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Implementing disruptive technological change in UK healthcare: exploring the development of a smart phone app for remote patient monitoring as a boundary object *

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Abstract

Developing and applying technological innovations in healthcare is a complex and uncertain process, due to the many surprising and unexpected effects upon the practices, perspectives and interests of the variety of professional and managerial stakeholders involved. In this paper, we draw upon the concept of boundary object to explore processes of collaboration, knowledge transformation and learning associated with the development, use and (prospective) wider diffusion in the English healthcare system of a particular type of healthcare innovation: a smart phone app for use by rheumatoid arthritis patients. Taking into account that technological artefacts can both enable and inhibit collaboration, as well as evolve during their development, we explore the challenges of overcoming tensions between the transformative and learning capabilities of such technological artefacts and the inhibitions that these capabilities simultaneously create for change at a wider system level.

Introduction

The paper is directly concerned with understanding the complexities and challenges of change in the healthcare context and specifically focuses upon the role of healthcare technology. It focuses upon the development and application of a particular novel technology within healthcare organizations, addressing how the development, adoption and implementation processes associated with the technology affected the various professional, managerial and patient groups involved or implicated in its design, delivery and use. It particularly concentrates upon understanding relationships between these groups as they were mediated through the technological object and the impact of technical innovation upon their (changing) knowledge and practices. In doing so, it examines some of the complex and surprising ways in which the

development of a particular technological artefact (in this case a smart phone app for patients' self-monitoring of rheumatoid arthritis) both reflects and, in turn, challenges the expectations, interests, influence and practices of key stakeholders involved in its design, development and use.

The purpose of this paper is therefore to examine the challenges associated with the development and implementation of new, disruptive forms of technological innovation in healthcare associated mobile phone technology. The specific case focused on is the development, implementation and use in an English hospital of a smart phone app for the use of patients with rheumatoid arthritis, whose data could be integrated into their electronic health record (EHR) and visible to clinicians during clinical consultations. The app was designed to enable more real-time monitoring of patient symptoms by patients themselves and to allow more bespoke individual treatment and targeted clinical consultations and interventions.

Developing and embedding such a technological innovation is a complex endeavour (Deering et al., 2013) and in this case involved contributions from various stakeholder groups including patients, clinical researchers, clinicians, practitioners (nurses, physios), software developers, hospital information technology (IT) specialists and hospital managers. In this paper we explore the complex inter-relationship between the co-production processes involved in the development of this innovation and the perspectives, interests and (changing) influence and practices of those stakeholders during its development and use. Drawing upon an empirical study which involved interviews and recorded clinical consultations with these stakeholders, we assess the wider implications for understanding the challenges associated with diffusing and embedding new IT innovations to support management of long term conditions within healthcare organizations and systems.

We do this by exploring the app, and the system of related objects involved in its development, as boundary objects (Star and Griesemer, 1989), considering its capabilities and limitations of integrating systems of knowledge and learning (e.g. Boland and Tenkasi, 1995; (Carlile, 2004 (Carlile, 2002) (Swan et al., 2007)). In brief, boundary objects assist individuals from different disciplines in translating or transforming information across disciplinary boundaries (Carlile, 2002) whilst allowing

each party to maintain their individual perspectives (Star and Griesemer, 1989). Three boundaries are of particular interest here: between development of the innovation and its use in practice; between the illness management led by the patient at home and that planned in the clinic; and between the implementation of the app from a single research clinic to wider scale up of the innovation.

Background

The challenges and complexities associated with diffusing and implementing technological change in healthcare have been studied extensively (e.g. Barrett and Oborn, 2010; Petrakaki et al, 2014). Indeed, research continues consistently to highlight not only the opportunities provided by innovations in technology – particularly those associated with information and communication technologies – but also the considerable difficulties involved in implementing and exploiting them in practice. This is due to the many unexpected challenges that arise in embedding them in and organizational systems due to the disruptive effects they might have upon professional and managerial practices (e.g. Lehouxa et al, 2012).

Research on technological innovations within healthcare has recently directed considerable attention towards understanding the role of technological artefacts – including both electronic and paper-based information systems – as boundary objects (Swan et al., 2007; Smith and Ward, 2015). Particular stress has been put on the integrative potential of systems such as electronic patient records (Saario et al., 2012) and magnetic resonance imaging (Reed et al., 2016) in helping bridge professional communities of practice in healthcare. Technological artefacts have also been shown to be important in connecting mainstream healthcare with complementary and alternative medicine (Keshet et al., 2013; Owens, 2015). However, a good deal of research has also emphasised the capacity of innovations – such as the development of new care pathways – to reinforce professional boundaries and barriers to interaction between professional groups (Allen, 2014; Hunter and Segrott, 2014).

Importantly, technological systems such as electronic health records (EHR) and electronic prescription services (EPS) can have disruptive effects on existing

professional work, practices and domains (Motulsky et al., 2011; Petrakaki et al., 2012, 2014; Reich, 2012). That means professional practices, norms and interests can be challenged and may need to be accommodated through the negotiation of interests in the development or implementation of new systems (Lehouxa et al., 2012; Constantinidis and Barrett, 2006). In turn, this inevitably creates considerable challenges to those attempting to develop, apply and diffuse such technological systems throughout healthcare organizations and across wider healthcare systems (Pols and Willems, 2011). Moreover, those challenges are magnified insofar as innovations in healthcare, particularly in telemedicine or through the use of mobile phone technology, also involve bridging the clinician-patient interface with all the complexities that brings for attempting to transform patient behaviour (Oudshoorn, 2008; Mol et al, 2010).

Stemming originally from the work of Star and Griesemer (1989), the concept of boundary objects has been used widely to help understand the ways in which knowledge is created, shared and integrated across boundaries of practice between specialist groups engaged in joint activity ((Boland Jr and Tenkasi, 1995), 1995; Carlile, 2002, 2004; Boland et al, 2007 (Boland Jr et al., 2007)). Crucially, the defining characteristic of boundary objects is that they have some interpretative flexibility or ‘plasticity’ (Star and Greisemer, 1989), which allows different groups engaged in distributed practices to interact with one another and to engage in joint activity – in the process, sharing or transforming their knowledge and practices (Carlile, 2002).

Research in this tradition has explored the use of various management systems, tools and techniques as boundary objects. Information systems have long been seen and conceived of as boundary objects (Levina and Vaast, 2005; Barrett and Oborn, 2010), since their specification and development presupposes the need for knowledge sharing across boundaries (Ewenstein and Whyte, 2009) and their operation directly involves flows of information and knowledge between inter-connected communities of practice. The focal partnership between clinician and patient in our case, may be viewed as one particular dyadic relationship which forms a boundary across which boundary objects may assist integration, knowledge transformation and learning. Other relevant boundaries may concern those linking actors involved in the development of the technological application itself (researchers, clinicians, software

developers, etc) and those concerned with its wider implementation and diffusion (practitioners, IT specialists and hospital managers).

While research has tended to emphasize the integrative possibilities afforded by boundary objects in bridging knowledge boundaries and facilitating joint knowledge sharing and creation (e.g. Star and Griesemer, 1989; (Boland Jr and Tenkasi, 1995)), more recent research has started to question their presumed ‘neutral’ qualities and ‘immutable’ characteristics. Increasing emphasis has been put instead upon understanding boundary objects as being not fixed or static, nor as neutral in how they shape action, but as flexible in how they are used over time such that they serve different purposes over the course of a particular collaboration (Nicolini 2011; Nicolini et al, 2012). Emphasis has also been placed on the role that boundary objects play when they are designed with the aim of aiding collaboration, and how they might evolve from being ‘designated boundary objects’ to ‘boundary objects-in-use’, integrated into everyday practice (Levina and Vaast, 2005).

Recent work has emphasized the importance of understanding the interconnectedness associated with systems of boundary objects that together facilitate processes of innovation and R&D. Traditionally, boundary objects have been seen as relatively stable and singular. However, recent work has moved away from this reliance on assuming that collaboration derives somehow from the essential nature of individual objects themselves and has looked instead at the set of objects and relations in which they occur.

Based on research in a case study of biomedical innovation, Nicolini et al (2012) make a particularly important contribution by proposing a three-level ‘hierarchy’ of objects. They differentiate between tertiary objects (that provide the infrastructure for collaboration, including built environment and electronic systems); secondary objects (that are the classic boundary objects found in drawings, design objects, etc); and primary objects (which are more fundamental and epistemic in nature and so which help inspire, motivate and sustain collaboration). They also demonstrate how such objects can develop and change in their role and use over time (e.g. from being an integrating idea that crystallizes into a more material object that helps further design and development collaboration) (see also Bresnen, 2010).

Scarborough et al (2015) have built upon this idea further by emphasizing the relational qualities of how such objects inter-connect and how collaboration and coordination occur not just through the use of a variety of objects , but also through the complex (and evolving) links between them. They describe this as a system of objects, whose inter-connectedness ‘orchestrates’ collaborative tasks (ibid: 217-8). As they put it:

... the capacity of the shared objects in our study to support coordination over time, and across multiple collaborative tasks, emerged not from their use independently, but rather from the routine way in which shared objects were inter-related and cross-referenced, with changes in one object prompting work to revise and update other objects. By maintaining these relations, the process-level coordination of work activities could be achieved, even in the face of an uncertain and emergent innovation process” (ibid: 212)

An important further strand of research emphasizes too how boundary objects are inscribed with relations of power, insofar as their design embodies a particular configuration of power/knowledge that may reflect dominant interests and perspectives and so prescribe or limit action (Thomas et al., 2008; Oswick and Robertson, 2009). As such, boundary objects can both facilitate and inhibit knowledge sharing and learning throughout the course of any interaction, since they are inscribed with meanings that shift as power dynamics and negotiations over their use unfold, thus enabling or hindering interaction, dependent upon their mobilization (Barrett and Oborn, 2010) and engagement by participants (Allen, 2014).

Consequently, it is as important to be aware too of the ways in which boundary objects can hinder, as much as facilitate, joint action. Moreover, it is also important to be open to exploring how their use may be associated with the empowering or disempowering of particular groups and what that means for established professional and management practices. In this paper, we therefore present a more nuanced, situated and dynamic interpretation of interaction around technological systems as boundary objects in the healthcare context, exploring how they can *simultaneously* enable and hinder integration, through the recursive iterations and associated social interaction that occurs in their development and use. This points to the possibility not only that

they may create tensions in their effects on particular groups, but also that these tensions may play out in ways that lead to the suppression and later activation of *latent* conflicts of interest or perspective – with implications for the stability, maintenance and generalizability of collaborative action centred around those particular objects.

In what follows, we therefore explore the unfolding development, use and (prospects for) wider implementation and diffusion of a mobile phone based technological innovation, focusing particularly upon its evolving and changing role within a wider localized system of objects and relations amongst the multiple stakeholder groups involved (clinicians, patients, researchers, software developers, IT specialist and hospital managers). Our case uses the development and use of a smartphone app, whose data are integrated into patients' electronic health records (EHR) in graphical form. We examine how its interconnected components acted as a system of boundary objects to help facilitate the crossing of three different types of boundary: between groups involved in its development; between clinician and patient in its use; and with actors representing wider organizational perspectives and interests. Our analysis questions the impact upon collaboration across these boundaries, the effects upon the different groups involved and explores the implications for the wider diffusion of such innovations.

Research Methods

The research in this paper is case study based (Eisenhardt and Graebner, 2007) (Eisenhardt and Graebner, 2007) and draws from qualitative data collected from a range of stakeholder groups involved in the practical development, application and use of a smart-phone app (for Android phones) to be used by patients for self-monitoring and reporting of rheumatoid arthritis (RA) symptoms. In total, data from 39 semi-structured interviews and two focus groups with patients, healthcare professionals, IT specialists and managers were collected and analyzed, in addition to 17 audio-recorded clinical consultation transcripts (see Table 1). Data were taken from two time points; one during app development and prior to its implementation ('pre-app') and the other following its implementation ('post-app').

TABLE 1 ABOUT HERE

The wider study, of which the interviews, focus groups and clinical consultations formed a part, was undertaken over a two-year period. The study had three main aims, the first two of which are of relevance to this paper. Firstly, to develop an app which would enable patients to collect real time data on their daily, weekly and monthly rheumatoid arthritis symptoms. Secondly, to enable novel integration of the data from the app into graphical form within the results section of the EHR, for use during clinical consultations between patients and their healthcare professionals. And thirdly, to create a rich dataset of patient reported outcomes on rheumatoid arthritis disease activity for research purposes.

The importance of the study lay in the fact that rheumatoid arthritis is a long-term condition, which fluctuates over time. The current model of care is for patients to see healthcare professionals sporadically (approximately six-monthly for stable patients). These sporadic interactions provide only a static snapshot of the illness and are heavily reliant on patient recall of the intervening period. The possibility of recall problems (inaccurate reporting of events), has implications for continuing patient care and an issue that is well-documented in the medical literature (Shiffman et al., 2008). In the meantime, patients are also left to manage their symptoms themselves.

The app was developed with direct patient involvement in its design, development and testing, and was led by a multi-disciplinary project steering group consisting of researchers, clinicians and project managers (which included all authors of this paper). Initial plans for the app were presented to stakeholders who were interviewed as part of the research process, with findings being fed back to the steering group in real time to inform the design and integration of the app. Project managers liaised with a University-based software development team to develop the app and with a hospital-based informatics team to integrate graphed patient reported outcomes into the EHR. Clinician researchers held consultations with RA patients who had used the app. The hospital trust hosting the research was a digitally mature site, which is of relevance given the technological nature of the intervention.

This paper draws on the semi-structured interviews and focus groups conducted with the various stakeholder groups involved. Interactions during the course of the project explored these groups' perspectives on the app and its development, focusing upon the handling of critical interfaces between different interests, perspectives and practices during both the development of the app and its subsequent use and interconnection with the supporting IT infrastructure. Initial, inductive coding was conducted separately by three members of the research team, using NVivo. The proximity of the authors to the project allowed for deeper insights to be drawn, but also prompted the need for care to be taken to ensure reflexivity during analysis. Comparison of emerging themes was made, with adjustments taking place at meetings between the team. Having data from such a range of stakeholder groups allowed for some comparison of themes across groups and broadened out the analytical possibilities to the network of interactions in which the key stakeholders were involved.

Main Findings

The section presents qualitative data from the interviews that explored stakeholder perspectives, interests and actions as they evolved and interacted across the three boundaries of interest, namely:

1. Boundary between technical development of the innovation and its application to clinical practice
2. Boundary between the illness management led by the patient at home, and that planned in the clinic
3. Boundary between the implementation of the app from a single research project to its wider scaling up and diffusion

Table 2 summarizes key features of the responses of five of the main stakeholder groups at each of these stages.

TABLE 2 ABOUT HERE

Analysis of the data highlights a number of ways in which developing the app and integrating it with clinical and hospital systems and practices variously reflected, reinforced or challenged different groups' interests and perspectives, thus generating tensions that needed effective handling. In particular, the summary table highlights a number of principal areas in which the development of the app disrupted existing practices and created challenges that needed some form of resolution. In particular:

- Through attempting to embed diagnostics within existing clinical pathways, systems and practices
- Through engaging users (patients) and encouraging them to move to a more self-help approach
- Through integrating data flows associated with a bespoke system with the wider standardized hospital IT system design

Important implications are drawn out from the analysis below for the effects on clinical practice and patient engagement, for the diffusion of the innovation in practice, and for the generalizability of the app-based system to other disease areas and other healthcare organizations.

Boundary between technical innovation and clinical practice

Developing the innovation and integrating it into existing IT and clinical systems involved navigating the boundary between innovation and practice. Project management of the app's development and implementation involved a number of different stakeholder groups. These included users (patients – predominantly using the app; and clinicians – predominantly using the graphed results in the EHR), as well as designers (app software developers and hospital IT staff working on the EHR) and hospital managers. Here, we explore firstly the needs of patients and clinicians, and how these were mediated. Secondly, we explore how the clarity of both the roles of individual stakeholders, and the project specification, were perceived to be key to the project's success.

Patient input into design

The research team proposed the initial design of the innovation, upon which patients were asked to comment. Key needs expressed by patients were to be able to use the app to identify factors that influenced their illness (e.g. triggers for fluctuations in disease severity) and the ability to use the app as a 'confidante'. Patients initially preferred to enter data only when something notable happened. In contrast, practitioners preferred to collect as much data as possible, encouraging the use of daily data capture (for both clinical and research purposes). However, practitioners anticipated the potential burden of regular data capture, which highlights the potential for negotiation:

[Researcher 12]: ...so there is finding the balance with the recall period and how much people are willing to sort of enter some of the information.

These potential tensions were mediated through compromise in the app's design. Patients were willing to input data more regularly, particularly if reminder functions were incorporated into the app; and the inclusion of a free-text diary function with the potential to fulfil the role of confidante was introduced.

Clarity of role

Clarity of roles within the project management team was felt to be important, highlighting the disciplinary differences and resulting boundaries between different stakeholder groups:

[IT Specialist 13]: There's two different worlds and it's difficult to know from people's job titles and things who I needed to speak to. I think that was the biggest thing. Eventually we thrashed out a solution where we published everybody's roles on a Google document that was freely available to all of us and then that got better. I still feel that more understanding of their world would have been beneficial.

Recognizing the potentially significant impact of these differences, participants placed an emphasis on the need for individuals to play a brokering role, rather than being embedded within their own separate organization. So, for example, members

of the research team, who might otherwise have been seen as ‘external’ to the IT staff, were instead embedded within the project:

[IT Specialist 5]: We’re not going to give [the app project] to an IT Project Manager, we’re just going to give a person who can, sort of, link people together. So, obviously, if [name] has a problem, he doesn’t know who to go to, whereas this person will be able to say you need to speak to X, Y or Z, nothing will change.

[IT Specialist 5]: Because people were aware of what [brokering applied healthcare research organization] was in IT, because we’ve dealt with them before, we’ve done other projects. So that visibility was there, it wasn’t like it was an outside, third party person coming in saying: ‘I want this, I want this.’ It was somebody that was perceived as working here.

Clarity of specification

Issues arose around the scope and expectation of those charged with developing the app. IT staff reported that establishing clarity of specification, particularly in the early stages of the project, could be frustrating, given the very different expectations and approaches in play and the need to manage those expectations across boundaries:

[IT Specialist 6]: It starts, I guess, with that high level specification to say that is what we expect. We didn’t get that in the beginning. It started with a discussion, as do all these pieces of work, especially when they’re quite new to us...so I think to write a good high level specification to inform the people, this is what we would expect, this is what we would expect the interface to do, this is what we want do with the results.

Importantly, this reflected the desire for the IT specialists to be able to make sense of work on the app as a project. Once *projectified* in that way – and establishing a clear specification formed an important part of that – it made it easier for IT specialists both to incorporate the work in their own routines and to respond to the needs of other groups.

Team members reported different experiences regarding the mode of information-sharing. Some found a shared drive useful, whilst others reported that it was limited because it was not kept up to date:

[IT Specialist 12]: there was a spread sheet that was produced which was to act as the one true statement of [work needed and done] ... But that wasn't necessarily kept up-to-date. That was also a weakness; so clear specification and then keeping the specification document up-to-date.

The shared drive itself might be viewed as a boundary object (a standardized form, according to Star's original definition (Star and Griesemer, 1989)). Its failure to retain its function in this role when not maintained resonates with Levina and Vaast's (2005) argument that designated boundary objects fail to become boundary objects-in-use when they are not incorporated into every day practice. In contrast, an alternative mechanism emerged as a more useful means of collaboration and integration:

[IT Specialist 5]: On other projects, between organizations, it's been quite hard to have one place where people can see, but this Google Document thing just got rid of that issue, and everybody could log onto it, they could change it, they could see it, they knew who was doing what, everybody's number was on there. That was very handy and people have come back to me and said: 'That was very handy', and people have come back to me and said: 'That was really good, that was really good.'

Integration of data from the app involved close liaison between software developers (who designed the app), and hospital IT staff (who enabled the flow of app data into the EHR). Hospital IT staff recognized there was a boundary between these groups and drew upon their previous experience in emphasizing that external partners commonly underestimated the amount of work involved in integrating data into the EHR. This led to the recognition that fostering a shared understanding regarding the project brief and specification was important to bridge this gap in understanding:

[IT Specialist 6]: It's very typical in that sense, from a starting point of them not knowing the EPR that way. Or us not knowing what they're going to do, trying to work a way to what is this really going to look like and generally the scope expands. The work expands, and we understand that's always likely to happen, that whoever walks in my door, and says, 'I just want a document in the EPR, it should be a ten minute development, can we start next week', and then it turns into a six month project, with all sorts of automated alerting and complex interfaces. So this was very typical ... sort of what we expected.

In this first section, we began with the different requirements of patients and practitioners, and how these were mediated. We then saw how members of different disciplines involved in developing the innovation were aware of, and tried to bridge, the boundaries between them. Clarity of role and project specification were regarded as key to enabling successful collaboration in this respect. The app itself served as a primary boundary object (Nicolini et al, 2012) that both inspired and helped sustain the collaboration needed.

Boundary between the disease management led by the patient at home, and that planned in the clinic

This second section acknowledges the traditionally hard boundary between patients and clinicians, and how the innovation mediated this, resulting in it becoming fuzzier. Initially we consider how the app empowered patients to self-manage their illness, although there were some limitations to its functionality. We then focus on how the graphs mediated the relationship between patients and clinicians during the consultation, acting as a boundary object-in-use between patients and clinicians, highlighted through a number of observed clinician-patient exchanges. The result was more focused and individualized care for patients, which might be seen to meet the current policy agenda for more patient-centred care (NHS England, 2014).

Empowering patients' self-management

Patients have responsibility for the 'self-management' of their RA between clinic visits for which there is no set formula, with a range of activities (e.g. exercise, pacing, joint protection and adaptations) being employed. There was consensus amongst patients, clinicians and managers that use of the app had the potential to enhance patient self-management. This came across strongly in interviews and from the interactions observed between patients and clinicians during consultations. This was, in the main, an unexpected finding, and testament to its impact as a boundary object, as the app itself did not offer any advice or prompts for patients to change their behaviour.

Patients reported that the simple act of entering data into the app encouraged them to reflect upon their RA, leading to better understanding of their illness. Some reported that the pattern of completing it, in conjunction with a diary function (which remained private to them and was not integrated into the EHR) enabled them to identify and therefore avoid potential triggers for flares, or fluctuations, in the severity of their symptoms.

[Patient 2]: If I hadn't have had the diary aspect, I might have remembered that I'd had a bad couple of days, but I probably wouldn't have remembered that I'd been poorly for a few days with a really bad cold, leading up to that. I might have just said, oh yes, I had a couple of bad days. And, he might have said, anything trigger it? Oh, no, I was alright, because you forget don't you? [...] So, because I've got, like, the diary thing, I found that really helpful.

[Clinician-researcher 1]: They said oh well, I realized that I'd been doing gardening that day. And the diary function helped them to see the pattern, so that kind of thing.

Both parties felt that the increased self-awareness arising from interaction with the app, led to a feeling of empowerment for patients:

[Clinician-researcher 2]: And I definitely saw that, that people were, kind of, more empowered to look after their own health. Not through necessarily

doing anything as a result of it, but just that increased awareness seemed to, kind of, give them more control and they reflected positively on that.

Acting as ‘confidante’

Some patients used the diary function as a safe space in which to record thoughts and emotions relating to their disease. As anticipated from interviews during the development of the innovation, several expressed this as being akin to having a ‘confidante’. The simple act of documenting thoughts and feelings became a coping mechanism in itself.

CONSULTATION:

[Patient 2]: Keeping that diary has sort of, you know, you are just sort of like let it go – even if it's only one word like shit, you know, sort of nobody is going to see that, but you get it out there and it makes you feel good if you say something horrible you can say it to dear diary.

Worsening healthcare anxiety

Whilst daily patient data entry was felt by many patients to be beneficial in managing their illness, it is important to consider the potential for unintended consequences. A minority of patients (post-app) and practitioners (pre-app) noted that the app might worsen anxiety, forcing patients to think about RA when they might prefer not to. This unintended effect is very much in line with findings on telehealth interventions for COPD (Brunton et al., 2015).

CONSULTATION:

[Patient 23]: I suppose the only downside, well...my wife said to me, she wondered by sitting every morning poring over that and looking...self-diagnosing...as I say, I had one really bad day about three weeks ago. Really down in the dumps, which ... was, you know, what the hell's happened? Where's my life going to? A really crap day to put it brutally. And I got over that, but she wonders sometimes with...by doing this it's days...you're diagnosing...

[Clinician-researcher 1]: You're focusing on it more.

[Patient 23]: It's in focus more...Does it make me more anxious? That's the only downside really.

At the same time, the surfacing of these anxieties could in itself be seen as a way in which engaging with the app prompted conscious reflection by patients on their condition and related moods.

Using problematic scales

Despite enthusiasm for the app, limitations regarding the scales used to represent patients' disease activity were also identified. Patients felt that reducing their illness to scores was problematic. Frequent reference was made to the fact that RA does not occur in isolation and that it was difficult for patients to score 'accurately' because of the overlap of symptoms with other illnesses, and from the stresses and strains of life in general. Clinicians use similar scoring systems during consultations which are heavily relied upon in determining access to expensive treatments for RA. This reveals a tension between the clinician's need to provide an 'objective measure' of disease activity, and the difficulty in disentangling the illness from the myriad other influences on patients' health and wellbeing.

[Patient 24]: I read the question and the first thing that came into my head I answered, but I have great difficulty because some of it's rheumatoid and some of it's osteo[arthritis]. And I don't know how - but it's how I felt very genuinely, I'm not quite sure it was all rheumatoid.

[Practitioner 10]: Yeah, well it's just like if a patient comes to the clinic and you can actually see what's going on and you can look at like the clinical manifestations, but if they're self-reporting things then would they be reporting pain that isn't down to their inflammatory disease because some of these patients do have other issues going on?... Yeah, multiple comorbidities.

In this respect, the scoring system that was integral to the app, like any scale-based subjective scoring system, had its limitations. Nevertheless, by the same token, its plasticity did enable the translation of patient symptoms into clinical data that, as will be seen, could then feed into consultant-patient interaction in consultations.

Boundary object between patients and clinicians

Our analysis here centers on how inclusion of data from the app into the EHR affected the nature of the patient-doctor consultation. Particularly important here were the use of graphs of data generated from the app, which formed the centerpiece of the consultation process.

In order to appreciate this, it is important to understand first the unique value in having this rich data available to the consultation. RA is a fluctuating illness and consultations have, until now, been limited both by the singular assessment being made, and the paucity of information available from the period between clinical consultations. Data from the app filled in these gaps, providing a bigger picture of what had happened between consultations, aiding patients' recall and enabling the identification of events that might otherwise have been missed.

Practitioners who were interviewed prior to development of the innovation felt that it would likely lead to a more collaborative, shared decision making process:

[Researcher 1]: It kind of just encourages more of that kind of collaborative effort and managing their symptoms. You look back and say like well before you started on Methotrexate, this is what your disease was like, and not just have like a one-off figure to show them.

In enabling visualization of patients' RA symptom activity, graphs were used to aid communication between patients and clinicians. These graphs effectively translated data from daily life into something more meaningful for each group. Patients reported that it took the burden of communicating their illness to the clinician away from them, in essence *transforming* their experience into something meaningful for clinicians. The

app was therefore crucial in acting as a mediator across this pragmatic boundary (Carlile, 2002):

[Patient 8]: [Clinician researcher 1] showed me the graph and you could see where it had shot up and then it sort of did that. So you could actually see it, which clarifies it, but clarifies it also for the person looking at it; because they can see rather than saying, oh well, how did you feel? [...] it's a real tool to be able to show somebody else what you are going through because it's very difficult when you go.

Clinicians were familiar with viewing graphical data (e.g. blood test results) in the same format which aided engagement, and they incorporated the task of checking the graphs into their routine prior to patients entering the clinic room. They used the information gained as a comparator with patients' responses to questions, probing further if inconsistencies between the two were apparent.

CONSULTATION:

[Clinician researcher 1]: So this is the three months. So that's August, this is October and this is the graph of your pain. So the reason I was asking if there's anything that had happened, any specific thing...

[Patient 23]: Oh I'll tell you what...

[Clinician researcher 1]: ... in all of your graphs, there's a, kind of, peak between August and September in the same place.....So there's...I suspect there's something happened to you through, sort of, the latter half of August...

[Patient 23]: Right. I'm trying to think what that would be [...] I know, end of August. Tell you where I went then, I went to Edinburgh. My daughter's an actress and we went to The Fringe for a couple of days, which is fantastic but I over did it. I'll be honest. I did

Clinicians also felt that it helped them to communicate their perspective, backing up their viewpoint with 'evidence' from the graphs to emphasize a point to patients. This

was not only with regard to treatment interventions but with more subtle aspects of the doctor-patient relationship:

[Clinician researcher 1] She was very stoical, and some people you can tell they're stoical [...] But then other people you can't tell that in a two-minute assessment of a personality, because that's difficult. But her charts did show a number of peaks and I said to her actually, you're telling me you've been fine but these are suggesting that you've been less fine. And then we had quite an open conversation. I was able to say to her look, you're coming here telling me something that appears to be quite different to what you're recording. I don't know if you're aware of that or not....So it was quite nice to be able to have that with some evidence to say look, you're not fine, this is telling me you're not fine.

On the one hand, the use of the data in this way could be seen as effectively reinforcing clinical practice and influence in the consultation process. On the other hand, as will be seen, it could be argued that it also meant some transformation of practice on the part of clinicians, who were able, through the graphs, to engage more effectively with the patient and their experience of the condition.

Shared consultation

Having seen how the graphs helped each party to communicate their perspective, we will now describe their role in creating a more shared consultation. Patients expressed surprise and delight at seeing 'their' data appear in graphical format on the clinicians' screen. That it now appeared outside their smartphone and in their electronic record, for some, validated it and made it seem more official.

CONSULTATION:

[Clinician researcher 2]: So I've had a look through the results, let me just turn the screen around so you can see it as well. So those results that you have get sent into the record and then we can make graphs of it.

[Patient 24]: What, you've got them already here?

[Clinician researcher 2]: Yeah, so I've got them there, I can see them. I've seen them already, so I'm asking you these questions knowing the answer to some of them.

[Patient 24]: I didn't realize that they'd come through...

Clinicians reported that using the graphs led to a more shared consultation. Not only was the content of the discussion altered, but the *nature* of the consultation had also changed, both topically and physically, as they debated events rather than there being one-way reporting from patient to clinician:

CONSULTATION:

[Clinician researcher 1]: And so, you are right that there is quite a significant sort of day to day fluctuation so that is three out of ten down here and that is seven out of ten up here...[...]

[Patient 12]: It's funny on this, you can see the trend can't you?

[Clinician researcher 1]: Yes, absolutely. So...

Similarly, from a clinician's perspective:

[Clinician researcher 2]: The patients really engage with that, they seem to understand graphs perfectly well. So the computer can potentially be a distraction, but I think it's more of a distraction if I'm buried behind the computer, the computer as a discussion point worked well.

Learning tool

Patients and clinicians both reported that they learned from the graphs. For example, a clinician reported that the graphs demonstrated to them the impact of a simple intervention (e.g. providing compression gloves). This kind of contemporaneous data was not normally available, meaning that they were previously unable to appreciate the extent and immediacy of the patient benefit. In another example, a patient reported that seeing a gradual trend in improvement in response to a medication had persuaded them of its utility.

[Clinician researcher 2]: [Following the intervention...] her pain graph got much better, as did her coping and her physical activity in the tasks that she

was able to perform, and clearly her whole life was transformed by this intervention, and that taught me the extent to which such interventions are useful

Clinicians reported that graphical representation of some of the traditionally less clinical features of RA such as low mood, fatigue and sleep, raised the profile of these features, helping them to develop a deeper understanding of the more holistic impact of disease flares and fluctuations than perhaps they might otherwise have had. This increased awareness led them to open up the consultation to discussion of these issues. In tandem with this, having completed the app data on these 'less clinical' features and seeing them on the screen, patients felt empowered to talk about features that they might otherwise have felt unable to raise.

[Clinician researcher 2]: It was interesting to me that patients ...saw the kind of formal reporting across a range of different fields as being useful to support the consultation, but also a way into certain discussions they felt they didn't have a way into, normally.

The app as boundary object between patients and their relatives

Patients who chose to share their app diaries or their disease activity scores outside the study, talked about how the app also helped to mediate the boundary between themselves and their relatives. In sharing this data with friends or relatives, patients reported that they felt better understood, without needing to offer lengthy explanations or justifications for how they were feeling. Again, this provided a compelling example of the app transforming knowledge and promoting learning (Carlile, 2002) – by removing the burden from patients of trying to explain their symptoms and enabling relatives to gain a more complete and informed picture of their condition.

Looking at the boundary between innovation and practice, this second section has highlighted several examples of the innovation providing the centrepiece for collaboration between clinicians and patients. As such, it was clearly fulfilling the criteria for being considered a secondary level object (Nicolini et al., 2012). We have seen how both the app itself and the resultant graphs generated in the EHR acted as interconnected boundary objects (Scarborough et al., 2015), allowing collaboration

between patients and clinicians. This collaboration occurred in ways that might have been expected (better communication – which was the primary technical goal of the app), but also, unexpectedly, in the process allowing each party to learn new information and develop better understanding of each other's perspective.

Boundary between the implementation of the app from a single research clinic to wider scale up

This third section examines the prospects and challenges faced in moving from localized adoption of the innovation during this 'proof of concept' study, to adoption at scale. Three areas emerged as important enabling and inhibiting conditions: first, the relationships necessary to ensure the adoption of the innovation; second, resourcing issues; third, the technical challenges of integration with wider HER systems and possible corresponding solutions.

Relationship considerations

Developing the app and bringing together the relevant stakeholders had involved a good deal of championing of the initiative with clinicians and other groups and considerable effort in building close working relationships. Such challenges are common in the implementation of any healthcare technology innovation and here they needed to be replicated n a wider scale:

[Manager 2]: ... thing that would be really important would be clinical engagement and local champions, so if you were trying to use this in another environment the people trying to use it would really have to believe that it made a difference, and how you do that would be potentially difficult. But again I suppose ultimately it would be local networks of likeminded colleagues who'd try and implement on other sites.

IT specialists and managers shared the view that building upon the pre-existing relationships nurtured during the development of the innovation would facilitate successful scale-up. IT specialists commented on the high level of clinical leadership which was felt to be vital to the success of the initiative and whose replication would enhance the likely success of any future project. In addition, the need for expertise in

various facets of the implementation process was noted, particularly with regard to app developers who were external to the NHS:

[IT Specialist 12]: I think there's no substitute for experience in terms of having experience with working on these kind of research projects integrating with NHS systems. I think for just any old app developer coming along I doubt that they could pick up a toolkit and suddenly know everything they needed to know about how to make this work, it's quite specialist really.

In considering scale up of the innovation, managers acknowledged the role of early adopters of technology, with strong support needed for those who might need more persuasion to engage.

[Manager 2]: That's why I talk about networks and personal contacts, it's going to have to be a rheumatologist in another hospital knows rheumatology in this one, and they're willing to adopt what is seen as emerging technology and is seen as being very much patient-centric and improving patient outcomes.

Clinicians felt that the benefits outweighed the burden of time taken up, and that this would likely enhance the likelihood of any future uptake. Patients, on the other hand, expressed concern that less forward-thinking clinicians might not engage with this kind of technology. This does highlight a tension, as patients and clinicians may well view telehealth interventions differently (Brunton et al., 2015). Although this was not the case here (as practitioners felt that the innovation represented a natural progression), such an attitude clearly might not generalize to other healthcare settings.

IT specialists and managers also reported that the increasing e-literacy amongst patients provided an opportunity to extend the reach of the app.

[IT Specialist 5]: The populous in general are becoming more technology savvy, so most people have smart phones, they can download an app, and they can work an app quite proficiently.

Indeed, some managers felt that scaling up the system might rely on patients to champion uptake of the app in order to encourage others to do so. Patients themselves reported that they would advocate the app to others, notwithstanding some challenges, including the difficulties in capturing RA disease activity using scales. However, both patients and clinicians questioned whether or not patients would continue to remain engaged in the long term, particularly if their disease was relatively stable and entering data regularly appeared to have less obvious benefit or meaning for them. These concerns mirror those made by patients prior to development of the innovation, who expressed a preference only to enter data when something notable had occurred. The more general point is that such enthusiasm would need to somehow transcend this particular case, if the app was to have the same corresponding impact elsewhere.

Clinician researchers also expressed some concern regarding the potential for healthcare professionals to become too reliant on the app data, forfeiting a thorough history in favour of dependence upon the graphs. Interestingly, this points again to the potential impact of the app in transforming aspects of clinical practice. They were also concerned whether patients who did not engage with the app were it rolled out wholescale, would be penalized for a new form of patient ‘non-adherence’ (a phrase which has traditionally referred to a failure to adhere to medication and other treatment plans). Neither of these concerns were played out in this study. However, they again demonstrate potential inhibiting factors related to the latent capabilities of the object in question.

Resource considerations

Both clinicians and patients saw the prospect of altering appointment scheduling based upon app data as an opportunity for more patient-centred care, but were concerned about the logistics involved and where the responsibility for triggering an episode of care would lie. Currently, secondary care organisations are remunerated

for each clinical consultation, so the interactions with app data, required for triaging appointments, would not be accounted for. Managers recognised that scale up of the innovation, with this kind of impact on service provision, would require changes in commissioning practice, but were broadly in favour if it meant that potential savings were realized:

[Manager 3]: I mean everything else is focused on cost and efficiency at the moment, and the driver for anything like this, the largest driver will be efficiency. So if we can follow up patients more efficiently that's going to be very attractive.

Maintaining the system once the innovation had been adopted, also raised issues of funding and personnel to support and sustain the innovation in the long term.

[IT Specialist 9]: So I think from our point of view in terms of scaling that up. That's a greater advantage to us to scale it up, but again, it comes back to how well can it be supported? Do we have the resources to do that? What would be the maintenance overhead? You know, is there any capital cost attached to it in terms of how long a life we can expect from this app and what do you do then for revisions?

From a pragmatic perspective, managers were concerned that increased patient anxiety (the potential for which was discussed above) might lead to an increase in consultation rates;

[Manager 8]: There's a wide spectrum of patients and we all know that some patients by sheer fact of actually giving them a focus on a particular aspect of their health increases the number of times they are likely to consult. So, is it actually giving them far too much of a focus on that particular aspect and, therefore, they are recording just about everything and the psychosomatic side of symptoms really.

Technical considerations

IT staff and managers both acknowledged that being a 'digitally mature organisation' was key to the success of future ventures, although managers' views were more

muted, with digital maturity being ‘nice to have’ rather than a pre-requisite for success as an organisation.

[IT Specialist 6]: So, the issues you'll have will be the level of digital maturity ... Technology is the same pretty much wherever you go across the world. The challenge would be whether their EPRs are mature enough to be able to do the sort of things that you want to do, whether they have that capability within the interface team.

Stakeholders identified a need to ensure that the app and associated infrastructure, particularly with regard to integration into the EHR, was as generic as possible, in order to maximize the chances of scaling up the innovation. Standardized ways of working were felt to improve the potential to integrate with a number of different IT systems, highlighting a real tension as boundary conditions varied between the project and IT systems.

[IT Specialist 6]: I can get my interface people to build an interface that will gather the pathology from each trust, but each one of those interfaces will be a point-to-point connection, it will be a bespoke development and a lengthy development as well ... But if everyone fed their information into a centralised port then we could all take it out. So we all build one interface in and we all build one interface out. So, it's getting agreement about standardisation, standardized way of working will enable us to move at a much faster rate. There is a danger we tend to get too focused on bespoke pieces of work.

At the same time, the need to incorporate more ad hoc interfaces was recognized:

[Manager 2]: It was a sort of ad hoc interface that was built, and what we need to be doing as a trust, as we are doing, is making sure that those interface and interoperability is in the right place for devices such as [the app] to interact with us. So we have an obligation, if you like, as a provider trust to try and move our infrastructure towards being compatible with those. And I suppose it probably needs on-going review, doesn't it, in terms

of when we upgrade we need to then check with all the systems which we interface with that actually that still works, and I think we don't know, to be honest.

In other words, the localized development of the app had been what had galvanized interest and been made possible through a logic of a bespoke design that flexibly met specific patient group and diagnostic needs. But, the real value was in widening that out (to other hospitals, other disease areas) and that required an approach that reflected a logic of standardization and efficiency.

Both IT staff and managers were concerned to ensure that the project might have long-term sustainability, in order to justify scaling it up. The limitations of the study developing an isolated research innovation rather than a longer term programme of development, was identified.

[IT Specialist 13]: For us, [the app] is a short tem project. There's been no mention of turning it into a product as it were. It's a research tool. If you wanted to turn it into a product then, yes, you need people to regularly update components, make sure it still works on the new smartphones and what have you. There's no easy silver bullet for that one.

In other words, the projectification that had served the initial development of the app so well was now insufficient for, or even potentially inhibiting of, its wider roll out.

Finally, IT staff identified that the development of the app by software developers working independently from the EHR team, meant that their compatibility following future updates was also at risk.

[Manager 2] We need to know that it works and that it interfaces with our systems. So I know that with [the app] I think a specific interface has been built into the electronic patient record. But from the middle of next year with our EPR upgrade we're looking at [compatibility] so that these devices can talk to us more reliably. So I suppose at the minute the interface is

unreliable. Where there are upgrades to the EPR [EHR] it can become technically more difficult to reformat that upgrade.

This third and final section of the analysis has highlighted three sets of boundary conditions affecting the successful scale up of this innovation. These important enabling and inhibiting conditions – inter-disciplinary relations, resources and technical infrastructure – represented important tertiary level conditions that related to the wider infrastructure with which, ultimately, the app needed to interconnect. The main point to emphasize here is that the transformation of knowledge and practice that was so central to the development and use of the app paradoxically created conditions whose replication was necessary – but potentially more challenging – if the innovation was to diffuse more widely.

Discussion

Analysis of the development of this innovation (which included the app and associated graphs), and attempts to generalize its application to other settings, throws up a number of important conceptual and practical implications.

First, that the development of the innovation across the boundary between innovation and practice, can be seen not just as a technical achievement, but also as an ongoing social accomplishment. That is, the object created a focus around which communities with quite distinct purposes, practices and perspectives could work, developing and deploying a common tool to achieve a common purpose (cf. Nicolini et al, 2012). The case demonstrated the importance of clarity of both project specification and personal role, in order that individuals from distinct (albeit closely related, in the case of software developers and IT specialist) communities might work together. However the innovation itself, as a primary object around which these communities who worked towards a shared purpose of app *development* coalesced, was not sufficient to enable them to accomplish this goal, with the need for individuals on the project team to act as brokers becoming clear. This echoes findings of (Sapsed and Salter, 2004) who identified that boundary objects cannot function without human interaction. In addition to the need for a brokering role, other boundary objects, such as the shared-drive, also

required updating in order to fulfil their potential as a boundary object-in-use (Levina and Vaast, 2005).

Second, and by the same token, making the system work in practice at local level was challenging since the design of the app inevitably contained within it certain prescriptions that, while they had normative value in promoting a common purpose (e.g. meeting patients' needs), also potentially conflicted with existing system and organizational imperatives (important for the efficiency of healthcare delivery). At a local level, this would ensure that the project required continuing action not simply to explain and justify any technical, clinical or administrative accommodations required, but also to sustain the coalition of interests involved in its design and implementation.

We saw that the app empowered patients to have greater awareness of their RA condition. Parts of the innovation as boundary objects-in-use really came to light in its role liaising between patients, and their relatives (app) and healthcare professionals (graphs), respectively (Levina and Vaast, 2005). That these two linked aspects of the innovation worked together as boundary objects is redolent of Scarbrough's (2015) findings on the systemic interconnectedness of boundary objects. It also demonstrates how, through transforming the nature of the diagnostic and consultation processes, it also unsettled normalized relations of power. It did so in two main ways: first, by challenging systems of generalized care and standardized information flows to allow for bespoke treatment. Second, by providing evidence for patients with which they could more effectively communicate with healthcare professionals, shifting the power dynamics within the consultation. The nature of the revised clinical consultation certainly created expectations on patients to provide a more accurate and salient version of events, but it also empowered them to take more control of their diagnosis and treatment. Moreover, it also created expectations on clinicians to demonstrate the utility of treatments and to appreciate the need for more open consultations that addressed less clinical features – even where that might not make a material difference to the patients' disease activity. These were unexpected findings in how the use of the app disrupted existing clinical diagnostic and treatment practices. This use of the innovation to cross this complex pragmatic boundary (Carlile, 2002) was not dissimilar in effect to Nicolini et al's (2012) depiction of the effects of secondary boundary objects in enabling collaboration and learning between clinician and patient.

Lastly, the innovation provided the opportunity for learning by both stakeholders; patients learned about triggers for disease fluctuations and clinicians learned about the impact of interventions and the value in addressing ‘non-clinical’ topics. The obvious challenge here for this, with implications for taking the project forward, is that what here was seen as patient empowerment and clinician changed practice, could elsewhere be seen simply as a threat by clinicians who might prefer or insist on more traditional, paternalistic models of clinical consultation. As such, its more disruptive effects were both a *sine qua non* of its development and application, but also a potential, boundary to its wider diffusion. While such challenges might be manageable at a local level, given the strength of local relationships and commitments demonstrated in our findings, extrapolating that to other contexts, transgressing the boundary between implementation of the app to wider scale up would likely be extremely difficult. There would likely be significant challenges to existing power/knowledge configurations that the roll out of the initiative would inevitably surface (cf. Newell et al., 2003).

As well as the direct impact upon established clinical professional practice noted above, we identified challenges to the long-term sustainability and scaling up of this innovation at a tertiary level (Nicolini et al, 2012) associated with three wider sets of infrastructural conditions – namely, interdisciplinary relations, resources and technical infrastructure. Firstly, the importance of strong clinical leadership and the need to build upon existing networks and relationships were considered the key to future attempts to scale up the innovation. Secondly, managers in particular noted that organizational change would be required with regard to the manner in which services are commissioned and all stakeholders expressed concern about the resource implications of sustaining the innovation. Finally, at a technical level, participants stressed that creating and utilizing generalizable and generic IT solutions would enhance the chances of ambitions to scale up the project. It should be noted that the focal hospital is an early adopter of information technology development and is known for its status within healthcare as a digital exemplar. Moreover, the availability of external research funding meant that undertaking this particular project was able to be prioritized by busy IT staff. These factors acted as facilitators in our case. They make

the prospect of scaling it up to other, less digitally mature organizations with fewer financial resources, clearly more challenging.

The overall implication is that boundary objects such as the app in question may have powerful integrative effects at certain points or stages in both its development and use. However, it may also suppress key differences in interest and perspective whose latent disruptive effects may emerge at other points or stages in the developmental or implementation process to inhibit further development or wider application (cf. Barrett and Oborn, 2010). More generally, it is important to see the development of the object as embedded within, and inevitably shaped by, the (shifting) constellation of social interests, relations and perspectives brought by each community of practice to the project. This of course has implications too for wider attempts to reconcile the embedding of new (technical) initiatives in local practice with the need to generalize new knowledge and learning gained from (technical) innovations across the sector.

Conclusion

In this paper, we have used the concept of boundary object to explore processes of collaboration, knowledge transformation and learning associated with the development, use and diffusion of a particular type of healthcare innovation, co-developed by clinical researchers with their patients. The use of boundary object theory to interrogate the development of technological innovations (Barrett and Oborn, 2010, Levina and Vaast, 2005, Swan et al., 2007) and to understand the mediation of relationships between healthcare professionals (Allen, 2014, Keshet et al., 2013) has been explored previously and is not in itself new. However, in interrogating both the development and shaping of this innovation over time *and* in exploring the development of the object as it became (re-)positioned as a boundary object-in-use, the work has built on recent attempts to understand the development of technological artefacts situated in systems of inter-connected objects and relations (Nicolini et al, 2012; Scarbrough et al, 2015). Specifically, it has demonstrated how the integrative and learning potential associated with such innovations in their (co-)development and use (cf. Carlile, 2002, 2004) paradoxically also inhibit the (potential) application and diffusion of such technology on a wider system basis. As such, the integrative and relational capabilities they bring also constitute the diffusion challenges they confront.

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Table 1. Summary of sources of data sources

Stakeholder / key	Timing	Interactions
Practitioner	Pre-app	3 x semi-structured interviews 1 x focus group (4 consultants, 3 specialty trainees)
Researcher	Pre-app	10 x semi-structured interviews
IT specialist	Pre-app	1 x semi-structured interview 1 focus group (6 members)
Manager	Pre-app	6 x semi-structured interviews
Patient	Post-app	16 x semi-structured interviews
Clinician researcher	Post app	3 x semi-structured interviews (2 with WD: 1 with CAS)
CONSULTATIONS	Post app	17 recorded clinical consultations (between clinician researchers and patients)

Table 2. Thematic analysis summary

Analytical theme	IT specialist view	Manager view	Patient view	Clinician view	Practitioner view
BOUNDARY BETWEEN INNOVATION AND PRACTICE					
Patient input into design			App to help identify triggers, to act as confidante Data entry of notable events	Preferred daily data capture	Preferred daily data capture
Clarity of role	Importance of role clarity; use of brokers				
Clarity of specification	Importance of clarity of specification (not always easy to achieve across professional boundaries); mixed success in use of boundary objects e.g. shared drives in achieving this				
BOUNDARY BETWEEN DISEASE MANAGEMENT LED BY THE PATIENT, AND THAT PLANNED IN THE CLINIC					
Empowering patient's self-management		Potential to enhance self-management	Potential to enhance self-management Improved illness understanding	Potential to enhance self-management Improved illness understanding	Potential to enhance self-management
Confidante			Use of the app as a personal confidante		
Worsening healthcare anxiety			Potential for app use to worsen anxiety		Potential for app use to worsen anxiety
Scales problematic			Scores felt to be reductionist Difficulty isolating symptoms caused by RA alone	Clinicians require 'objective' measure of disease activity	
Boundary object between patients and clinicians			Transformed patients' experience into something meaningful for clinicians	Provided evidence to communicate their perspective	Encourages shared decision making

			Reduced burden of communication	Routinized use of graphical data Used this as an aid to history-taking	
Shared consultation			Validating patient-entered data	More shared consultation (conversationally and physically)	
Learning tool			Highlighted benefits of particular interventions Empowered to discuss less-clinical features	Highlighted benefits of particular interventions Increased awareness of importance of discussing less-clinical features	
Boundary object between patients and relatives			Reduced burden of communication		
BOUNDARY BETWEEN THE IMPLEMENTATION OF THE APP FROM A SINGLE RESEARCH CLINIC TO WIDER SCALE UP					
Relationship considerations	Importance of clinical champions and high level clinical leadership Building upon pre-existing relationships important Strength of experience in integrating research with NHS systems Opportunity provided by patients' increasing e-literacy	Building upon pre-existing relationships important Need to capitalize on early adopters and support laggards Opportunity provided by patients' increasing e-literacy Use of patient champions	Concerned whether less forward-thinking clinicians would engage Use of patient champions Questioning long-term engagement with data entry	Benefits outweigh time-burden Questioning long-term engagement with data entry Potential risk of over-reliance on app-data vs history taking Potential for marginalization of non-users	
Resource considerations	Long term funding and personnel required to sustain	Scale up would require changes to commissioning practice Long term funding and personnel required to sustain Increased patient anxiety might increase consultation rates	Use for triaging opportunity for patient-centered care; but where would responsibility lie?	Use for triaging opportunity for patient-centered care; but where would responsibility lie?	

Technical considerations	Importance of digital maturity Generic infrastructure to aid scale-up Long-term sustainability important to justify scale-up Issues of compatibility following updates	Importance of digital maturity Generic infrastructure to aid scale-up Long-term sustainability important to justify scale-up			
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