Meaningful Technology at Work – A Reflective Design Case of Improving Radiologists' Wellbeing Through Medical Technology

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ABSTRACT

In radiology, medical technology providers (MTP) focus mainly on technology-related issues, such as image quality or efficiency of reporting. Broader notions of radiology as "meaningful work" are largely seen as out of scope for an MTP. The present paper challenges this. In a real-world case with a large MTP, we showed that medical technology could be designed more holistically to explicitly improve radiologists' wellbeing. We first gathered work practices experienced as especially conducive to wellbeing. From there, we distilled ideal practices to increase wellbeing and turned them into two software applications. The MTP's initial skepticism dissolved, while radiologists unanimously emphasized wellbeing and demonstrated how they work towards improving it. Based on our insights, the applications resonated well among the radiologists involved, the healthcare provider, and other customers of the MTP. We close with a critical reflection of the challenges and opportunities of designing wellbeing-driven technology in the work domain.

Author Keywords

Wellbeing-driven design; job design; technology at work; practice-based.

CSS Concepts

•Human-centered computing~Interaction design~Interaction design process and methods

1 INTRODUCTION

> *"As manager, I care about the wellbeing of my staff. No matter in which domain, getting good staff is very difficult. And to keep it is at least as difficult." (C-level manager, 2015)*

The work of radiologists heavily depends on technology, such as computed tomography (CT) or magnetic resonance imaging (MRI). While radiological technologists carry out exams with scanners, radiologists plan, diagnose and report their findings predominantly to referring physicians.

Radiologists, such as all other individuals, not only work for sustenance but also meaning. As Steger and Dik put it: *"Work plays a powerful role in how people understand their lives, the world around them, and the unique niche they fulfill"* ([41], p.131). Over the years, numerous models of good and meaningful work have been proposed (for an overview, see[15,39]). These models, for example, suggest to provide employees with feedback, to strengthen social exchange, or to emphasize the contribution they make to the "greater good." Typically, these aspects are seen as either in the responsibility of the work organization or the radiologists themselves. In contrast, the technology used is seen as rather neutral. In this view, technology, such as scanners or diagnostic workstations, are simply tools, which need to be able to fulfill a given task in the most efficient way possible.

Unsurprisingly, medical technology providers (MTP) share this view and focus primarily on functional- or usability-related issues, such as image quality or efficiency of reporting. Broader notions of radiology as "meaningful work" are perceived as out of scope by MTPs. This is comparable to car manufacturers, who now and then seem to acknowledge that their product might be rather "good mobility" than cars per se, but still find no way to actually broaden their understanding of what a car is. To give an example, a large portion of people use their car for their daily commute. A car manufacturer provides the means (the car), makes it halfway comfortable, but does not see the time people spend in their car as an occasion to create positive experiences. In the same way, car manufacturers should start thinking of how to provide people with happier commutes through their cars (e.g., [20]), instead of confining themselves to endlessly improving functionality and usability issues. MTPs could broaden their scope to provide more meaningful work to radiologists through the medical technology they provide to the healthcare providers (HP), who employ the radiologists.

This reasoning is in line with current approaches to *Experience Design*, *Positive Design,* or positive technology (e.g., [12,16]). These approaches argue that work practices

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are inseparable from the tools and technologies used [9,43]. Thus, technology shapes work in various ways. For instance, the *task-artifact cycle* [8] suggests that technology will inevitably alter the tasks they are adapted to. In the same vein, current approaches to the philosophy of technology, such as *Postphenomenology* (e.g., [43]), view technology as active mediators of how humans interact and experience the world rather than as neutral, merely functional objects. We believe that given the power of technology to subtly shape work, we need to engage not only in making the technology usable concerning a given task, but to rather make it instrumental in shaping meaningful, fulfilling work. However, while approaches to meaningful work as well as meaningful technology all point in the same direction, only a small body of according work exists in Human-Computer Interaction (HCI) [26,31,32,45]. Real-world cases seem even rarer.

Luckily, in 2015, a UX-department of a large German MTP, approached us to explore the notion of wellbeing-driven design in the domain of radiology. This provided us with a chance to explore the notion of designing for meaningful work through technology in a real-world setting. This paper presents insights from this exploration. First, we ground our work on existing approaches to job design from work psychology as well as to designing meaningful technology from HCI. Second, we present a case of designing for more meaning in the domain of radiology. We conclude with a critical reflection of the challenges and opportunities of a wellbeing-driven approach to the design of technology in the work domain.

2 MEANINGFUL WORK

Summarized under the term *Meaningful Work* [6,23], this broad field of research comprises of approaches that inquire how employees "find meaning in work" and "approach, enact, and experience their work and workplaces." ([39] p.92). In an excellent review of this field, Rosso and colleagues [39] show how approaches in the subfield of job design consider the work environment and the intrinsic motivation of employees as central explanatory mechanisms. In line with this, HCI offers specialized models, such as Experience Design or Positive Design, which strongly relate to intrinsic motivation and offer a dedicated design-oriented perspective on the role of technology at the workplace. Since the motivation of employees is the subject in both job design (i.e., through organizational changes) and HCI (i.e., through technology), the following section provides a brief overview of approaches from both areas. Note, it is beyond the scope of this paper to provide a complete review of *Meaningful Work* and job design literature. Excellent reviews are available from Rosso et al. [39], Grant et al. [15], and Parker and Ohly [36].

2.1 Approaches in Job Design

For quite a while now, designing work is considered an important issue. In its beginnings, job design predominantly focused on cutting costs and improving efficiency. This functional and predominantly economic perspective on work had its origins in movements such as *Scientific Management* by Taylor [42]. Soon, the *Human Relations movement* suggested considering the psychological needs of workers, e.g., fueled by famous studies, such as the *Hawthorne Studies* [38] in the 1920s and 1930s, which by accident showed that feedback is prime to work motivation.

Since then, the experiences and motivation of workers became a crucial aspect to consider, and models began to focus on the wellbeing of workers explicitly. Approaches such as Herzberg's *Two-Factor Theory* [21,22], theories by Porter and Lawler [37], or the *Job Characteristics Model* (JCM) by Hackman and Oldham [35] empirically tested and formalized the importance of aspects, such as providing workers with feedback, letting them know that their work has an impact on others (e.g., task identity), letting them experience that their work contributes to an overall process, rather than only focusing on a single isolated part (e.g., task significance), or letting them experience that their work requires several different skills and abilities (e.g., task variety). These models started to consider resources, such as the intrinsic motivation fulfilled by a job. In this respect, models such as JCM are consistent with broader approaches to motivation [14], such as Self-Determination Theory (SDT) [11]. Other approaches, such as the *Job Demands-Control-Support* model or the *Job Demands-Resources* (JD-R) model (see [1,24,25]), present clear conceptual links to SDT and perceive the satisfaction of basic needs (e.g., autonomy, relatedness, or competence) as an essential motivational mechanism.

More recent approaches, such as *Job Crafting* (e.g., [3,44]), further suggest that employees should have the potential to develop their own jobs into something more fulfilling. Job Crafting actively involves employees in making physical and cognitive changes to their own tasks or relational boundaries [44]. Thus, employees receive more freedom, but also more responsibility, to actively influence the work process as well as the outcomes in terms of motivation and meaning. Wrzesniewski and Dutton [44] describe three needs people try to satisfy when crafting their job: (1) the need for control and meaning, (2) the need for a positive self-image, and (3) the need to connect with others. Regarding the needs for autonomy, competence, and relatedness, postulated in SDT, Job Crafting is, in great part, consistent with SDT.

In summary, despite all theoretical differences, in most models of job design, intrinsic motivation is a central explanatory mechanism [13,39]. However, motivation and meaning are primarily improved through organizational changes, and less through work-related technology. To give an example: If an organization wants to promote a more mindful approach to time management aimed at creating more freedom and less time pressure, this organization will rather consider regulations or individual education than introducing a new work calendar system, which shapes time-related practices in line with the promoted goals (see [17,30]).

2.2 Approaches in HCI

In contrast to the aforementioned approaches, using technology to address intrinsic motivation and meaning (i.e., subjective wellbeing) is at the heart of *Experience Design* or *Positive Design* [12,16]. These approaches provide a theoretical foundation on how interactive technology can explicitly address and improve subjective wellbeing. While these approaches are prevalent in the consumer and leisure domain [2], more recent work in HCI focuses on the workplace as an application domain for design for wellbeing.

For instance, Zeiner et al. [45] collected positive experiences at work and condensed them into 21 *experience categories*. Akin to experience patterns ([16], p. 70), experience categories summarize meaningful experiences and can be used as practical starting points for designing work. Lu and Roto [31] proposed a more theoretically refined framework based on the *Positive Design Framework* (PDF) [12] and *Mechanisms of Meaningful Work* (MMW) [39]. To test whether the framework is useful for design, they developed several concepts to increase wellbeing at work through the technologies used. For instance, they proposed a captain's chair on a tugboat illuminated by a special light setting to highlight the central position. The goal is to emphasize an experience of virtue, pleasure, and personal significance. Thus, the chair is not only ergonomically-optimized, but designed in a way to stage and emphasize a "captainish" experience based on what captains consider enjoyable and meaningful. While the framework helps to understand the workplace as a promising area of design for wellbeing, it remains rather vague about design processes. In addition, Lu and Roto critique PDF to lack "empirical evidence" ([31], p. 117). While it structures wellbeing into different aspects, it still has to be empirically shown that it is able to increase subjective wellbeing. Most importantly, PDF remains vague about the mechanisms of how wellbeing is actually influenced by technology.

Hassenzahl et al. [18,19] suggest an approach to the design of wellbeing, which focuses on the fulfillment of psychological needs, such as competence, relatedness, or popularity through technology use. However, while needs are important to ground design (similar to experience categories), they remain quite abstract. For example, it is important to acknowledge that a captain relishes competence and popularity at work. How to achieve this in a particular context remains an open question. More recently, Hassenzahl et al. [4,28] suggest S*ocial Practices* as a way to better understand how needs are fulfilled through activities and which role technology plays in doing so. Shove et al. [40] provide a particularly helpful concept to unpack social practices further. To them, each practice consists of *materials* (objects, tools, and infrastructures), *competencies* (knowledge and embodied skills), and *meaning* (cultural conventions, expectations, and shared meanings). On the one hand, these elements help to gather and better understand existing everyday practices. On the other hand, they suggest ways to redesign practice, by for example, changing a technology (a material). From the perspective of practice theory, changes in the material will inevitably impact meaning, i.e., need fulfillment. This provides the mechanism for creating and shaping meaning deliberately through the design of technology. In this view, for example, steering a tugboat is a central work practice to a captain. The bridge controls and the captain's chair are not only necessary materials in the practice, but substantially shape the way the practice is carried out and how it is experienced.

All in all, while HCI has a longstanding tradition in designing socio-technical systems, the notion that technology has not only to be perfectly adapted to the work task at hand but can also be explicitly used to increase meaning, is still in its infancy. While several theoretical approaches, examples, and an increased interest in 'meaning' exist in experience literature, industry, and HCI [34], we lack studies as well as real-world cases to further explore the opportunities and challenges of a wellbeing-driven design of technology in the work domain.

3 Case Study: A Wellbeing-driven Approach to the Design of Medical Technology in Radiology

3.1 Background

In 2015, a large German medical technology provider (MTP) approached us to explore the notion of design for wellbeing in the domain of radiology. The project was part of a research collaboration conducted by a German university and commissioned by the MTP. The MTP is one of the world's leading providers of medical technology. For instance, it develops radiological equipment, such as ultrasound devices, CT scanners, magnetic resonance imaging (MRI) scanners, as well as imaging software, picture archiving, and communication systems (PACS). Typically, healthcare providers (HP) buy this equipment from the MTP (a B2B relation). Radiologists, in turn, are employed by HPs. HPs offer radiological imaging (i.e., using technology) and diagnostics (i.e., done by employed radiologists) to referring physicians. For our case study, the MTP put us in contact with one of its clients, a HP which employs over 60 radiologists at eight radiological departments all over Germany.

	Gender/ Age	Years of professional experience	Date and participation in step:		
			2	4	6
R1	male/51	26	08/2015	04/2016	08/2018
R2	female/36	14	08/2015	04/2016	
R3	male/34	8		02/2016	
R4	female/32	1		02/2016	
R5	male/42	17			08/2018
C1	male/41	16	08/2015	04/2016	01/2019

Table 1. Date and participation in each step.

Typically, referring physicians request radiologists to obtain further diagnostic information relevant for patient treatment. Radiological technologists acquire radiological images according to protocols, which are set-up by radiologists depending on the diagnostic task. The radiologists' daily work consists mainly of reading images, diagnosing, and reporting findings to referring physicians based on the

acquired images. This work is highly mediated by technology, especially by the diagnostic workstation and its respective software.

3.2 Overview

In this case, we focused on radiologists working in a radiology department in a German hospital. The study started in 2015 and lasted about 15 months in total. During the case, we held six interviews with different radiologists from two sites and three interviews with a C-level manager, a member of the management board of the HP with personnel responsibility. Additionally, we met with employees of the MTP for project meetings and presentations (8 times in total).

In sum, six individuals (5 radiologists, 1 C-level manager) participated in our case (2 female, 4 male, median age=38,5, min=32, max=51). The MTP recruited the participants, and they were neither part of the research cooperation, nor were they compensated for their participation. The participants had different levels of professional expertise, ranging from a senior radiologist with 26 years of work experience (R1) to an assistant radiologist in training with only one year of work experience (R4) (see Table 1, third column).

For the case, we adapted a process suggested by Klapperich et al. [28]. Just like Klapperich and colleagues, we also gather successful (i.e., meaningful) practices to "inspire the (re)design of activities and technology to create more enjoyable and more meaningful ways of performing an activity" (p. 75). In the following, we briefly describe the six steps the present case comprises:

The objective of the initial step (1) was to *familiarize with the MTP's mindset*, their understanding of the customers and attitude towards wellbeing as an outcome of using their technologies.

In the second step, we (2) *gathered existing work practices* of radiologists, which had the potential to increase their subjective wellbeing, i.e., practices that make them "happy" at work. The objective of this step was to identify and better understand meaningful and enjoyable work practices.

In the third step (3), we *designed* five *wellbeing-driven concepts* of medical technologies inspired by four positive work practices gathered in the previous step. The objective of the step was to create concepts that evoke everyday work practices able to instill need-fulfillment. We used animated storyboards to describe the use of the medical technologies.

In the fourth step, we confronted radiologists and the C-level manager with the storyboards from step three to (4) *collect feedback from all stakeholders* involved. Three out of five concepts received positive feedback from the C-level manager of the HP as well as individual radiologists.

In the fifth step, we implemented the wellbeing-driven concepts that received positive feedback in step four in the form of functional prototypes of two software applications. The objective was to evoke positive work practices through the interaction and functionalities offered by the prototypes.

In the sixth and final step, two radiologists and the manager used both prototypes in a guided session to (6) *evaluate the functional prototypes*. Subsequently, they were interviewed about their experiences to see if the intended experiences (i.e., positive work practices) potentially emerge through the interaction with the prototypes.

Table 1, column 4-6 shows, who participated in which step on which date. An exception is step 1, in which twenty representatives of the MTP participated in a workshop.

In the following, we present each step, starting with the applied method, findings, and conclude with a short reflection.

Step 1. Familiarize with the MTP's Mindset

Method. To familiarize ourselves with the MTP's mindset, we conducted a one-day workshop with twenty product managers and UX consultants of the MTP. We presented our approach to *Design for Wellbeing* and *Experience Design* and showed some examples of the results of this approach, mainly in the form of student design cases or research prototypes. Subsequently, we asked participants to reflect on their business unit regarding wellbeing as an approach to generate new ideas, products, or work practices. We also asked participants to consider all people involved in the diagnostic procedure, such as referring physicians, HPs, radiologists, as well as patients.

Findings. In general, all participants were skeptical whether a wellbeing-driven approach to design could identify routes to innovative products, given the existent portfolio. For instance, participants referred to the complex business-to-business (B2B) relations in which they are operating. Here, purchasers of medical technologies (i.e., C-level managers of HPs) are different from users (i.e., radiologists). Participants assumed that managers focus on cost-effectiveness and performance indicators, such as the number of exams per unit. While they acknowledged the general importance of wellbeing, they clearly believed that it plays no role, neither in improving the business relationship between the MTP and HPs nor in developing future products.

For participants, wellbeing most likely played a role in the relationship between employed radiologists and HPs. They assumed that a HP would treat its radiologists well to improve staff retention. Providing medical technology, which increases employee's wellbeing, may help to improve the relationship between radiologists and HP. However, participants interpreted "treating employees well" exclusively as providing functional and usable tools concerning the task of diagnosing and reporting.

Finally, we agreed with our commissioning division to start the project with a focus on radiologists working in a hospital as the most promising testbed for design for wellbeing.

Reflection. In sum, the MTP, as represented by the participants, seemed exclusively driven by notions of *technological* innovation, improved efficiency, and cost-saving. To their

mind, managers of HPs, which are the real customers, expect this. The wellbeing of radiologists, albeit important, is not part of its business. Hence, participants were skeptical about whether wellbeing is a way to innovate their products. Of course, this is understandable, primarily since the success of the MPT so far is based on technological progress.

Step 2. Gathering Existing Work Practices

Method. For the second step, we conducted a one-day participatory observation in the radiology department of a German hospital. The first author interviewed two radiologists (R1, R2), to gather existing work practices radiologists perform to facilitate or impede their wellbeing particularly (e.g., "Describe positive moments in your job that make you happy."). To complement the radiologists' perspective and include organizational insights and requirements, we interviewed a C-level manager (C1) working in the same organization (e.g., "Does your employees' wellbeing play a role for you as an employer?" or "Would you invest into employees' wellbeing?"). On average, interviews lasted 90 minutes. Due to the presence of patients, the participatory observation and interviews with R1 and R2 were not video- or audio-recorded. Verbatim quotes were written down during the observation. The interview with the manager was video-recorded. We used thematic analysis [5] to organize the collected data. We then described individual work practices observed and mentioned during the observation and interviews. Several work practices emerged, which were finally consolidated.

Findings. Radiologist enjoy their work most, when they *(1) receive feedback from and have personal contact with the referring physicians*, *(2) keep track of their everyday amount of work and work content*, *(3) record interesting cases and lookup previous ones*, and *(4) have an undisturbed time period for diagnostic work*. Radiologists engaged in these four informal practices during the observation. In the following, we describe them in more detail:

(1). One of the first practices both radiologists emphasized was *to receive feedback from and to have personal contact with the referring physicians.* The radiologists especially enjoyed knowing whether their reports contributed to the treatment of the patient. One radiologist outlined: *"Of course, you want to know if the report was helpful in further treating the patient"* (R2) and "*Sometimes I make a list of interesting cases and call the referring physician later"* (R2). The subject-specific feedback fulfills the radiologists' needs for competence and popularity. The more informal exchange with referring physicians fulfills a need for relatedness. For instance, during the observation, an internist (a referring physician) came to R1 to talk about a case. After the consultation, R1 highlighted the importance of their close relationship, but also noted that these types of moments are rather rare. To receive feedback is also an advantage to the organization. The manager stated: *[…] the radiologists get their feedback. […] This makes them happy. […] We would like to have a technical solution [to support feedback], but not primarily to make the radiologists happy, but as a quality management tool for us"* (C1). He further mentioned that the referring physician's loyalty depends on close communication. Although feedback has positive effects for both radiologists and the manager, it is neither part of a formal practice nor addressed by any existing technology (beyond the telephone).

(2). *Keeping track of their everyday amount of work and work content* was important to both radiologists. One radiologist stated: "*I think we do more reports than in Münster [another radiological department]. I guess it is a great output we achieve every day"* (R1). The high caseload is not only a matter of stress but something to be proud of. A barrier to this pride was the feeling of losing track of individual cases and their careers amid the high workload. The manager mentioned that the organization already tracks machine utilization on a quantitative basis. But these figures are only reported to department managers when the performance of the department is too low, e.g., to increase the number of scans. Although a summary of the radiologists' individual diagnostic development and performance would instill pride (i.e., fulfilling the need for competence), no formal practice or technology addresses this.

(3). During the participatory observation, one radiologist (R2) used a small, black paper notebook to *record interesting cases and lookup previous ones*. When asked, she reported that she records interesting and typical (i.e., pathognomonic) cases. She revisits these cases when she writes reports on similar cases, e.g., to assure herself what she wrote before and to use sharp phrasing. Moreover, she revisits cases because they have personal significance (e.g., because she was the first of four radiologists to make the correct diagnosis.). On top of that, she uses interesting cases to teach assistant doctors, which is also of importance for the HP. No medical technology supported this informal practice.

(4). Due to the many interruptions when writing reports, both radiologists expressed the wish for *an undisturbed time period for their diagnostic work*. For example, during observation, a radiological technologist came into R2's office and asked for help, although R2 had just started to record the report of a complicated case. R2 remarked that after answering questions or leaving her office, she had to reconsider the whole case once more. R1 already self-created an informal practice to act upon interruptions. He usually doesn't start diagnosing until noon, since in the morning, many interruptions prevent him from working continuously on cases. More focused and efficient radiologists are also an advantage to the HP, because both the quality and the number of reports probably increase if radiologists are not continuously disturbed. Nevertheless, such a practice is neither part of any formal practice nor addressed by technology.

Reflection. Both radiologists and the manager were well aware of the relevance of meaningful work for their wellbeing. Without much thinking, both radiologists reported about informal practices, they established and

perform in their daily work to increase their wellbeing. They use their autonomy to "craft" their jobs towards more meaning. The manager straightaway agreed on the importance and the impact of employees' wellbeing on the organization's economic interests. He even had distinct ideas in mind (e.g., providing feedback to radiologists through personal contact to referring physicians) to increase the quality of reports, referring physician's loyalty, and radiologists' wellbeing. Thus, while, for example, the beneficial role of feedback is well-known from a job design perspective as well as acknowledged by the manager, the HP did not promote wellbeing beyond allowing for informal practices.

Although the manager already searched for a technical solution to provide feedback and increase the social contact of radiologists, neither the manager nor the radiologists considered medical technologies to be of relevance to their wellbeing. This is astonishing, given the fact that the information R2 collected in her "little black notebook" is readily available from any diagnostic workstation and PACS system. However, since this is an informal practice not directly addressing the immediate diagnostic process, it seemed irrelevant to medical technology – the same with feedback. Here the telephone is considered the predominant technology, although MTPs increasingly work towards more networked systems, where images and diagnoses are electronically shared. To include feedback mechanisms among referring physicians and radiologists does not seem especially challenging technically. Still, our MTP did not seem to consider this, merely due to a lack of understanding and focus on informal, wellbeing-related work practices.

Step 3. Designing Wellbeing-Driven Concepts

Method. We designed five wellbeing-driven concepts of medical technologies in the form of storyboards. They are inspired by the observed informal practices from step 2. Inspired, because the described interaction represents an ideal performance of each informal practice in terms of need-fulfillment. Besides the radiologists, we included the perspective of the manager because new practices and work-related technologies will only find their way into the workplace if they seem beneficial from both the employees' and the employers' perspective. In other words, beside the radiologists' personal benefits (i.e., increased subjective wellbeing), the concepts integrate the HP's organizational benefits (e.g., increased job retention and productivity) and thus create a collective benefit, which means that everyone benefits directly from using and purchasing the concepts (i.e., technologies). This is in line with Steger's and Dik's [41] findings that most research on meaningful work focuses on personal benefits only, although organizational benefits are equally important.

We used storyboards (e.g., [33]) to describe the concepts. The storyboards clarify and situate the aimed for experience of a given target person. Unlike other storyboards in HCI, a crucial aspect to design for positive experiences is to describe the personal meaning, and how the practice fulfills psychological needs in detail. However, the technology itself becomes a means to an end and is only vaguely described. Thus the storyboards create *"a space for critical and creative dialogue during participatory concept development"* ([7], p. 1). We summarized the five concepts in two animated storyboards with voiceover (see figure 1 and video figure 1 as an example) to better communication with the stakeholders involved.

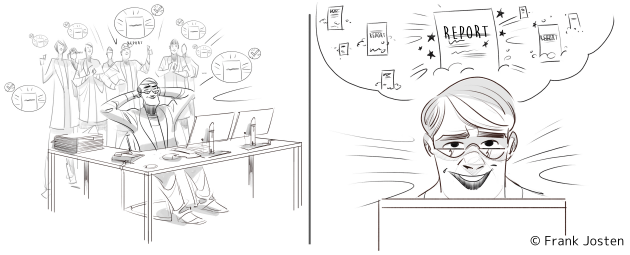

Figure 1. Two scenes from the animated storyboards

Findings. In the following, we briefly describe all five wellbeing-driven concepts.

Feedback Loop. This concept enables a simple feedback loop between radiologists and referring physicians. Referring physicians can mark received reports as useful or can request additional clarification for the diagnosis. Consequently, if a referring physician appreciates a report as worthwhile (e.g., because the radiologist contributed significantly to the diagnosis of a disease), the radiologist would see that in a summary and may feel popular and competent. In addition, the concept includes a long-term summary of all feedbacks that radiologists received during their career to provide a more general picture of their competence. Such a review should help to buffer single requests and potentially negative feedback emotionally. From an organizational perspective, a case-by-case feedback improves the quality of reports.

Contact to the referring physician. To reduce the distance between referring physicians and the radiologists, this concept enables both to contact each other. First, a case-by-case communication enables referring physicians to ask emerging questions concerning reports. Second, before a referring physician refers a patient to a radiologist, the physician's questions can be addressed. Because of different daily work routines of both, the concept provides an asymmetric communication channel (e.g., chat, messaging). An asymmetric channel initiates communication unobtrusively (e.g., by callback requests), that might eventually even lead to a phone call. The concept addresses the radiologists' needs for popularity (answering questions) and relatedness (having personal contact). Personal contact also addresses the perception of the referring physicians' service quality to increase the referring physician's loyalty.

Short- and long-term retrospection. Like an activity tracker, this concept records all reports written by a radiologist. The data can be used for both a quantitative and qualitative review. Radiologists can focus on a long-term (career-

oriented) or short-term (situation-oriented) period. The concept thus addresses the radiologists' needs for competence (quantitative), stimulation, and meaning (qualitative). From an organizational perspective, the concept provides information on machine utilization and the changing expertise of the employed radiologists.

Accomplishment Library. This concept enables radiologists to store cases they find exciting and meaningful. They can look up stored cases based on curiosity (stimulation) or to teach assistant radiologists (popularity). Especially teaching others is associated with increasing meaningful work [10]. Training is of organizational importance to retain existing radiologists, expand their expertise, and attract new staff.

Time management. With regards to slow-downs or interruptions, this concept senses when radiologists write reports most effectively. Over an extended period, the concept and the radiologists find the most effective time slots to do diagnostic work. The concept enables radiologists to become more productive and thus addresses the radiologists' need for competence. For the organization, it is also crucial to increase the quantity and quality of work.

Step 4. Collecting Feedback from All Stakeholders

Method. We showed the animated-storyboards (i.e., videos) of the concepts to radiologists (R1-R4) and the C-level manager (C1), followed by an in-depth interview. While Larsen and Buur [29] used improvisational theatre as a research method, we employed animated storyboards to present our ideas and to collect feedback to develop the concepts further. Concerning the radiologists, the objective of the confrontation was to gain a deep understanding of the participants' emerging feelings and thoughts, when they envision themselves using the concepts (i.e., performing the work practices through the interaction) (e.g., "*Does the presented video resonate with your work routine?* " *or* "*What would you feel using the presented concept?*"). We asked the manager to focus on organizational benefits, such as increased staff retention or productivity. We used thematic analysis [5] to organize the interviews – emerging topics were used to consider whether concepts resonated or not.

Findings. In general, both radiologists were able to empathize with the practices shown in the videos. In particular, they expected that the use of the *Feedback Loop*, the *Contact to the referring physician*, and the *Accomplishment Library* leads to an especially meaningful positive experience. For the *Short- and long-term retrospection* and *Time management,* they could either not envision using the concept or did not expect positive experiences. In the following, we briefly summarize the feedback per concept.

Concepts that did not resonate. Concerning the *Short- and long-term retrospection*, all radiologists did not expect a positive experience from quantitative feedback. They believe that their work is not best represented by numbers. In contrast, especially both junior radiologists (R3, R4) associated insights into their professional development (i.e., qualitative feedback) with increased wellbeing. C1 perceived the practice as not needed since the organization already collects quantitative data.

Both radiologists and the manager regarded improved *Time Management* as incompatible with existing workflows. For instance, radiological technologists will always have to ask questions concerning patients. Moreover, colleagues should always have the chance to ask questions.

Concepts that resonated: Feedback Loop. We expected that feedback from referring physicians on reports would create a feeling of competence and popularity among all radiologists. R3 mentioned: "*A problem we all know as radiologists. That you send out a lot […] and do not get a lot of feedback […]*. R2 mentioned: *"It would be nice to get positive feedback. […] I would definitely feel better"* (R2). Even negative feedback was appreciated by the radiologists: *"And 'wrong' is as important– or even more important – as positive feedback […]. Because next time I would review the image differently"* (R1). In addition to the increased wellbeing of radiologists, the manager considered the feedback on the reports to be positive since it would improve the quality of the reports: *"This feedback loop will not save money immediately. But with that, I have a great potential to increase quality. And I would invest a budget to increase quality"* (C1).

Contact to the referring physician. We expected a case-based communication to create a feeling of relatedness among radiologists. Moreover, the opportunity to answer further questions of referring physicians should facilitate the feeling of popularity. R1 mentioned: *"For a long time, attempts have been made to make radiologists more anonymous. I think this is wrong. […] If you don't know the people [referring physicians] at all, […] it becomes difficult [to work with each other]"* (R1). However, the amount of communication should be carefully managed: *"In my opinion, it [the additional communication] is too much. Too much communication given the amount [of cases] […]"* (R2). The manager perceived the practice as very positive regarding customer loyalty: *"You automatically create customer loyalty […], this can't be bought with money. Because referring physicians commit themselves to him [radiologist]. […] The report is even secondary […]"* (C1).

Accomplishment Library. All radiologists expected to collect cases in a personal library to be stimulating and meaningful at once. One radiologist mentioned that she would look up earlier cases: *"You create your own library. How did I write [the report of a similar former case] that back then? You develop a personal guide"* (R2). Beyond practical aspects, she liked the idea to collect meaningful cases: *"Yeah, that was a personal aha-experience. I was the first to find something in this patient. Of course, these are also cases that you show to colleagues [or] colleagues, who are still learning. And you can say: 'Here, I've seen that'"* (R2). The manager speculated that radiologists are rather interested in

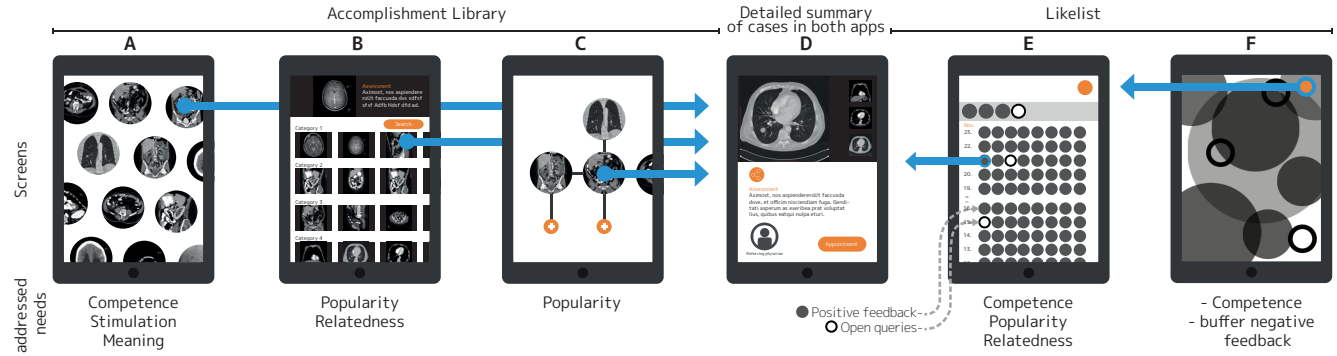

Figure 2. Different perspectives provided by the Likelist and Accomplishment Library.

a personal collection than a quantitative summary, especially for further training. However, for the organization, the quantitative feedback in the sense of key performance indicators remains important.

Reflections. It is noticeable that both radiologists and the manager could easily imagine using medical technologies that focus on increasing wellbeing. Additionally, they could critically reflect on them. Although they hadn't thought about medical technologies at all, they now even expected both an improved meaning of work and organizational benefits of such a technology. On the one hand, this indicates that radiologists are accustomed to incorporating technologies in their work and adapt work practices. On the other hand, it indicates that technology is capable of changing work practices.

From a design perspective, it is noticeable that the storyboards of wellbeing-driven concepts are a unit of design. Although they were not tangible, participants could easily envision their use and reflect on the experiential consequences. However, although the findings were very promising, the project ended here for the moment. It took a one-year break, plenty of positive feedback by the HP, and a lot of effort of our commissioning division to continue the project.

Step 5. Implementing Wellbeing-Driven Concepts

Method. In the fifth step, we designed two concrete medical technologies based on the three wellbeing-driven concepts that resonated in step 3. This step aimed to create functional prototypes that can evoke positive work practices through their interaction and functionalities, such as the animated storyboards did. We decided to design and implement two software applications because they easily integrate into the current work environment of radiologists.

Findings. In the following, we will briefly describe the essential functionalities of both software applications called *Likelist* and *Accomplishment Library*. Note, based on the industrial property rights of the MTP we worked with, we will only present schematic screens of both apps. However, all functionalities and elements of the medical technology designed are represented.

Accomplishment Library. This app provides radiologists with the infrastructure to build a collection of cases. During e.g., diagnostic work, radiologists can collect cases they consider exciting or meaningful in their library. The library offers three different perspectives on the collection. The first perspective (see figure 2 A) shows all cases (by showing key images for each case in circles) in a map-like view radiologists can browse through. If a case arouses their interest, they can open a detailed summary of the case (see figure 2, D). The objective is to fulfill the needs for competence (i.e., to bring to mind that you worked on exciting cases), stimulation (i.e., to discover old cases and developing relationships), and meaning (i.e., to assure that you do not lose track of meaningful cases). Similar to movie streaming services, the second perspective offers a more structured view on the collection (see figure 2 B). Categories, a search option, and a sharing function help the radiologist to find the right cases to e.g., teach assistant radiologists or show to colleagues. The objective is to fulfill the needs for popularity (i.e., to teach others) and relatedness (i.e., to meet colleagues). The third perspective lets radiologists compose simple presentations of cases from their library (see figure 2 C) for informal meetings with colleagues. Cases can be arranged in a mind-map like structure (e.g., based on a specific topic). The objective of the perspective is to fulfill the need for popularity (i.e., to show exciting cases to others).

Likelist. For the most part, the Likelist comprises the concepts called *Feedback Loop* and *Contact to the referring physician.* It offers two different perspectives on received positive feedbacks (solid circles) and queries (hollow circles) of referring physicians. The first perspective (see figure 2, F) summarizes all received positive feedbacks and queries radiologists ever received during their career in a blurry ambient visualization. Starting the app, radiologists always see this summary. The objective is to provide a general picture of radiologists' competence and to buffer single queries (i.e., potentially negative feedback) to fulfill the radiologists' need for competence. The second perspective displays a more detailed view of the feedback received from the last weeks in a calendar-like view (see figure 2, E). Starting at the present day, radiologists can scroll back in time. Beyond a certain period, the summarizing, first perspective is used. Each circle (i.e., case) provides a detailed summary of the case (see figure 2, D), including details such as key images or name of the referring physician. If the referring physician has queries concerning a case, both the radiologist and the referring physician can use this

detailed view to find an appointment to talk to each other. Note, that referring physicians would also have an app to provide case-by-case feedback or to use the chat-function. The objective of this perspective is to fulfill the needs for competence (i.e., to receive feedback from referring physicians), popularity (i.e., to answer queries and support referring physicians), and relatedness (i.e., to talk to referring physicians).

Step 6. Evaluating Functional Prototypes

In a guided session, R1, R5, and C1 explored the essential functionalities of both functional prototypes and were asked to imagine their daily use (see figure 3). The central question of the subsequent interview was whether both apps are capable of evoking the intended practices (i.e., including the associated need-fulfillment.) for both radiologists. We conducted a thematic analysis [5] to organize the interviews to understand how the stakeholders experience the sessions.

Findings. In the following, we briefly present our findings of the guided sessions and interviews.

Accomplishment Library. Both radiologists indicated that the library evoked the intended experiences. R1 mentioned: *"I find it exciting, it makes me curious."* Moreover, he outlined: *"Of course this has a personal meaning, these things [cases] that you have collected in a certain time, that you have somehow actively worked through [...], you pass on something personal [while sharing cases]"* (R1). The other radiologist mentioned: *"A general problem in radiology, you work through lists and it [cases] disappears into nowhere. Something is being kept here [in the library], I really like that."* and *"[...] that [the library] would be great for teaching, too"* (R5). The C-level manager highlighted the teaching aspects of the library: *"That's awesome. I would never have had such an idea. To collect cases where the images are defective [Images that cannot be used for diagnoses due to incorrect scanning] and then to show them [to others to teach them]" (C1).*

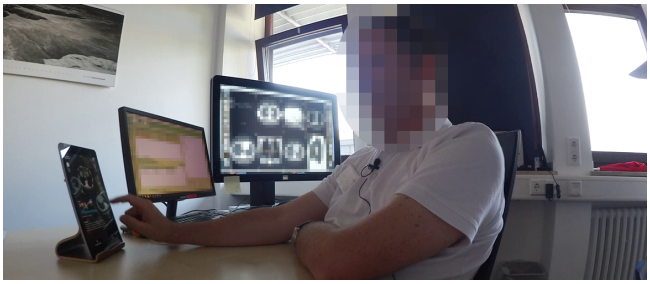

Figure 3. R1 using the prototype in a guided session.

Likelist. Both radiologists indicated that the app evoked the intended experiences. One radiologist mentioned: *"That would create a strong closeness [to referring physicians]. I don't even know how most of them look like."* and *"There would be a strong relationship [using the Likelist]. You get a favorite referrer, so to speak. I think that's really good"* (R5). R1 explained: *"Such a foundation of trust is built up in different ways. Here, personal communication is always important and of course you can easily establish that with it [using the Likelist]"* (R1). The C-level manager found the Likelist appealing, especially the opportunity to increase the quality of reports: *"A means for case-by-case communication [...] giving feedback, asking questions. That's the kind of tool we actually need"* and *"Quality assurance measures. We urgently need something like this. [...] and we would invest in such a tool"* (C1).

In sum, both prototypes evoked the intended experiences (i.e., need-fulfilling practice) for both radiologists and met the C-level manager's economic interests. Moreover, both radiologists were motivated to use the apps in their everyday work, and the C-level manager mentioned that he would even invest in both apps.

Reflections. Besides the positive feedback by all stakeholders, it should be noted that the wellbeing-driven concepts served very well as a basis for the design of both apps. For the development of the prototypes, we worked together with a prototyper that was commissioned by the MTP. Usually, UI-designers only receive requirement lists to design a user interface. In this case, as the UI designers of the prototyper told us, the wellbeing-driven concepts were something new to them, which they surprisingly found great to work with.

4 DISCUSSION

The contribution of this case study to HCI is twofold: First, the case provides a deep insight into how medical technology can be designed more holistically to explicitly improve radiologists' wellbeing. Second, the case contributes to wellbeing-driven design by providing a step-by-step process to the design of meaningful, technology-mediated practices.

4.1 On the Meaning of Work of Radiologists

In the present case, radiologists, as probably any other employee, clearly strived for meaning in work. For instance, they enjoy when their reports contribute to the proper treatment of patients and, thus, are helpful to referring physicians. They were able to describe in detail, why and how their work becomes especially meaningful. To experience all this, radiologist develop personal, informal work practices.

The same applied to their employer. Management was well aware of the importance of meaningful work for both radiologists and the economic interests of the HP. In this sense, many performance indicators, such as improved employee retention, increased attractiveness as an employer, or improved quality of reports, come along with meaningful work practices. Nevertheless, the management so far did not explicitly consider the introduction of dedicated formal work practices to increase wellbeing.

Unsurprisingly, neither the management nor the radiologists considered medical technology to become instrumental in increasing the wellbeing of radiologists. Medical technologies were associated with usability, effectiveness, or performance. This makes it especially difficult for MTPs to consider design for wellbeing. As long as all stakeholders believe that medical technology plays no role in improving

wellbeing, innovations, such as the "Likelist" or the "Accomplishment Library", are hard to introduce. It literally took two projects separated by a one-year break, plenty of positive feedback from HPs and radiologists, who wanted to use the apps, to convince the MTP of their further development. Cases, such as the present, are thus important to demonstrate the outcome of wellbeing-driven design in a tangible way. While initially neither HP nor the radiologists considered medical technology as instrumental to their well-being, the moment they saw the first concepts, this changed. Suddenly, this medical technology appeared especially attuned to the everyday emotional needs of radiologists.

All in all, despite the initial skepticism of all stakeholders, the MTP included, the present case indicates that medical technology is able to increase the meaning of radiologists' work. In addition, this must not necessarily contradict the economic interests of HPs. It highlights a way for MTPs to innovate beyond technical innovation. This is especially interesting in highly saturated markets, such as CTs, where technical innovation already reached a plateau. While successful, the present case also showed the challenges of design for wellbeing in the work domain.

4.2 Methodical Contribution to HCI

Beyond our findings concerning the design of medical technology in radiology, the case provides a methodological contribution to the field of Experience Design and HCI.

In the following, we briefly discuss our methodological findings. Most importantly, in the second step, psychological needs helped to 'look out' and 'sharpen the view' for meaningful work practices. This possibility-driven perspective helps to see potential starting points to increase wellbeing instead of solving mere (usability) problems. Additionally, in step three, one central unit of design of our approach were the wellbeing-driven concepts. They helped to bring together the creativity of interaction designers and the data from the second step. Subsequently, in step four, animated storyboards worked as a medium to consider several perspectives, which was very important in the work domain. A crucial aspect of the animated storyboards was to specifically focus on the intended interaction and experiential outcomes, without getting lost in small practical design decisions yet. Although functional prototypes are common means in HCI, the challenge for the apps in step five was to create the intended practices only through the interaction and functionalities offered, without further explanations or instructions as provided in the storyboards.

The present case made use of a practice-based approach to wellbeing-driven design. The approach was helpful to better understand a complex workplace and to identify first starting points to redesign existing work practices to become more meaningful. Such an approach has two advantages. First, its elements fit professional contexts. In professional contexts, work-related technologies (material), which entail specific goals and know-how (competencies) are prevalent. Though subjective wellbeing (meaning) is an important concern of users, available technology does not address it extensively. Second, novel practices are cost-effective. They do not require years of technological development.

Nevertheless, there are at least three limitations of the present case, which require a brief discussion. First, it is limited in sample size. However, we believe that in-depth, real-world cases represent a substantial contribution to the experience design – i.e., HCI. Second, to turn a promising prototype into a final product, further development is needed. To this end, approaches from product development or business case analysis should complement the present process with more controlled studies. Finally, practices and their business benefits appear to be vague and intangible as compared with more established requirements. Such an intangibleness makes it hard to "sell" practices internally and externally. Here, UX research should involve industry partners' requirements to compete with well-established approaches.

5 CONCLUSION

The present case study focused on the design of medical technologies as a means to increase the subjective wellbeing of radiologists. Although the practices and technologies developed are promising in terms of wellbeing as well as acceptance, the case shows that technology is still predominantly considered to serve narrow functional, task-based purposes. This overly pragmatic perspective on the work-related technology is reflected by Human Factors as well as HCI [27]. Although HCI emphasizes the relevance of the quality of interaction with technology, this is still mainly done narrowly, and the main criteria for good interaction, namely efficiency, clearly mirrors the MTP's perspective in the present case rather than a personal (i.e., the wellbeing of radiologists). Although approaches such as Experience Design have long shown how technology can go beyond functionality, it is still challenging to apply these approaches in the work domain. The present case is thus important since it demonstrates the potentials of a wellbeing-driven approach to design in terms of innovation and work-place improvement. While traditional HCI was mainly about adapting technology to the work tasks at hand, the wellbeing-driven approach more broadly focuses on the quality of emerging work practices. In this view, meaningful work is to a good part the consequence of using technologies designed with positive practices in mind.

Future research should provide more detailed cases of the opportunities and challenges of employing academic approaches to design within industrial settings. Not only do those examples go beyond theoretical frameworks and arouse the industry's interest in wellbeing-driven design. They are also a way to test according models and approaches. In the best case, this will result in an increasing number of available products which demonstrate that wellbeing-driven technologies have a market and finally increase happiness.

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