users with different options to classify their mood or the factors that could influence their mood. However, without clinical knowledge, the developers required input from the clinicians to populate the list, for example ‘taking medication’, or ‘spending time with friends’. The patients could test the features developed and also made inputs into the development, such as proposing the use of a mood diary to help keep track of their mood, which would also improve their interactions with clinicians.

“I think the clinicians, they thought of an idea like, "We want like a mood diary, we want a graph,”… And I think they asked the users as well, "Will this benefit you?" Because obviously you don't want something in the app which isn't really beneficial. And then actually once we had the app complete we went into like a sort of… workshop but just to see some users and then demonstrate the app with them, make sure they can sign up and see their reactions to how the app works and dabble with features, and things like that. Yeah, the feedback was generated very positive.” (FE)

In this example, the interaction between all three groups – developers, clinicians and patients – demonstrates the nature of co-creation in this process. Another example that originated with developers was the use of a traffic light indication of mood – green for positive, red for negative. While the concept of a visual representation was appreciated by clinicians, they rejected the negative connotations of a red light. Later, in consultation with patients, an alternative was developed:

“…we added a little twist to it…you have like a question, ‘How is your mood today?’ And then there would be a set of answers ranging from, ‘Really good’ to ‘Really poor’. Things between. And there's an avatar at the top. So when you press on an answer before submitting you have to select an answer and then submit. So when you select an answer the avatar changes face, changes emotion, and the users really liked this sort of emotional feedback which came along with it.” (FE)

The origins of such features depend upon inputs from all three parties and the specific knowledge each provides. Developers can make propositions, based on their knowledge of technological capabilities, and their analysis of trends in app development. The clinicians can both contribute content and provide medical reasoning to support or oppose the features, while users provide both a source of ideas and evaluation of the apps, based on their knowledge of symptoms and user experience.

Both content and solution evolve through a process of co-creation. The technical aspects are handled within the developing firm by both the FE and BE specialists, and require the sharing of specialist domains of expertise. The perspective of the clinician is also included in the process, as the technologists cycle back and forth

collecting insight and iterating upon the solution and concept in a process of reflective practice (Schön, 2017).

The solution development requires research and the meshing of the FE and BE specialist knowledge to ascertain technical boundaries, which informs their exploration of potential ideas and opportunities. This process takes place iteratively, the technologists calling on the clinicians for their input and approval before any technical coding is undertaken for a unified vision. The developers describe the process of generating buy-in of their ideas, building clinicians' understanding of the idea from initial knowledge transfer discussions, to sketching ideas, to showing UML (unified modelling language) flow diagrams, and eventually visualising an interactive prototype, all prior to technical development:

"Initially the UX developer would be like drawing with the free hands and with paper and pen and pencil. Then he'd be showing to clients, and then we'll be Photoshopping it. Then we'd get it approved from the client again. Then I'd start to create layouts in Android with Java. Then I'd start to create a back-end algorithms" (BE)

Despite the gap of perspectives, having buy-in and sharing knowledge is crucial for the developer in arriving at the best possible solution: "These are doctors…as technical guys we've got to explain them what are the pros and cons and then how we can improve the app performance-wise or improve the marketing so all people start to use it" (BE).

Evaluation and Iteration

Evaluation and iteration is a looped process. Multiple evaluation sessions were carried out with patients throughout the development process. The feedback from these sessions was then incorporated into versions of the app as it was improved and readied for launch. However, for ethical reasons, testing and evaluation of the app could not be carried out directly between developers and patients. Instead, this gap was bridged by the clinicians. To surmount this division, the developer compiled a methodology which would gather the information required from end users in a workshop run by clinicians:

"I put together almost like a training program that the clinicians could run in a focus group. And it was basically pieces of paper where the groups of users would make decisions on the floor. So they would take a step and they would have to make a choice" (MD)

A final dimension to the iteration and evaluation phase concerns the external technological environment. This represents a further knowledge gap: developers have no control over updates, new releases or timing of these on the platforms for which they are developing. In this case, Android released a significant update during the development period which necessitated redevelopment, from scratch, of work already completed.

“In terms of the period that we were designing it, the challenge was that Android would release newer versions so quite quickly the product that we've built was outdated. So we had to almost build from scratch” (MD)

While such a setback can be frustrating, especially close to launch, it can be used as an opportunity for knowledge creation and maintenance, and development of organisational capabilities. Developers described attempting to anticipate technological changes by interacting amongst their “community” (BE), as well as research to keep abreast of trends and developments. Development of such capabilities increases the likelihood of repeat business, or fostering an ongoing developer-client contract to keep the product remains fully functioning and at the cutting-edge of technology. As an extension of the link between knowledge and business sustainability, the MD describes offering assistance to individual entrepreneurs through a process of offering advice based on the firm’s capabilities and acquiring of new knowledge:

“I've got a number of people I'm working with individually. I'm giving them free consultancy to help them convert their ideas into something. Hopefully at the end of that we might get some work out of it, but at the same time it's nice to be able to support people through the process” (MD)

Experimental research allows the developers to push boundaries and innovate. In essence, knowledge, innovation and the business are inextricably interlinked:

“We have to implement something new to achieve something new in the market” (BE)

Furthermore, there was the potential to roll out the app as a product for other NHS trusts. There was an early indication of interest in this product elsewhere in England. In this case, the app development firm had an obligation to inform the initial commissioning trust, however since the solution framework is the intellectual property of the developer, it is feasible that this product could be replicated, packaged and sold, in a less intensive partnership, to other interested clients.

DISCUSSION

The development of healthcare apps brings into play a number of knowledge boundaries. Firstly, there is an internal challenge of collaboration between designers and programmers. Each of these represents a distinct community, based on education and history, with a shared knowledge base, vocabulary and body of methods that creates a divide between the two groups. Next there is an external challenge, common to all professional services, of knowledge boundaries between customers and service providers that can be referred to as opaque quality (Von Nordenflycht, 2010). In other words, since customers lack knowledge of the service, and the professional may be unable to fully describe the process, it is difficult for customers to understand and evaluate the service prior to experiencing it. In the scenario described in this paper, this knowledge boundary occurs in two places: firstly between the patient and the clinician, and secondly between the clinician and software development firm. Additionally,

there is the challenge of user acceptance, which is familiar for all software related innovations (Venkatesh et al., 2003). The combination and interplay between these challenges makes healthcare app development particularly difficult. Overcoming such challenges is therefore a priority, given the potential benefits to service providers and service users.

Co-creation in this context entails the sharing and integration of knowledge across boundaries. Unless this is achieved, none of these groups of actors is in a position to create a workable solution individually. This study identifies the use of boundary objects within the process as a tool for co-creation. Knowledge from patients (experts in their symptoms and use of apps), clinicians (experts in the service, including diagnosis and treatment of patients) and software designers/developers (experts in user-centred design and in software development) is integrated. The app itself acts as an open boundary object (Ewenstein & Whyte, 2009; Nandhakumar et al., 2013), which is a dynamic means of facilitating interaction across boundaries. As an initial concept that becomes more refined over the development process, it helps to elicit user feedback, generate ideas and align concepts with the multiple, often competing, criteria that the service must meet. And when in use it acts as a boundary object that facilitates co-creation between service provider and service in service delivery.

Through the analysis of our data, three particular themes emerge from the description of this healthcare app development process. Firstly, the need for co-creation across knowledge boundaries is evident. While the co-creation literature highlights the need to combine resources, this study helps to elaborate the specific challenges this entails. Secondly, the use of boundary objects as a means to facilitate co-creation during service design and delivery is outlined. And finally, the role of apps as an open boundary object as well as the change in this role over the stages in service design and delivery represents a valuable contribution to knowledge.

In the Perks et al. (2012) study of co-creation, a detailed analysis is offered of how specific services emerge through the influence of employees and of customers. In most cases however, interaction between both is required irrespective of the origin. In this study, the extent of co-creation is examined by demonstrating the inputs of developers, clinicians and patients. The co-creation literature assumes that all value is co-created, and that goods and services merely hide the exchange of knowledge resources between actors (Vargo & Lusch, 2008). Here we are able to reveal how each actor contributes their resources and how these resources are integrated.

In framing the problem, an interaction is required between clinician and developer. This was described by the MD in terms of workshops to outline both the solution and problem. This closely resembles the processes outlined in the design thinking literature. Co-creation takes place at the boundaries between the knowledge of developers, clinicians and patients. We focus primarily on the app development, demonstrating that without the contributions of the other actors, this app would be difficult or impossible. Developers wait for input from

clinicians. Clinicians seek feedback from users. Users propose ideas that are adapted and then improved through interaction between developers and clinicians.

Just as the clinicians are required to maintain their clinical knowledge, the developers continue to invest time and resources in updating their knowledge. This also has the effect of creating greater boundaries. Indeed, one feature of communities is they are defined as much by who they exclude as who they include – hence the moral obligation to the community.

The app itself acts as a boundary object. From the descriptions of its intended usage, the app clearly mediates the boundary between patients and clinicians. It allows patients to communicate more effectively with the clinician, partially overcoming the challenge of information asymmetry in professional services (Løwendahl, 2005; Von Nordenflycht, 2010). Additionally, it provides a means of encouraging the patient to follow the clinician's instructions. This has been identified as a challenge when the success of the service demands the customer's continual input, for example in taking medication (Seiders et al., 2015).

In the development process, the app also acts as the boundary object that allows the diverse knowledge bases of actors to be overcome. The clinicians display lack of software knowledge from their vague initial brief and although the software developers could make suggestions, they typically required clinical input. For example, in discussing the development of a drop down menu as part of the mood diary feature:

"…if someone says that their sleep was really rubbish what does that mean?... So that's when we started to think, "Well okay, so if it's a negative value let's have a sub-question that pops up." So then we put it back to the clinical team and said, "What would those questions look like? …So that's when they came up with a list of sleep's being rubbish because I forgot to take my medicine, or relationship problems and things like this. So I think there was seven or eight different choices."

In this particular example, the overlap between the knowledge boundaries is demonstrated. Developers, as people who may suffer "rubbish" sleep may have some understanding of mental health. However, their knowledge is insufficient to reliably create the content for a mental health app. The interaction is facilitated by the ability to design and create features that act as boundary objects.

One question arising from the development process described is whether the case in question is unique - in other words, to what extent this form of co-creation is representative of other contexts. This question can be partially answered by comparing the development of these healthcare apps with others that are less service oriented. For example, other apps that were included in the NHS App Library include Zombies Run, a smartphone based app to enhance the experience of jogging, thereby encouraging exercise and good health. Using the phone's audio player, the app will allow the user to imagine they are being chased by zombies, whom they must outrun. This is intended to stimulate

excitement and enjoyment of exercise. Mental health services demand certain levels of understanding and a sensitive approach to patients. This can be seen in the rejection of a traffic light visualisation and the approval of a happy face to personify the user's mood. For a fitness oriented app however, the patient's needs are easier to understand and less demanding of professional, clinical knowledge. It is, therefore, conceivable that a fitness app can be developed without clinical knowledge and without user involvement beyond usability testing. The difference is that a fitness app can be viewed as a product. This is because it requires little ongoing interaction between customer and service provider. Yet for the mental health apps examined in this study, the app alone is insufficient - its main purpose is to support the delivery of a complex service.

Information systems researchers have considered the extent to which processes that happen traditionally in physical form can be repeated in a digital or virtual form. Finding healthcare service through an app could suggest that even these professional services can be transformed into standardised products. On the evidence of this case however, there are some services that cannot be productised. The apps described play a vital role in supporting the service delivered, but do not deliver the service in isolation.

CONCLUSION

This paper makes important contributions to knowledge on service innovation and digital healthcare services. Firstly, it presents empirical evidence of co-creation through an account of a complex service innovation project. While many studies of co-creation assume that customers are resource integrators, they rarely demonstrate what resources customers possess and how these are integrated. In this study, the resources are defined in terms of the specialised knowledge of different actors. The knowledge is combined by overcoming knowledge boundaries between and within groups of developers, clinicians and patients. Each group contributes knowledge that is maintained and developed, but which is difficult for the other actors to capture. Mobile apps appear to be a promising direction for extending the efficiency and effectiveness of healthcare services, particularly given the resource constraints that are increasingly placed on these services. Exploring the knowledge boundaries and value co-creation in this case however suggests a note of caution for managers. The time, effort and specialised knowledge involved mean that human contributions cannot be easily replaced by apps. Apps do, however, help to support the delivery of more effective services and present a valuable avenue for further research in design, service management and information systems.

Our findings offer novel insights into the relationship between co-creation and iterative mobile application development processes across knowledge boundaries. The research suggests that addressing knowledge boundaries is salient in positioning formal structures of actor participation in mental health mobile app development. However, the findings also suggest that the adoption of iterative co-creation may facilitate service innovation where an application

serves as a boundary object between groups of actors during its development process.

This research contributes to knowledge of co-creation in digital service development by focusing on the exchange of knowledge across professional boundaries as well as between customers and firms. It builds on the concept of boundary objects as a means of sharing knowledge in the innovation process.

For practitioners, this research provides two key recommendations. Firstly, it highlights the importance of co-creation in app development. Users of technology provide valuable insights and a source of ideas that complement developers' abilities. Equally, professional service providers possess knowledge that is necessary for the creation of the app, and must be involved effectively. Secondly, the research proposes the use of boundary objects throughout the innovation process as a means of engaging actors, and ensuring they are able to engage in co-creation by overcoming knowledge boundaries.

We therefore contribute to the understanding of service innovation by exploring the development of apps to support the delivery of healthcare services. Drawing on theories from design, service management and information systems, we examine the knowledge boundaries, and the complex interactions required to overcome them, in development and use of these apps. Ultimately, we argue that the knowledge boundaries prevent some services from becoming completely standardised products. For software development and healthcare professionals, close collaboration to overcome knowledge boundaries creates opportunities for service innovation. For policy makers or managers seeking to cut cost and improve quality of healthcare services, apps should offer opportunities in the long term. Our findings, however, suggest that developing these apps demands investment of time and knowledge in the short term and supports rather than replaces professional service employees.

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