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RESEARCH PAPER

Expanding the representation of user activities

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Space is often designed based on the representations of user activities (*i.e.* lists, organograms or flowcharts) that streamline user activities in stepwise, oversimplified, representations that may leave insufficient room for future activity development. However, design can anticipate activity development if users are able to represent their own activities while participating in the design process. A case study of a medical imaging centre reveals that once users have such opportunity, their spatial practices are not only taken into account but also expanded. The designers, the users and the researchers created a range of instruments to expand across three units of analysis: operations, actions and activities. As a result, the representations of space proffered by the designers were expanded to a space of representation for the users, where new ways of working were realized. Based on this study, an integrated model for the production of space and the development of activity is proposed.

Keywords: activity representation, briefing, design process, early design, hospitals, medical imaging, production of space, user activities

Introduction

In architectural practice, the design of space is a social activity as much as the activities of people using space. In our current society, these activities mainly interact by negotiating representations that stand for the presence or the absence of users in the design process (Lefebvre, 1983, 1991). The design activity represents user activities during briefing and early design phases, based on information collected from meetings with clients, interviews with users, document analysis, references from similar projects or specific literature (Voordt & Wegen, 2005). Instruments such as lists, organograms and flowcharts are used to represent user activities at three levels of understanding: the operation level – related to immediate spatial conditions; the action level – related to strategic goals; and the activity level – related to the motives behind doing something together (Leont'ev, 1978).

When representing user activities there is a danger that the process gets stuck due to reliance on an instrument that does not allow for properly shifting the unit of analysis, from one level to another. A list of requirements, for example, might not disclose the underlying goals, as these goals may not be best represented by a list. ~~This is more than just a technical matter of replacing the instrument or adding more information to it.~~ The underlying challenge is to find a unit of analysis that expands the user activities into the future. The difficulty lies in representing activity beyond the current state of development, in order to consider the requirements in relation to actions that have not yet happened and that are quite unpredictable. As designers are accustomed to represent what they already know (Loukissas, 2012), user activities pose a new question to them: how does one represent something that is not yet known?

This question requires a distinction between two ways of approaching representation in design. There are theories that consider representation as the mental result of thinking about activity that can eventually be externalized by instruments, corresponding more or less to reality (*e.g.* Zhang & Norman, 1994). Other theories consider representation as an integral part of activity itself, based on its communicative role (*e.g.* Lorino, Tricard, & Clot, 2011).

Following the first definition, the answer would lead to improving knowledge-gathering and instruments to represent user activities accurately in relation to space. Following the second definition, the answer would reveal that design representation is also activity, with its own spatial conditions, strategic goals and motives that may contradict those of the user activities (Bødker, 1998). The current authors prefer to follow the second definition, as it transforms the lack of knowledge about user activities into an unfolding process of negotiating the presence and the absence of users in design. Following this path, the political and methodological difficulties of representing user activities in design will be highlighted.

These difficulties were faced in practice during an intervention conducted by the researchers in the design of a medical imaging centre in the Netherlands. In this project, the representation of user activities had a fundamental role in guiding the design of space, yet not as straightforward as designers expected. The designers, the users and the authors created a variety of instruments to represent user activities across the three aforementioned levels: operation, action and activity. This resulted in a new production of space, but also in a next step of development for user activities.

The goal of this study is to describe the intervention in the project and then to theorize the representation of user activities done for the purpose of designing space. The theorization reflects on architectural practices such as briefing (Barrett, Hudson, & Stanley, 1999), programming (Pena & Parshall, 2001), functional analysis (Voordt & Wegen, 2005), simulation (Loukissas, 2012) and participatory design (Sanoff, 2006) in light of cultural–historical activity theory (Engeström, 1987, 2011; Leont'ev, 1978) and the production of space theory (Lefebvre, 1983, 1991).

The paper is structured as follows. The next section explains the theoretical framework. This is followed by the analysed case data. The last sections present an addition to the framework regarding the role of space in expanding the representation of user activities. This is believed to be an important step toward a user-centred theory of the built environment (Vischer, 2008).

Activity representation and expansion

In the architecture literature much has been said about representations of space (Bendixen & Koch, 2007; Ewenstein & Whyte, 2007; Luck, 2007; Whyte, Ewenstein, Hales, & Tidd, 2007), but little about the representations of activity. In the few existing sources, the representation of activity is supposed to begin with a broad unit of analysis which is then divided into progressively smaller units (Kim, Rajagopal, Fischer, & Kam, 2013; Lou, Simoff, & Mitchell, 2006; Perin, 1970; Shen, Zhang, Qiping Shen, & Fernando, 2013; Thiel, 1997). This reductionist strategy may offer formal advantages to develop representation systems, but it does not take into account the efforts of practitioners to fill in the gaps between these units when trying to develop a coherent design.

Instead of further examining environmental psychology (Barker, 1968; Gibson, 1986), the referred source for this strategy, another psychological theory is explored: cultural–historical activity theory (Engeström, 1987; Leont'ev, 1978; Vygotsky, 1978). Its strategy of working with progressively larger units of analysis has been demonstrated to be useful for studying the representation practices in architecture (Groleau, Demers, Lalancette, & Barros, 2011).

Cultural–historical activity theory arose as a counterpoint to behaviourism, an experimental programme that aimed to explain human behaviour as reflex to immediate conditions (Pavlov, 2003). Activity theorists did not reject the idea that humans respond to conditions, but added the dimension of representation: human action is mediated by instruments that represent the immediate conditions in order to change them in a certain way, defined by an internal goal (Vygotsky, 1978). The subsequent development of the theory led to the implication of actions in society: individuals must coordinate their actions to pursue a joint achievement (Leont'ev, 1978). The fundamental concept was the notion of the object, the thing that motivates the joint achievement and that binds a community, with its own rules and a division of labour (Engeström, 1987). The object is sometimes mistaken for an instrument, especially when an instrument is used to represent the object (Hasu & Engeström, 2000). In that case, the instrument has a shorter life; it may soon be replaced for one that better represents the object.

This ~~expansion~~ from conditioned to social behaviour in cultural–historical psychology is summarized in three levels or three units of analysis: operation – responding to conditions; actions – aimed at goals; and activities – oriented to objects and motives

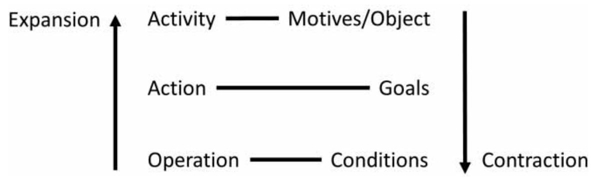


Figure 1 Expansion and contraction of the unit of analysis for understanding human activity
Source: based on Leont'ev (1978)

(Engeström, 1987; Leont'ev, 1978). This shift is contrasted with other psychological studies that divide activity into progressively smaller pieces (*e.g.* Zhang & Norman, 1994), a process that is called contraction (Figure 1). Expansion and contraction happens to any activity – not just psychological studies: an action may be expanded to an activity – *e.g.* the work done by a single individual may be taken over by an institution – and, in the same way, an activity may be contracted to an operation – *e.g.* due to automation. Representation plays a crucial role in both processes, anticipating the next level of development with instruments crafted to the corresponding unit of analysis.

In a design activity, for example, a list of requirements may be used to identify conditions that should be changed to accommodate new operations. The list may help in realizing that the source of trouble lies not in the immediate conditions, but in unclear goals. In that case, a particular operation must be reconsidered as an action responding to a goal. The list gives rise to a series of steps that fulfil goals, *e.g.* a flowchart. While making the flowchart, designers identify goalless actions that can be automated as operations. They may optimize the action without carefully considering the consequences in other levels. These consequences only become visible when a user announces an intention to leave such activity due to the lack of motivation for doing a repetitive optimized procedure. In response, designers direct their efforts at the activity level to prevent the disbanding, using persuasive speech and abandoning the existing analytical instruments.

This brief example discusses how instruments alone do not provoke contraction or expansion of user activities. It depends on how they are used, who is involved and the purpose of representation. These relationships are best captured by the activity system model (Figure 2): a subject of a community transforms an object for an outcome using instruments, regulated by rules and division of labour (Engeström, 1987). In the example above, the subjects are the designers who are working on transforming space (object) with different kinds of documents (instruments), following an optimization mindset (rule) and excluding the participation of users until the very last moment (division of labour). The model is applied to grasp how these relationships change over time – *e.g.* how the division of labour changed to account for the disbanding. Every change is sought to affect other elements of the model as well, in a ripple effect. The small changes accumulate until there is a major breakthrough: object expansion, when the object orienting activity is reconsidered in a totally new way (Engeström, 1987; Engeström & Sannino, 2010).

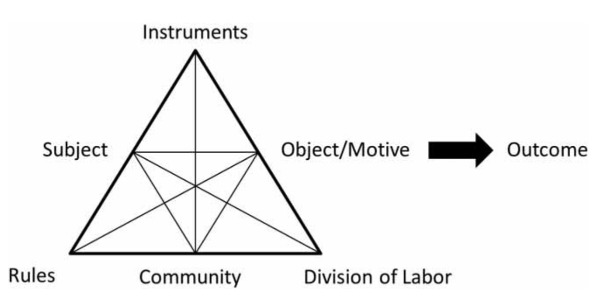


Figure 2 The activity system model
Source: redrawn from Engeström (1987)

Object expansion may also occur when different activities try to produce something together, in collaboration. In that case, the initial object is reconsidered as an expanded object in face of the differences and the similarities between the collaborating activities. Later, these expanded objects in each activity may converge into a single shared object (Engeström, 2001), jointly constructed by both activities, provoking changes in both sides (Figure 3). Depending on those changes, the object can last for a while or for a longer period. The permanence of the shared object can provoke a merger between the activities or give birth to an entirely new activity (Engeström, 2008).

This model reveals a collaborative challenge when applied to the design realm:

> For designers, as for any practitioners involved in complex organized activity, making sense of their own work as a collective activity system represents an expansive challenge of 'visibilization'. But this is only the first step. Opening up and making visible the activity systems of key customers or users is the logical second step of expansion. [. . .] The formation of a partially shared object between the designer and the customer/user is a crucial challenge.
>
> (Engeström, 2006, p. 4)

The object of design is expanded from an instrument to be used by a generic user activity (initial object) to a specific user activity, as represented by design (expanded object). If expansion stops at this point, there is a risk of putting too much structure – rules, instruments and division of labour – into the user activity (Redström, 2006). Since representations are proffered in order to stand for the user's presence (Lefebvre, 1983), there is little chance to realize the

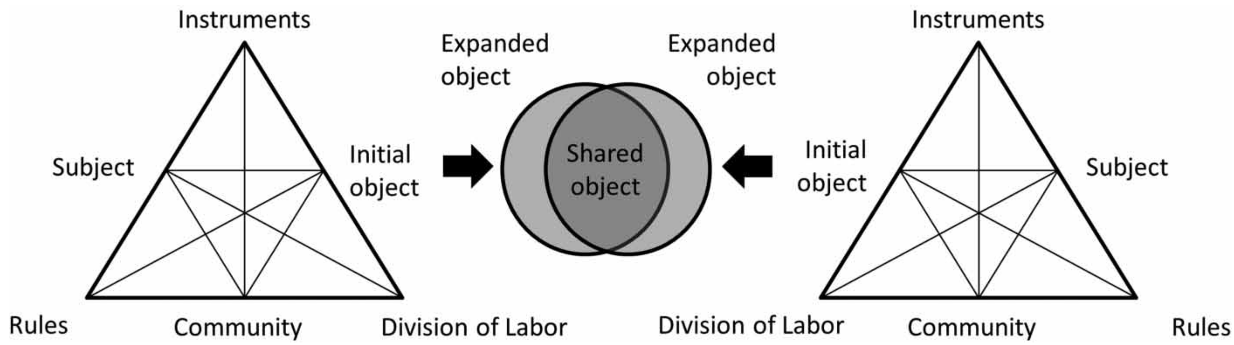


Figure 3 Activities interconnected by a jointly constructed, shared object
Source: redrawn from Engeström (2001, p. 136)

resistance to the over-structuring that might occur later. In contrast, the expansion to shared objects requires the users to be present, participating in and resisting the transformation of the design object. When users interfere with the course of the design activity, it is possible to say that the design activity becomes an object of the user activity, and vice versa (Bødker & Grønbæk, 1996). The shared object is, thus, a jointly constructed representation and material thing that permeates both design and user activities.

Despite the documented evidence of mutual learning between designers and users (Béguin, 2003; Bødker & Grønbæk, 1996), this process of expanding the representation of user activities is not well covered in the design literature. There is still a noticeable lack of knowledge about the formation of shared objects between design and user activities (Luck, 2007). As these objects are emergent, performative and situated, it is hard to rely on generic descriptions of these two. To grasp the emergence of shared objects in practice, an analysis of a specific design project is presented that the authors observed and supported the representation of user activities in depth. The theoretical framework here introduced underscores the analysis; however, the role of space in representing activity deserves an addition to the framework, which will be presented after the study.

Case study

The case study is based on a forthcoming medical imaging centre in the Netherlands. The centre will offer state-of-the-art diagnostic machines such as magnetic resonance imaging (MRI), positron emission tomography (PET-MRI), computed tomography (CT), single photon emission computed tomography (SPECT), and electroencephalography (EEG). The project is unique in the Netherlands for its attempt to combine research, technology development, education and care in the same space. This study covers a small part of the design process: the evaluation and final adjustments of the floor plan, which happened between July 2012 and January 2013.

This case study was selected because it offers a practical challenge to represent user activities in the context of designing space. In healthcare, activities are constantly changing due to regulations, demand fluctuation and new technologies; they are fragmented and respond to emergencies. Requirements are very specific, often contradictory and difficult to balance in an overall plan. Designing space that allows user activity expansion is very hard, but an essential effort.

The method employed in the study is formative intervention, a variation of action-research that aims to facilitate activity expansion in organizations (Engeström, 2011). A unique feature of this method is that it unfolds by empowering the analysis of the situation made by participants themselves:

> The unit of analysis is usually a conceptual idea strictly for the researchers. In formative interventions, we turn the unit of analysis into an external auxiliary means, a mediating conceptual tool, for both the participants and the researchers.
> (Engeström, 2011, p. 608)

Within the application of the method, the authors developed custom-tailored representation instruments to support the design process instead of using the cultural–historical activity theory models (Figures 2 and 3) – as is usually done in formative interventions, since these models do not offer a clear guidance on representing activity in relation to space. The first two authors followed the meetings of the design activity, analysed the design documentation, interviewed the project participants, developed representation instruments and joined design workshops as participant observers. They worked closely with the two managers of the project, who represented the client organizations and led the design activity.

The interviews and workshops were video-recorded and notes were taken. The notes and documents collected were transferred to an Issue-Based Information System (IBIS) where they could be classified and graphically

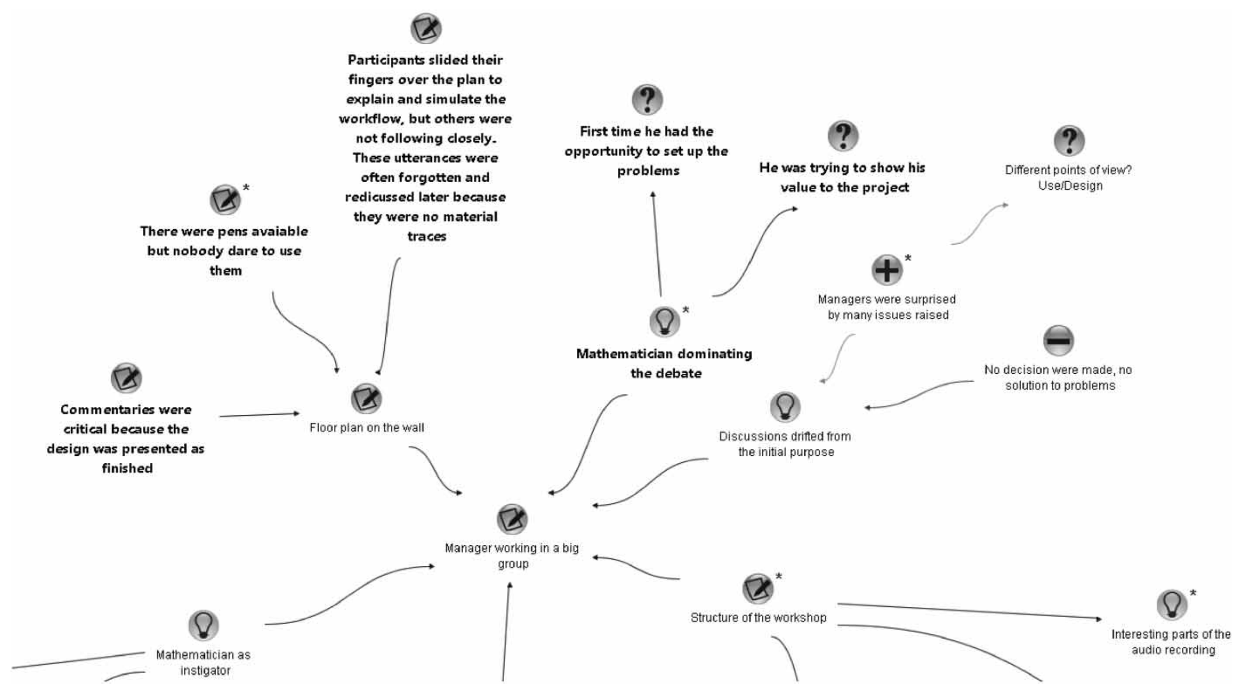


Figure 4 Issue-Based Information System (IBIS) used to analyse graphically the qualitative data collected on the case study
Note: each node in the map contains an issue (light bubble icon), an issue's advantages (plus icon), an issue's disadvantages (minus icon), a doubt (question mark icon) or a note (pen and paper icon)

interlinked (Kunz & Rittel, 1970; Selvin et al., 2001). Each encounter the authors had with the designers and the users – online communication, interview, meeting or workshop – was represented as a graphical map with old and new issues (Figure 4). These maps were composed of six types of nodes: issues (topics that endured long discussions), an issue's advantages (arguments that try to close the discussion with a possible solution), an issue's disadvantages (arguments that try to close the discussion with no clear solution), questions (interpretation doubts), observation notes (descriptions), and links to collected digital files. Other authors reviewed the recordings and the discussion among them produced new notes for the IBIS.

The graphical maps were used to track how an issue developed throughout the intervention in an effort to reveal traces of contraction and expansion in the representation of user activities. They were also shown to the project managers to report the partial account the researchers had at different moments of the project for validation, and to help the researchers to keep track of what was being discussed in workshops. The graphical maps served as an intermediate step in the research process, being often consulted and updated, but never fully formalized. The maps were used mainly for keeping up with the big picture while analysing data and developing representation instruments. The narrative that follows completes the qualitative data analysis, roughly based on the interaction analysis method (Jordan & Henderson, 1995). The theoretical concepts from cultural–historical activity theory – operation, action, activity, collective subject, instrument, object, rules and division of labour – are employed along the narrative to make sense of the historical process (Bødker, 1995).

From the business plan to the spatial conditions

The researchers began the intervention when the project was in the early design stage. Briefing had been completed and a floor plan served as the main representation of the object of design activity: the imaging centre space. The floor plan was designed and annotated by architects, machine providers, structural engineers, installation advisors and the project managers, whom together constituted the collective subject of the design activity, hereafter called 'the designers'. Among them, the project managers had an active role in aggregating the design community, taking responsibility for briefing the users, elaborating the programme, handling information from one designer to another and also confronting their different perspectives. For these purposes, they organized a biweekly meeting and set up an online document-sharing service.

The designers considered the requirements for user activities non-problematic at the beginning of the project and strived to meet the business plan, in particular, the list of diagnosing machines to be acquired and their expected income. They designed the facilities to host the machines according to national regulations and based on the expertise acquired in similar projects. This initial object of design presented complicated problems such as load bearing, radiation, high-energy consumption and intense noise that kept the designers busy with the spatial conditions for many months. Designers were very collaborative with each other, but the professionals who are going to work in the centre were not directly involved, although they were considered in the design process.

The professionals included were medical imaging researchers, radiologists, radiographers, technicians and nurses from the main hospital of two medium-sized cities, hereafter called fictionally Northwest Hospital and Southeast Hospital. The centre was to be located in a retrofitted building between the two cities and could serve as an outreach for both hospitals. The business plan relied on the idea of sharing diagnostic machines to promote knowledge exchange between research and clinical practice. The medical professionals who are supposed to work in the centre constitute, in each hospital, a collective subject negotiating with the design activity, hereafter referred as 'the users'.

The users were indirectly involved through individual interviews about spatial requirements conducted by the project managers. Based on that, the designers compiled a list of rooms (including information about medical equipment, square metres, adjacent rooms, daylight needs and the name of the user) which was circulated among the users for validation. The project managers realized their lack of understanding when the designers presented a first design that contained undefined areas. Since it was not possible to meet all the requirements and their reasoning was not documented, the project managers could not decide what could be contracted in user activities to fit the spatial conditions.

In the meantime, the interviews triggered an informal discussion among the users about the motives for joining the imaging centre. When the project managers came back to them for a follow-up interview, they noticed disagreements. The users from Southeast Hospital were particularly sceptical about whether the centre would offer any advantage to them (as they already had similar machines at their own radiology and nuclear medicine departments). The users from Northwest Hospital were enthusiastic, but worried about the capacity of the centre to deal with patient complications during a scanning procedure. In any case, both manifested a concern about how sharing the machines would work.

To evaluate the current design and to make adjustments, the researchers suggested a workshop with at least one person present for each user activity. To give an example of what could be discussed during the workshop, a sample animation was created based on the floor plan depicting the usage schedule of the building by different activities, their costs and revenues (Figure 5). The animation had five dimensions: the three dimensions of space plus time and money. This animation was not used in the project, but it reflects the authors' understanding about the centre's spatial and economic conditions at that point.

The contraction of user activities represented by the designers and the authors (for a summary, see Table A1 in Appendix A) did not help to address the issues raised by the users, as the issues were positioned at different levels of understanding activity. Before going through spatial conditions, the users wanted to discuss the motives and the goals behind each space, particularly the why and the how of sharing the diagnostic machines.

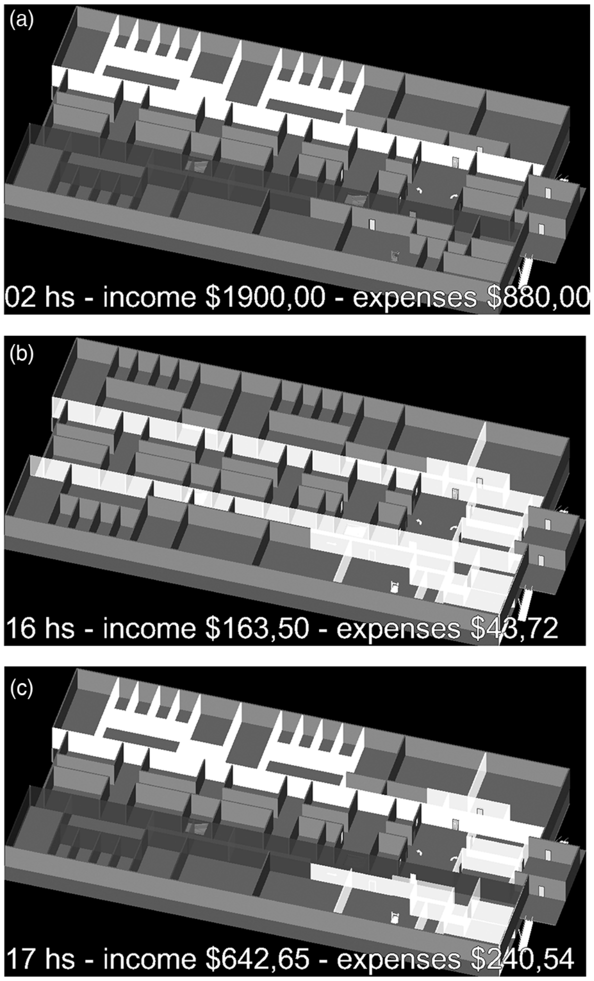


Figure 5 Stills from the five-dimension (5D) animation about the building's usage schedule
Note: the rooms light up in colours to represent user activity, while the income generated and operating costs are shown at the bottom

From spatial conditions to healthcare operations

Despite the researchers' offer to organize a workshop with users, the project managers decided to organize one on their own. They sent an invitation letter to radiologists, radiographers, nurses and technicians from the two hospitals, with the addition of two healthcare logistics experts and the authors. The letter set the explicit goal of planning the centre's care logistics; however, the implicit goal was to raise commitment. The hospitals had not yet signed the collaboration contract with the centre, so they expected their involvement in design to contribute to that decision. Here, there was already a mismatch between the unit of analysis proposed to the workshop – care logistics, or in other words, operations – and the next level of development – an object that motivates the hospitals to expand their care activities to the centre.

The workshop began with a quick introduction of the business plan, the current project phase and the importance of having the user evaluation. The project managers fixed a printed floor plan on the wall, stood beside it and explained the design rationale behind the floor plan, pointing to certain areas of interest.

As soon as the discussions became more intensive, all the participants stood up and came closer to the floor plan fixed on the wall (Figure 6). They began to question the proposed spatial conditions by formulating potential problems with particular operations, based on their previous experience with similar spaces. Participants represented operations using verbal narratives while sliding their fingers over the printed document. The discussion jumped from one operation to the other, without considering the actions or activities to which they were subordinated. Every time the conversation came back to an operation mentioned previously, the operation had to be represented again, since the floor plan was not being marked in any way. There were actually some markers on the table, but the managers did not explicitly offer them to participants. In fact, they wanted to avoid as much as possible having to change the floor plan, since it would imply revising the complex system of electricity, heating and air-conditioning already set up.

Figure 6 Participants in the first workshop slide their fingers over the plan to represent their activities

The floor plan was designed with the assumption that activities do not overlap in space; each activity would use different diagnostic machines at different times. When participants noticed that there would be overlaps in space and also in time, the unit of analysis jumped directly to activity: hospital professionals discussed which kind of patients they would send to the centre (their object), the regulations that would apply (their rules), and how the two hospitals would work together (their division of labour). There was a major doubt if the capacity of the shared waiting and dressing rooms would be sufficient to keep machines busy with patients in both hospital areas, a doubt aggravated by the double function of these rooms as circulation hubs. The bottom line was that the activities intersect in space and the subjects were unaware of how they would interfere with the operations of each other. The workshop concluded with many unresolved issues.

The project managers were quite surprised by the results, but they did not complain about the fact that the workshop drifted away from logistics to space, which had been considered adequately resolved prior to the session. They were happy to learn more about the user activities, but worried about the necessary rework on their design. Their initial focus was on the operation level – improving the logistics – but the conversation expanded and contracted throughout the levels without a clear guide (see Table A1 in Appendix A).

From healthcare operations to individual actions

The project managers then decided to organize a second workshop with the same participants to pursue the issues that had been raised. In the meantime, they also visited the two hospitals to improve their own understanding of the user activities and their current space. They observed the positions of the machines, the corridor widths, the number of dressing rooms and experienced the space with their own bodies. Nurses and radiographers helped them to understand the goals supported by this particular spatial design. The project managers then showed their own design plans and asked for suggestions on an individual basis. Later, the project managers came back to the design community and asked them to make changes in the floor plan based on their interpretation of users' actions and goals, which was compiled in a linear workflow diagram.

The design options were consolidated in one major redesign of the facility. For the second workshop, the project managers sought the research team's assistance. The researchers suggested letting users represent their own activities and interfere with the object of design: space. Since the project managers were afraid that the discussion could drift from the intended scope, the researchers suggested guiding the discussion with an instrument other than the printed floor plan, as the plan only represented the spatial conditions but not the operations.

Instead of a floor plan, it was suggested to use discrete-event simulation of a typical day in the centre. The simulation had the machines arranged in the same way as the spatial layout which took into account the walking time of nurses and patients in the performance measure. However, the simulation did not take into account possible delays, deviating behaviour and walking detours. The intention was that the doubt concerning the number of dressing rooms could be clarified by simulating the care procedures with the number of patients expected per day by the business plan. The simulation output was an animation video of a typical day in the medical imaging centre (Figure 7), plus the resulting performance in figures such as the percentage of machine and room capacity used.

The simulation was based on the steps that patients and staff are supposed to follow in the scanning procedures of each machine, as prescribed in the workflow diagram. The diagram did not specify where in space each step happened, so this entailed guessing by the researchers where to route patients and nurses. Here, again, there was a mismatch between the next level of development – actions and goals – and the unit of analysis used for representing – step-by-step operations.

The researchers considered the possibility of using the simulation during the workshop as a collaborative instrument to expand representation through discussion and iteration. The participants would suggest new parameters and the simulation would show the consequences on performance, instigating a consideration of the goals. However, the software user interface proved to be too complicated for quick use in such an interaction. The software was probably not designed for that purpose, but the simulation was shown during the second workshop, without the possibility of changing the parameters, just to support the managers' argument that the number of dressing rooms was enough for the expected number of patients.

The project managers' visit to the hospitals can be considered an expansion in understanding user activities. However, the instruments used to document that experience did not cope with the expansion: activities were represented as a series of steps, with little information about space, object, instruments, rules, community and division of labour (see Table A1 in Appendix A).

From individual actions to collective activities

After realizing the limitations of the simulation to represent actions, the researchers created a low-tech version of the simulation that looked more like a game. Pushpins were attached to each room of the floor plan, and sewing threads were offered to represent the movement of nurses and patients. This instrument is similar to what Grunden and Hagood (2012, p. 109) used in their lean healthcare design: the subjects are supposed to tie and untie the threads while discussing how to optimize a particular action flow. Thread colours represented different persons walking around the building. The tool was named 'the knitting game', since the hand movements required to use the tool resemble knitting operations (Figure 8). The goal was to represent and optimize the flow of patients and nurses in the scanning action, avoiding back and forth movement. The material itself imposed the rules: each step in the flow must depart

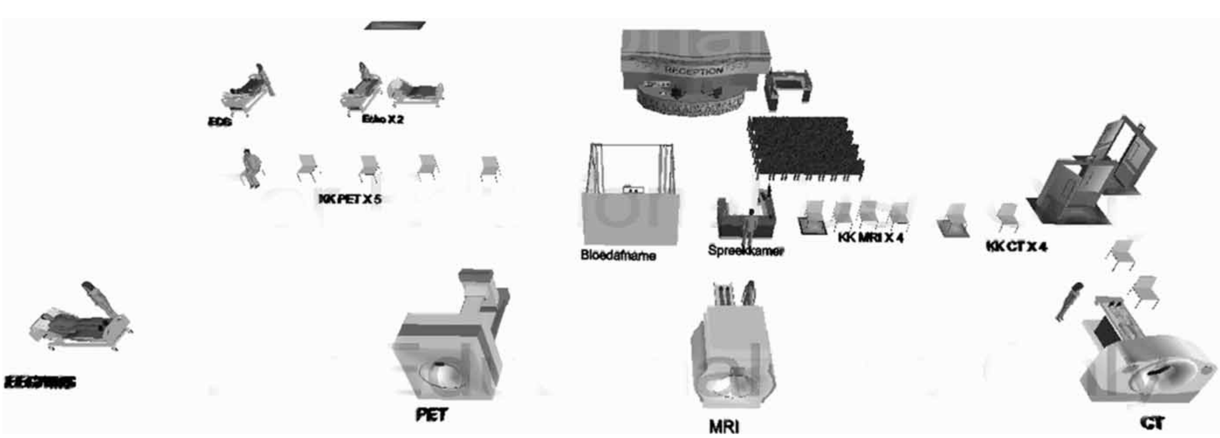


Figure 7 Simulation of the scanning procedures of the imaging centre. Source: courtesy FlexSim Software Products, Inc.

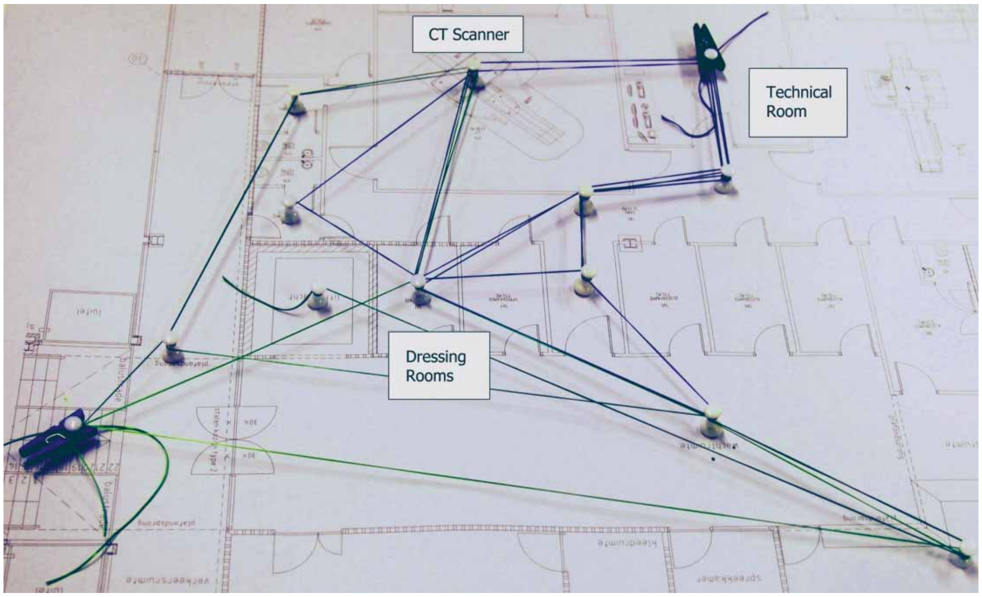


Figure 8 Knitting game made by the CT scan group
Note: the blue threads represent nurse movements; the green threads represent patient movements. Room labels are overlaid to the picture for readability

from and arrive at pushpins otherwise they are loosely represented. As the project managers wanted to avoid a situation where the users propose changes in the floor plan, there was this physical distance between the paper and the strings lifted by the pins. Stretching the threads between the pins actually required more than two hands, which purposefully underlined the collaborative nature of the representation. Though the game did not have a winning objective, there were goals, rules and roles.

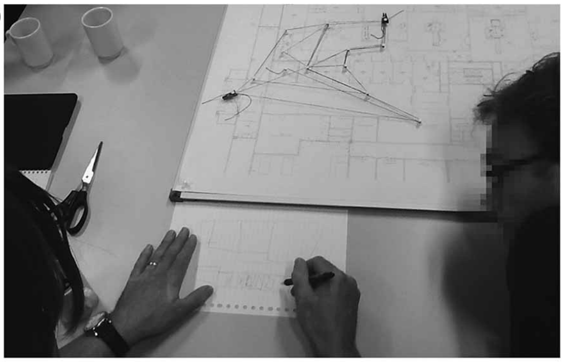
The game was introduced right after the simulation. Project managers divided the participants into two groups, according to the actions under consideration: CT scan and MRI scan. The CT scan group visualized the central role of the dressing rooms in the process and discovered the back-and-forth movement of the nurse between the technical room and the CT scanner, but they did not question the designed space. On the other hand, the MRI scanner group found so many problems in the space that they actually refused to play the game. One of the main complaints was about the space around doors and corridors, too tight to manoeuvre patients on stretchers.

As the discussion within the MRI group was stuck, the CT scan knitting game was brought to the MRI group table to create a combined version. The game helped the MRI group reflect in a more positive way about the design. At some point, a radiologist from the MRI group asked for a sheet of paper from the architect's notebook and sketched an alternative concept for the area between the CT and MRI machines while asking other participants for their contributions (Figure 9). The sketch opened up a corridor that connected once separated actions: CT scan and MRI scan.

While making the sketch together, the professionals from the two hospitals considered new issues, such as the division of labour between researchers, radiologists and radiographers in scan monitoring and producing images. Although they had different rooms for each action in their hospitals, they were in doubt if this was also necessary in this facility. A researcher from Northwest Hospital suggested a single room integrating both functions, as this would allow researchers eventually to look at image post-processing and talk to the technicians. The radiologist from Southwest Hospital was sceptical whether this collaboration could happen and was worried that researchers could put too much pressure on technicians. The issue was not resolved during the workshop, but the suggestion of an integrated room was later incorporated by the designers.

Rethinking the floor plan was not what the project managers had in mind, but they realized that this was necessary to proceed to arrive at a more detailed design. They asked other members of the design community to incorporate the sketch in the drawings, while the hospital professionals took a break to visit the construction site, *i.e.* the existing building that would be altered. There they experimented with their own bodies the spatial dimensions represented by the floor plan – *e.g.* how large were the rooms

(a)



(b)

Figure 9 Healthcare professionals sketch a new concept (a) and later the design team incorporates it in the drawings (b)

and the corridors. The project managers guided them through the main outside operations: arriving, parking, entering the building, etc. When the healthcare professionals returned, the designers' sketches were presented and a new round of discussions and adjustments occurred. At the end of the workshop, the project managers could reach the desired agreement with the designers' sketch done over the floor plan. The users' sketch expanded user activities to capture the motives raised, while the designers' sketch consolidated them in tangible goals (see Table A1 in Appendix A).

The second workshop was considered successful by both organizers and participants. The organizers had the level of agreement and information they needed to move the project forward, while the healthcare professionals enjoyed sharing knowledge and learning how others conducted the same actions differently in their hospitals of origin. Most importantly, they felt much more committed to and excited about the project.

Intervention outcomes

In a conversation with the authors during the construction site visit, the hospital professionals revealed that they did not understand very well what was occurring in the discrete-event simulation shown at the beginning. The animation played too fast and the underlying assumptions were not clear. The professionals did not question the animation since the value of joining the project was still not clear to them. The simulation shown at the workshop did not represent an object they would like to commit to at that stage.

The workshop became interesting when they had the chance of participating in the design of space. Space became a context for exchanging knowledge between the two hospitals, the machine providers and architects. One radiologist from Southwest Hospital mentioned that it took almost a year to achieve the same level of understanding with architects in their own hospital rebuild project, which was achieved in just two workshops in the medical imaging centre project. Such knowledge exchange was seen by both hospitals as the biggest advantage offered by the medical imaging centre, since they all pursued their own radiology and nuclear medicine departments, with more or less the same machines. They were more motivated by learning from each other, from researchers, from operation experts and from machine providers than by the extra capacity incentive offered by a new outreach facility.

The project managers also realized this fact on their own, and made sure that the contributions would be implemented in the official drawings. The concept of the common corridor between the CT and MRI scans was, thus, expanded to the whole plan, integrating Northwest Hospital's PET-MRI and SPECT areas. A comparison between the official drawings before and after the workshops (Figure 10) reveals a dramatic increase of floor area dedicated to circulation and shared facilities.

The managers explained that this corridor allows for greater flexibility, since the dressing rooms can be used by both hospitals when necessary. The participants believe that the extra circulation might increase the visibility of actions (entering or going out of a room), and therefore awareness, a very important feature for coordination – at the expense of patients' privacy. There is also a greater probability of informal encounters and exchanges between the professionals in this corridor. The spatial strategy of visual relations and flexible zoning suggested by a study in a radiology department seems to apply here (Tellioğlu & Wagner, 2001).

The role of space in expanding the representation of user activities

Workshop participants acted as if space were the fundamental underpinning to the consumption, production and distribution of knowledge by the centre;

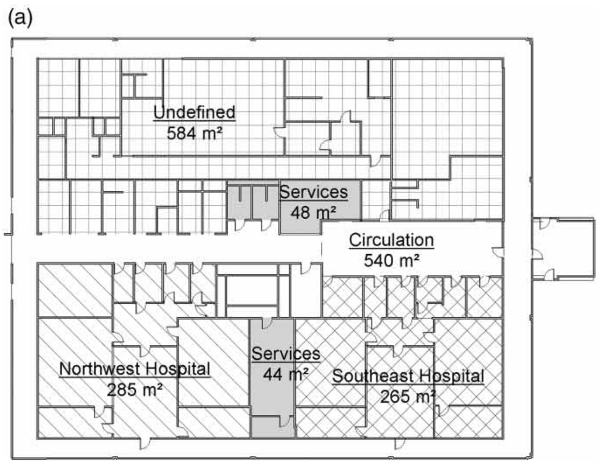


Figure 10 Floor plan before (a) and after (b) the workshop
Note: a larger amount of circulation now connects the once separate hospital activities.
Source: drawn based on video stills of the original documents

however, the researchers did not know exactly how to classify space within the theoretical framework. Is space an object, an outcome, an instrument, a division of labour or simply a rule? The few studies in cultural–historical activity theory that explicitly deal with space (Engeström, 2003; Engeström, Puonti, & Seppänen, 2001; Gutierrez, 1999; Popov, 2010) are quite vague on how to approach space, with one exception (Leander, 2002).[1]

A criticism that could be posed to this study is that the empirical observation focuses too much on the actions of certain individuals, reducing the collective level – activity – to a matter of switching contexts. The medical imaging centre case study has shown that the expansion of the unit of analysis from operations to activities, and their corresponding orientation, from conditions to motives, can reveal more about activity as a subject and space as an object. Users have mitigated positioning their activities as collective subjects demanding changes in space to the designers, who responded by sharing the object of design with users. Space was reconsidered from a mere instrument for use to an essential object for social production.

A theory that has been quite influential in architecture to consider space in this way is the production of space, which departs from the notion that space is constantly being produced by collective activities, and vice versa (Lefebvre, 1991). Instead of a framework or a system, this theory offers a conceptual triad between the spatial practices that (re)produce the material conditions of life, the representations of space that impose an order to these practices, and the spaces of representations where people find meaning for the everyday life.[2] The terminological inversion between the last two is deliberate: they are opposites, though deeply interlinked by the spatial practices. Architecture, as a spatial practice, is expected to produce works that represent society and, if successful, those works can be (re)represented in many ways by other spatial practices, thus becoming a space of representations. Notwithstanding, architecture must take into account the diverse representations of society that are already present in society to produce such a multifarious work (Lefebvre, 1983, p. 247).

The theory of the production of space has inspired many architects to become more sensitive to social issues (Stanek, 2011) without offering much design guidance, which limits its relevance to practice (Hillier, 2008). The production of space theory can perhaps help clarify the challenge of representing user activities and designing space observed in the case study if the triad is integrated into the shared object model (Figure 3), becoming the initial, the expanded and the shared object between activities (Figure 11).

In the case study, the designers were initially very concerned about developing a buildable and believable representation of space, which includes the floor plan and the construction site visited during the second workshop. On the other hand, the users were just reproducing their current spatial practices while evaluating the representations of space. The users found it difficult to think about working in such a different space. The expansion of the design activity towards the users' spatial practices is synchronized with the expansion of the user activities towards the representations of space, which produced the collaborative sketch of a representation of space that embeds not only designers' knowledge but also users' knowledge.

These encounters all happened in a temporary space, a continuum between the places that held the interviews, the workshops, the document sharing and the small

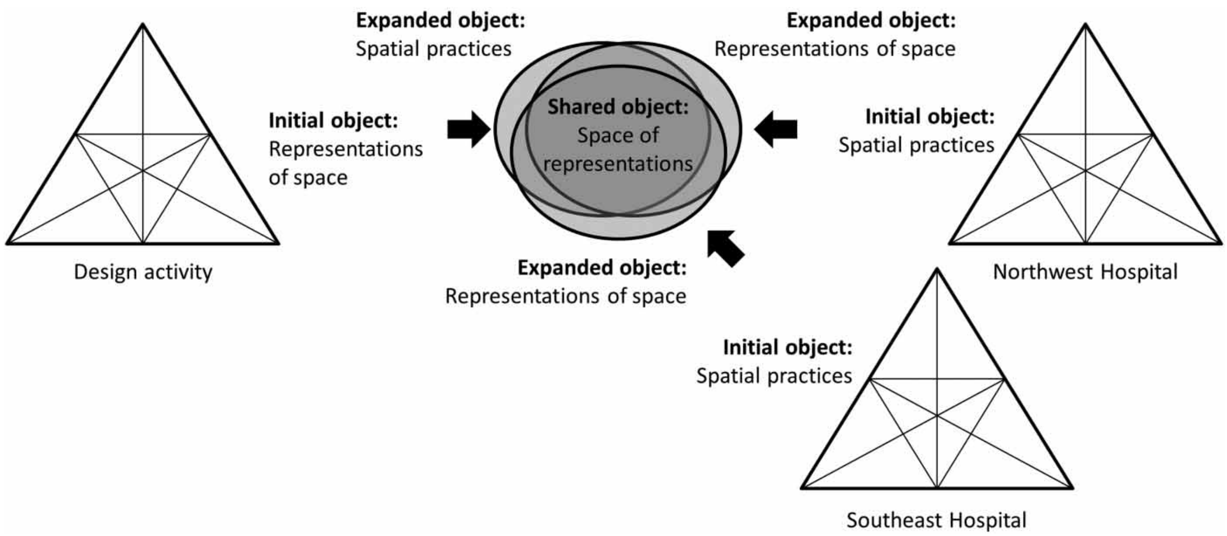


Figure 11 Space of representation as a shared object between the design activity (left) and the user activities (right)

talk related to the project. In this temporary space, subjects took positions and represented their activities. This space was nothing less and nothing more than the medical imaging centre itself, not yet a building, but already a set of social relationships, *i.e.* a produced space. The shared object between the design activity and the user activity can be considered a space of representations, where subjects found the meaning and invested motives for developing this project together.

The shared object did not automatically emerge from the encounter and can still fade after the intervention. Object expansion is neither linear nor stable (Engeström, 2005; Engeström et al., 2001). However, in this case the researchers think it could last longer if the designers adopt a collaborative approach with the users, *i.e.* participatory design (Sanoff, 2006). The degree of participation in this project can be considered low since users were involved too late, when most of the decisions were already made. Nonetheless, it made a big impact in the project. If the shared object is preserved until the building is completed and the facilities used, then it will possibly ground the formation of a new self-standing activity that encompasses the medical imaging centre as a whole community, integrating imaging research, technology development, teaching and care, as envisioned by the business plan.

Discussion

The constant shift of the unit of analysis by participants and researchers during workshops generated not only knowledge, but also confusion. New instruments were developed without knowing their full potential for representing activity. On several occasions, the activity was contracted, instead of being expanded by the representation. The project timeframe did not allow the participants to learn much about that. In other design projects, the expansion of activity representation may not necessarily go through all the levels mentioned in this paper, and it is unlikely to be in the same order. The intervention performed is very limited to understand how expansion happens in design projects because of its time frame. Formative interventions usually track a project across many years, since expansion may stop and continue later (Engeström, 2011). Future studies on the representation of user activities should examine how expansion triggered by participation in design can be sustained after design implementation.

Architects recognize that representations of space can never fully represent what users will experience (Luck, 2007), but the case study findings suggest that if the design object is expanded towards spatial practices, then the experience becomes actual: designers and users talk as if the building were already there (Luck & McDonnell, 2006). Instead of reification of an abstract concept, the representations of space are already as material as the spatial practices they imply, since they are produced under very concrete economic, political and cultural conditions. Following Lefebvre (1983, 1991), representations can be understood as concrete abstractions.

Apart from this study, the role of the representations of space in activity development remains unexplored. Leander (2002) observes that space has been considered merely metaphorically in cultural–historical activity theory, expressed in concepts such as expansion (Engeström, 1987), zone of proximal development

(Cole, 1985), and third space (Gutierrez, 1999). He suggests that – as done in this study – these concepts are employed to understand the material production of space, a necessary step to avoid losing the empirical ground of the field to an increasingly complex abstract space of theoretical concepts (Lefebvre, 1991). Cultural–historical activity theory has been described as difficult to support a design practice due to its theoretical complexity (Mwanza, 2000). However, this case study showed it was applicable along a formative intervention. Cultural–historical activity theory could guide the representation of user activities in a context of uncertainty without hinging on reductionism – in this case, the imposition of a contracted units of analysis. The intervention participants took over the unit of analysis and represented their activities at a different level than what the researchers proposed, which ultimately led to the expansion of their own activities.

Altogether, formative intervention seems to be an interesting method to develop further a user-centred theory of the built environment (Vischer, 2008). Being grounded in the process of change, formative intervention can show how and when the design of space became user-centred, or even participatory (Sanoff, 2006). Instead of focusing either on the impact of space or on the impact of activity on each other, formative intervention can approach space and activity in a dialectical relationship, revealing how they mutually constitute in practice. The focus is expanded beyond space's capacity to support user activities to the user's capacity to produce space, or in a word, spatial agency (Awan, Schneider, & Till, 2011).

The recognition of user agency before, during and after design clarifies why users cannot simply convey their needs to designers: users are the ones who, in the end, are going to fulfil their needs through the production of their own space. In the case study, user needs were clarified when the object that can fulfil them – the imaging centre – became available to them. The question of user needs is a typical case of expansive learning (Engeström, 1987; Miettinen & Hasu, 2002): the needs are not yet there; they are learnt while being produced.

Recommendations

The representation of user activities for the design of space requires dealing with multiple instruments and units of analysis. In a workshop, trying to keep participants focused on one instrument and one unit of analysis might generate confusion and disagreement when participants try to push its boundaries. In some situations, keeping the instrument, but changing the unit of analysis, is enough to create a productive discussion. That is what participants did when the floor plan was used to discuss actions' consequences instead of just optimizing operations. In other situations, the instrument must be replaced to deepen the understanding of the same unit of analysis, such as when researchers switched from the floor plan used to learn about conditions to the healthcare simulator that explored operations. And there are situations when both need to be replaced, *e.g.* when the participants moved from a discussion on optimizing workflow towards sketching a spatial connection between different activities.

The practical challenge is to perceive the appropriate moment to switch the instrument or shift the unit of analysis. This is not possible to know in advance, as what the instruments are trying to represent – user activities – are developing and changing by being or not being represented. What is possible to do is to evaluate critically the representation instruments to ascertain if they are tuned to the unit of analysis that follows the next step of development for user activities. Replacing, adjusting and reframing the instrument should seek to expand user activities rather than contracting, although contraction might be necessary before expansion.

Due to this instability, following a top-down representation (*i.e.* disaggregating activity into nested categories, *e.g.* actions inside activities and operations inside actions) is not recommended despite this being suggested by some authors (Kim et al., 2013; Lou et al., 2006; Perin, 1970; Shen et al., 2013; Thiel, 1997). Nor is a bottom-up representation recommended, as happened in the studied case. The recommendation is to have users participating in representing, creating instruments and being able to shift the unit of analysis when necessary. As such, representations become the presence, not the absence of users (Lefebvre, 1983).

Conclusions

This study adds to the discussion on the role of representations in collaborative design (Bendixen & Koch, 2007; Ewenstein & Whyte, 2007; Whyte et al., 2007) and participatory design (Bødker, 1998; Christiansson et al., 2011; Luck, 2003, 2007, 2012). It described the process of expanding the representation of user activities from the operation level (oriented to spatial conditions) to the action level (oriented to strategic goals) and to the activity level (oriented to motives). At the activity level, it was possible to see a connection between different activities by a jointly constructed, shared object. This object connects not only the user activities to each other, but also the design activity to the user activities, promoting their mutual learning (Béguin, 2003; Bødker & Grønbæk, 1996).

The unfolding characteristic of expansion replaces the problem of not knowing the future by the problem of finding the objects, instruments and units of analysis that can anticipate activity development. Anticipation here does not mean producing abstract knowledge such as predictions, simulations and scenarios, but actually departing from them to build concrete social relationships such as commitment, learning and space. In the case described, the representations of space were brought from their abstract origin to a concrete emancipatory purpose, working as springboard to expansion (Engeström, 1987) instead of just restricting behaviour, as is usually done by design (Lefebvre, 1991). By ascending from the abstract to the concrete through design participation, users can control their own activities from an outside perspective using representation instruments. Henceforth, representations of activity and representations of space do not stand anymore for an absent community because this community is present, anticipating the appropriation of space that typically happens only after design is implemented. Participation in design may lead to the formation of a shared object between the design activity and the user activities which can, ultimately, ground the formation of a new activity, with more advanced spatial practices, representations of space and spaces of representation.

In the context of design, space has the potential to anticipate activity development and ground the formation of new activities. However, in order to grasp space as lived by users, it is necessary to see the human body as producing, not only occupying space (Lefebvre, 1991, p. 170). The implication for the design of space is that to be consistent with user activities, space must be produced by these same activities. In a methodological sense, this means that activity and space can only be fully grasped in the making. By and large, design arises as a privileged practice to study the role of representations of space in activity development and the role of representations of activity in the production of space.

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Endnotes

[1]This study documents the construction in a high school of a replica of the wooden cabin used by Henry Thoreau to write *Walden, or Life in the Woods*. The traditional schooling object – the text – was expanded to a physical representation of the text – the cabin, which actually became more than just representation when being produced by students and teachers. Their wood shop became an alternative context to the classroom, where students and teachers did not need to follow the conventional schooling script of representing knowledge in the form of speech or text. The physical contact with materials allowed them to explore their own bodies to represent knowledge about the object: the wooden cabin and everything else it represents. Space was, then, considered an object in the study.

[2]The translation 'spaces of representation' is adopted (from the French *espaces de représentation*) as preferred by recent scholars (Schmid, 2008, p. 44; Soja, 1996, p. 30; Stanek, 2011, p. 81) against the 'representational space' used by the official English translation (Lefebvre, 1991).

Appendix A

Table A1 Summary of representation instruments and unit of analysis shifts in dealing with user activities' issues described in the case study sections

Case study section	User activities' issues	Representation instrument	Unit of analysis' shift
From the business plan to the spatial conditions	Financial sustainability	5D animation	Contraction from activity to operation
	Technical problems (radiation, noise, energy consumption)	Floor plan	Contraction from action to operation
	Spatial needs (room size, room adjacency, daylight)	List of requirements	Expansion from operation to action
	Sharing diagnosing machines	List of requirements	Contraction from activity to operation
From spatial conditions to individual actions	Optimization of care logistics	Floor plan	Contraction from action to operation
	Possible troubles caused by space	Floor plan	Expansion from operation to action
	Overlapping activities	Floor plan	Expansion from action to activity
	Waiting room and dressing room capacity	Floor plan	Contraction from activity to operation
From individual actions to healthcare operations	Existing spatial conditions in the hospitals	Hospitals' existing spaces	Expansion from operation to action
	Future spatial conditions in the centre	Floor plan	Contraction from action to operation
	Nurse and patient walk paths	Workflow diagram	Contraction from action to operation
	Dressing room's capacity	Discrete-event simulation	Contraction from activity to operation
	Existing spatial conditions in the hospitals	Project manager's and nurses' bodies	Expansion from operation to action
From individual actions to collective activities	Dressing room capacity	Discrete-event simulation	Contraction from activity to operation
	Nurse and patient walking paths	Knitting game	Expansion from operation to action
	Manoeuvring patient stretchers	Floor plan	Contraction from action to operation
	Division of labour between researchers, radiologists and radiographers	Users' sketch	Expansion from action to activity
	Connection between MRI and CT	Users' sketch	Expansion from action to activity
	Room and corridor size	Construction site	Expansion from operation to activity
	Arriving, parking, and entering the building	Construction site	Contraction from action to operation
	Connection between MRI and CT	Designers' sketch	Contraction from activity to action

Note: 5D = five dimension; CT = computed tomography; MRI, magnetic resonance imaging.