

Linking Activity Theory with User Centred Design: A Human Computer Interaction Framework for the Design and Evaluation of mHealth Interventions

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Abstract. mHealth can offer great potential for the self-management of health conditions and facilitating health services. It is therefore imperative that the design of mHealth systems afford optimum efficacy and effectiveness. Involving end users in collaborative decision making is an essential aspect of increasing acceptance of the treatment intervention. Involving users in the design and evaluation of mHealth systems helps to enable a better understanding of the complexity of user needs and how to incorporate this information effectively into the design process. This chapter discusses how Activity Theory can help to provide a theoretical lens for a User Centred Design framework in the design of mHealth systems. A general overview of Activity Theory and User Centred Design are provided, followed by their application in mHealth. Two use cases are provided that demonstrate how Activity Theory has helped provide a broader contextual analysis to a User Centred iterative approach to system design and evaluation.

Keywords. User Centred Design, Activity Theory, Human Computer Interaction, mHealth

Learning objectives

After reading the chapter, the reader will be able to:

1. Understand the groundings of Human Computer Interaction, User Centred Design and Activity Theory.
2. Demonstrate how Activity Theory can be applied to a User Centred Design approach throughout the technology life cycle design.
3. Understand how to apply User Centred Design principles in the design, implementation and evaluation of mHealth applications.
4. Explain how Activity Theory can provide a contextual analysis of user needs in mHealth applications.

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1. Introduction to User Centered Design and Activity Theory as a Human Computer Interaction Framework

In recent years, there has been a huge increase in the development of mHealth interventions to improve healthcare delivery and services. The ubiquity of mobile devices allows for the provision of mHealth interventions, which affords several benefits including patient autonomy through self-management, cost saving and an increase in health literacy [2, 3]. To optimise both the effectiveness and usefulness of these mobile interventions, usability and acceptance are paramount. Involving end users in the technology lifecycle process could help to ensure that end users' needs, and expectations are met, as well as increasing the likelihood of acceptance and adoption for optimum clinical impact where relevant [4]. This section explores the origins of User Centred Design (UCD) and Activity Theory (AT), and explains the usefulness of their application in terms of understanding the complexities of users and their interactions in system design.

1.1. An overview of Human Computer Interaction

While there has been a significant development in mHealth self-management interventions, these are sometimes lacking in theoretical underpinnings and adequate assessment of end-user needs [5,6], which then restricts their effectiveness. Human Computer Interaction [HCI] is an interdisciplinary field concerned with the design, implementation and evaluation of interactive systems [7]. Its methodologies and theories are drawn from multiple fields including computer science; sociology; psychology; ergonomics; anthropology and cognitive science, however its roots fundamentally lie in the social sciences, specifically cognitive theory and human factors [8]. The theoretical underpinnings of HCI contribute to the understanding of aspects of design specifically relating to perception; cognition; behaviour and interaction. A selection of some of the theories and models used within HCI include:

Perception (Psychology)

- Hick's Law: states the time it takes to make a decision increases as the number of alternatives increase [9].
- Fitts' Law: predicts that the time required to rapidly move to a target area is a function of the ratio between the distance to the target and the width of the target [10].

Cognition & Behaviour (Sociology)

- Action Theory: Norman's seven stages of action models the way people act when they are interacting in the world to achieve their goals [11].
- Activity Theory: a theoretical framework for analysing human practices as developmental processes with both individual and social levels interlinked at the same time [12].

Interaction (Unique to HCI)

- GOMS: models tasks and user actions; set of Goals, Operators and Methods for achieving goals, and a set of Selection rules for choosing methods for goals used [13].
- KLM: predicts how long it takes a user to complete a task. Based on GOMS, it provides an analysis of steps taken [14].

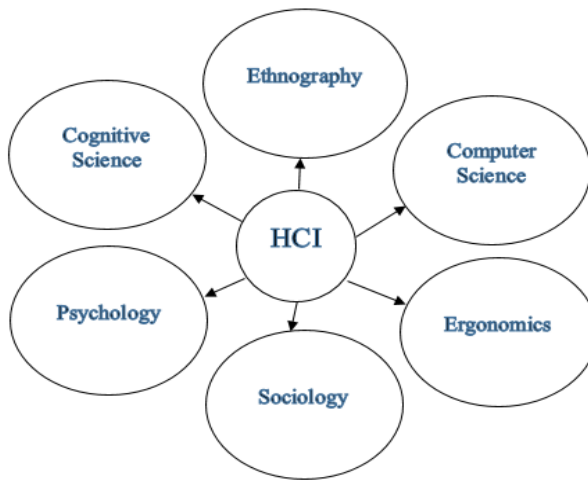


Figure 1: The interdisciplinary field of HCI

Human decisions that relate to health outcomes are multifaceted and are enacted within complex and dynamic contexts. HCI offers a means to enable designers to comprehend how humans use and interact with health systems [15]. Engaging users in the design process early and throughout the design life cycle helps to develop systems that are easy to learn, increase user productivity and satisfaction, increase user acceptance, decrease user errors, and decrease user training time [7]. Several design methodologies for HCI focus on feedback and conversation between users, designers and the technical system. Furthermore, research has identified that healthcare researchers, software developers and practitioners often overlook relevant user characteristics, user tasks, user preferences, and usability issues, resulting in systems that decrease productivity or simply remain unusable [7,16]. The importance of involving target users in the design process for effective interaction with mHealth interventions is, therefore, emphasised [8]. mHealth interventions need to be developed with adequate consideration of the needs of their intended users so that they are efficient, easy to use and perceived as useful [15]. This has increased the interest in applying a UCD approach to mHealth interventions [17,18].

1.2. Understanding User Centred Design as an approach to successful design, implementation and evaluation of interactive computer systems

UCD is an approach that places users at the centre of the design process from the stages of planning and designing the system requirements to evaluating and deployment of the product [18]. UCD refers to how end users influence design through their involvement in the design processes and has been shown to contribute to the acceptance, adoption and success of systems [2]. It can be characterised as a multistage problem-solving process that not only requires designers to analyse and foresee how users are likely to use a product, but also to test the validity of their assumptions with regard to user behaviour in real-world tests with actual users. Figure 2 shows the iterative stages of UCD.

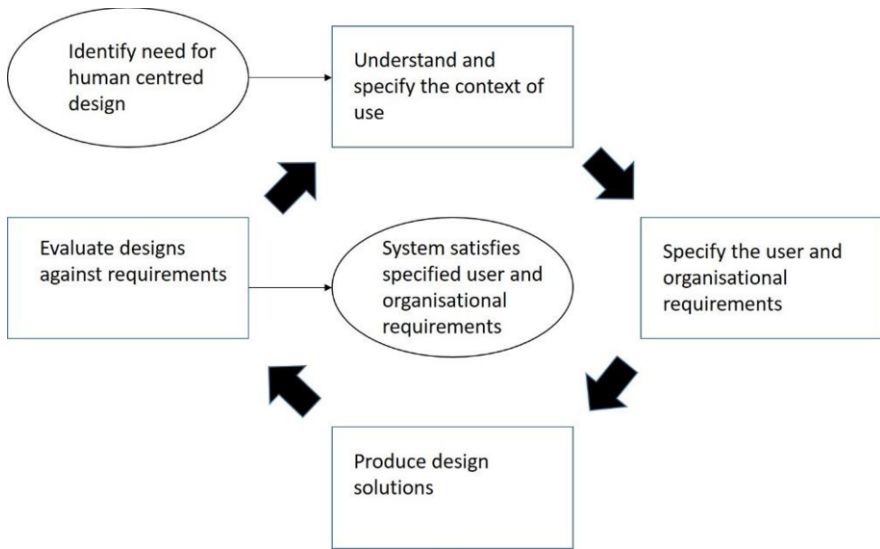


Figure 2: ISO 9241-210 standard for human-centred design processes for interactive systems (Based on [19])

ISO (the International Organisation for Standardisation) 9241-210 provides clarification on the principles of human-centred design and how human-centred methods can be used throughout the system life cycle. These principles are described as follows:

- **Understand and specify the context of use.** This consists of gaining a clear understanding of the users, task analysis, as well as context and environmental analysis. Each stage of this analysis can be dynamic and provides different but necessary components that inform the design of the system. The user analysis consists of examining and learning about the characteristics of the intended users [7]. The task analysis examines the goals of the user, the required functionalities of the system. The environmental analysis not only examines the environment in which the users work but also their social and cultural milieu [14]. It specifies the conditions in which systems are used.
- **Specify the user and/or organisational requirements.** This can be achieved through various ways such as including end users in a design team, as well as consulting with potential end users and relevant stakeholders to assist in requirements usability testing. Participatory design involving end users is an important component of UCD and should be upheld throughout the design and development process of a system [19]
- **Produce design solutions.** Findings from the evaluation inform the design and implementation of the system. This principle emphasises the importance of user centred evaluation to inform the design and to improve it within all stages of the technology life cycle. Prototyping from low fidelity (paper prototypes) through to high fidelity and modelling interaction and tasks can be adopted to design and evaluate the system. Storyboarding, which facilitates the communication of design to potential users, post-experience interviews and satisfaction questionnaires for preliminary design can also be used [19].

- Evaluate designs against requirements.** In accordance with the UCD ISO process, evaluation of the iterative interface design is evaluated against the requirements. This iterative design is a way of getting end users involved in the process. This includes active user involvement in evaluation and design throughout the entire development process, and the evaluation of use in the context of real user goals and environments [8]. The system is continuously evaluated, using the results to inform the requirements of system redesign where necessary. A range of methods including empirical user testing, heuristic evaluation and cognitive walkthroughs are applied. Gaining end-user feedback is an integral part of this stage [19].

The design addresses the whole user experience, not solely focusing on usability but also promoting a positive user experience during the interaction. User experience can be evaluated through the use of interviews and/or questionnaire which probe end user experiences after using a system [18]. The design and development team includes multidisciplinary skills and perspectives. This can be a combination of various perspectives that can include the stakeholders, potential end users, experts, non-technical. Several techniques used within UCD are shown in Table 1 below [14-16].

Table 1. Overview of the User Centered Design framework.

UCD techniques	Stages in User Centered Design cycle			
	Context of use	Requirements	Design	Evaluation
Diary Study (medical research)	✓			
Activity theory	✓	✓	✓	✓
User Personas	✓			
User scenarios	✓			
Focus groups	✓			
Interviews	✓		✓	✓
Participatory design		✓	✓	✓
Paper prototyping		✓	✓	
Empirical evaluation			✓	
Cognitive walkthrough			✓	
Think-aloud protocol			✓	
Heuristic evaluation			✓	
Surveys	✓		✓	✓
Field studies	✓			✓

1.3. Limitations of User Centred Design in providing contextual user analysis

A usable application is one that not only understands the fundamental needs of the user, but also understands a user's situation, i.e. context and environment and takes appropriate actions to enable the user's tasks. To enable this, the application needs to collect and infer relevant contexts to understand the user's situation. However, this is limited when applying UCD solely to the development of mHealth interventions. Users will invariably have different perceptions, understanding and expectations of a mHealth system and this will affect how they interact with the system. Furthermore, human activity is directly influenced by social, cultural and historical context [12], which adds further complexity. It is therefore important to consider the way people interact with mHealth interventions and their perception of the purpose of using or engaging with the mobile intervention. The necessity of understanding the users and context of use of health systems has already been emphasised. It is then necessary that the social, cultural and psychological aspects of the user in context is captured [21]. One method of achieving this is by using a theoretical tool such as Activity Theory [AT], which can help provide emphasis on user context and interaction. Applying AT to UCD can help bridge the gap in adapting contextual information to the user's situation and needs.

1.4. Introducing Activity Theory as a conceptual framework in User Centred Design.

AT is a theoretical framework for analysing human practices as developmental processes with both individual and social levels interlinked at the same time [12;22]. AT was originally based upon the work of Vygotski and the study of cultural-historical psychology [12]. The AT framework uses 'activity' as the basic unit for studying human practices. Activity or 'what people do' is reflected through actions as people interact with their environment. It can be conceptualised and used in a variety of ways. Because of the way in which it can provide a richer analysis of user needs and context, AT has been adopted as an HCI conceptual framework to help guide and inform the different stages of UCD. Our understanding of AT can be described as follows: the basic unit of analysis is an activity which includes a context. An activity includes eight components with a triangular relationship.

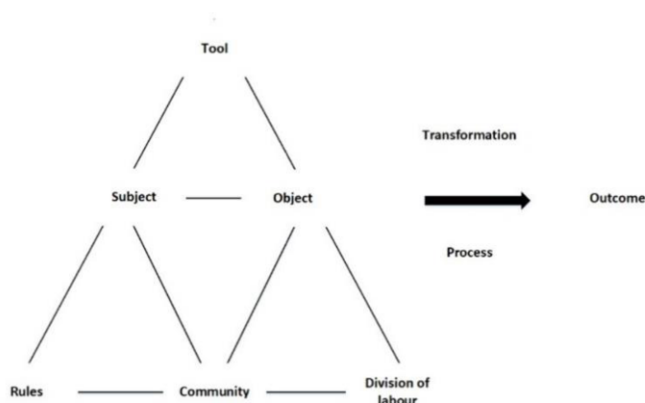


Figure 3: Engeström's Activity system model (Based on [23])

As illustrated in Figure 3, the components of activity include subject, object, tools, rules, community, division of labour, transformation process and outcomes. Engeström modified the original activity framework to include ‘rules and division’ of labour to understand work activities. An activity is bounded by its subjects (individual or subgroup) and objects (objective). Activities are directed at objects [or tasks] and are motivated by the need to transform the object into an outcome [12]. The relationship between the subject and object of the activity is mediated by a tool or instrument. Tools are the means used in performing an activity; they can enable the subject to transform objects into outcome. This is located within a community, and the community is governed by a set of rules and organised through a division of labour. AT can be applied at different stages in the UCD life cycle. It is particularly effective in capturing the requirements for a computer system design to establish what it is the end-user wants from the proposed computer system [22]. AT has also been used for the design of context-aware applications [23] because it is fundamentally user centred in its approach.

2. Linking Activity Theory with a User Centred Design approach in mHealth interventions

This section provides an overview of how an HCI approach can be used in the design of mHealth interventions, by using AT to provide a conceptual framework when using the UCD framework. Firstly, the importance of a UCD approach in mHealth is highlighted, along with the theoretical framework that AT provides. Two use cases are then provided to illustrate how AT can be linked within a UCD framework and then applied throughout different stages of the reiterative project lifecycle. In the first use case, AT and UCD are applied in the initial three stages: requirements analysis, design and evaluation, whereas the second use case provides an example of usage in the deployment stage and then returns to the requirements stage following analysis.

2.1. Overview of how User Centred Design has been used in mHealth Interventions

UCD begins with a thorough understanding of the needs and requirements of the users. This is critical to the success of mHealth interventions. Understanding user requirements can improve user satisfaction and user experience, increase acceptance and adoption rates and reduce the need for training [24]. The role of user requirements analysis in the development of healthcare interventions is fundamental [7, 17]. Users are generally not brought into the developmental process until after the design brief for a new product has been produced, which can lead to assumptions being made and ultimately lead to the failure of systems [15, 7]. It is recommended that patients are actively involved in the design of healthcare technologies, to help promote a better match to user needs and increase acceptance. UCD provides an approach that enables end users to participate during the life cycle of technology intervention. UCD does this by adhering to core principles that were outlined in section 1.

AT has been used to provide a theoretical framework for collaborative decision making in analysing mHealth systems [25]. The process of engaging patients in decision making can help provide a positive impact upon treatment adherence and health outcome. AT can be applied at different stages in the project life cycle. The two use cases presented below give examples of how activity theory has been applied to a user centred design framework of implementing mHealth interventions.

2.2. Use case 1: The design of a Mobile Health IT system to improve healthcare delivery in Windhoek rural health centres

A mobile health IT system was designed to improve the healthcare delivery service in Windhoek rural health centres, in Namibia [26]. The aim was to help ensure the provision of efficient and effective healthcare services to patients and to enable efficient work processes of both nurses and doctors [26]. Acceptance, perceived usefulness and ease of use of the MHSF was crucial in this study and UCD provides an approach for evaluating these factors. As previously mentioned, the UCD approach begins with a thorough understanding of the needs and requirements of the user. Interaction amongst potential users was very important for the MHSF and based on the UCD approach, establishing the context in which users may use the system should be defined at the beginning. Therefore, participants involved in requirement elicitation were purposely selected. This involved conducting the study in rural areas and early integration of potential users involved in the delivery and receiving healthcare delivery service in the design process.

AT helped provide a structure and a richer understanding of the needs of subjects/users as well as their related activities/tasks. This study demonstrates an emphasis on using AT in investigating the patient needs and requirements; activities are then separated into subjects, tools and objects. The healthcare delivery needs and requirements in Windhoek rural hospitals were then analysed using constructs from AT within a UCD framework, which also included evaluating acceptance of the mobile phones using principles of UCD [26]. Reflecting on Engeström's activity system model (Figure 3), we note the different constructs of AT and how these are featured in this case study. AT is used to understand the interaction amongst the subjects (doctors, nurses and patients) and the objects (activities and processes involved in providing and receiving healthcare delivery service). The tools in this study are the patient health cards used to record patient health information and activities; this was described as a mediating tool between the patients, nurses and doctors. The rules guiding these activities include the queuing and payment process, vital signs checking, diagnosis and drug prescription. The community which takes part in these activities include the doctor, the nurses and patients, and within these activities, work is divided among them. The nurses are responsible for checking vital signs; the doctors are responsible for diagnosing the patients and prescribing drugs while the patients are receiving this healthcare delivery service.

Structured interviews were conducted with doctors, nurses and patients to investigate the healthcare needs of patients. The findings helped establish the current work process, daily activities in the rural health centres, needs and requirements of the patients. These subsequently informed the design and development of the MHSF. A doctor, a nurse, IT specialists and researcher then provided expert opinion on the proposed MHSF. Although there was no iteration in this study, it was indicated that the framework would be expanded which would lead to another iteration of the UCD approach. Hence some of the requirements might change or be redefined [26].

Table 2 illustrates how UCD principles were enabled by applying activity theory. The table highlights the different stages during the UCD lifecycle and how the related UCD principles are applied to the relevant stages in the featured Use Case by using AT within UCD methods.

Table 2. Summary of the application of UCD and AT in the requirements, evaluation stages of the Mobile Health Service Framework.

UCD Lifecycle Stage	UCD Principle	Application of UCD and AT in the Use Case
Understand and specify the context of use	Gain a clear understanding of users, healthcare tasks and environment.	Analysing the characteristics of the users and relevant stakeholders, their health activities, work processes and the environmental conditions in which the system will be used. Structured interviews were conducted with a group of potential users to identify the healthcare needs of patients. Applying UCD helped with the definition of the users and to understand the context of use. Users here are doctors, nurses and patients. UCD also facilitated understanding the needs of potential users early in the requirement process. AT helped identify and understand the interaction amongst the users, the activities they perform and the use of the patient health card as a mediating tool. Findings from the study were also analysed using constructs of AT. Two criteria were considered for acceptance, perceived usefulness and perceived ease of use.
Establish the user and/ or organisational requirements	Formal specification of user requirements, inferred from the defined context of use.	The requirements are based on both the needs of patients, the work process of doctors and nurses in the healthcare delivery service. The requirements of the MHSF include reduced waiting times and appointment durations, and SMS facilities regarding health information.
Produce design solutions	The design solutions are produced while trying to meet user requirements as much as possible.	Transforming user needs and requirements to inform the development of the MHSF.
Evaluate design against requirements	The design is evaluated.	The proposed MHSF was evaluated using an expert review on the acceptance, usability, perceived usefulness and ease of use.

2.3. Use Case 2: Implementation evaluation of a mHealth system used by community health workers

AT can also provide a theoretical lens for adopting a UCD approach to evaluating systems in the deployment phase. MomConnect is a mHealth system used by community health workers in South Africa to provide advice to pregnant women via SMS [27]. The system was part of a government initiative to improve public services due to the high South African rates of pregnant women facing poverty and multiple health conditions. The users of the system are the community health workers, the pregnant women and the clinic managers. Community health workers use the system to register pregnant women, to enable them to receive messages from the system. Pregnant women use the system to receive advice and appointment reminders via SMS. Clinic managers run the antenatal clinics where registration takes place and have access to the system data [27].

AT was used to help understand usage of this mHealth system from the perspective of the users and to provide analysis on the key drivers of use. This study was able to bridge the gap between the limited understanding of how innovations are adopted in practice, and how this relates to specific characteristics of the technical system and users. AT was used to study routine use of the system by the observation of subjects (community health workers, pregnant women and clinic managers) and the processes of registration activities, as well as the connection between the tools and the community involved in these activities. The analysed data were used to provide a broader understanding of user needs and to implement the requirements into an improved contextual technology fit. This use case also illustrates the reiterative approach applied, in accordance with a UCD framework, commencing with an evaluation of the system in deployment and then using that analysis to inform the requirements of a system redesign (see Table 3).

Table 3. Application of UCD and AT in evaluating the implementation of *MomConnect*.

UCD Lifecycle Stage	UCD Principle	Application of UCD and AT in the Use Case
Understand and specify the context of use	Gain a clear understanding of users, healthcare tasks and environment.	This stage consists of examining the user context. Drawing on the features of UCD, potential users were collaborated with throughout the process. It helped to establish who the users of the system are and to understand the context of use. AT facilitated the breaking down and binding of entities with design tasks and goals. It facilitated the understanding of the influence of the mHealth solution in the context of existing work practices, tools and the broader context of the health facility.
Establish the user and/or organisational requirements	Formal specification of user requirements, inferred from the defined context of use.	This included gathering the information that informs the design of the system. Open-ended interviews and observation were conducted with community health workers and clinic managers to understand key drivers and constraints of use. AT was used as a framework to provide a structured set of concepts used to analyse the goal-oriented action. AT was used to analyse the dynamics of mHealth use by the facility staff.
Produce design solutions	The design solutions are produced while trying to meet user requirements as much as possible.	The findings were used to inform the proposed concept of affordance that is focused on distinguishing between the situation where user groups and work practices in facilities are centrally or peripherally targeted by the designers. It was also used to contribute to theory more broadly by developing an Activity Theory-framed approach to affordance actualisation.
Evaluate design against requirements	The design is evaluated.	UCD facilitated a continuous evaluation of the system following deployment. In this case, after an initial round of data collection, the researcher returned to the field some months later, to conduct additional observation sessions so that they could develop a fuller picture of how the usage practices were playing out.

3. Explanation of success or failure of mHealth systems

It has previously been emphasised within this chapter that there is a fundamental need to ensure that mHealth interventions demonstrate strong theoretical underpinnings to ensure efficacy, effectiveness and acceptance, as well as other important factors relating to optimum usage. This section firstly provides a brief overview of critical success factors used in mHealth. It then examines the determinant critical success or failure factors that relate to the aforementioned use cases, and how an HCI approach that links AT as a theoretical lens to a UCD framework can help support these factors.

Research shows that the: quality; intention to use; efficiency; usability; trust and increased user satisfaction are critical success factors for healthcare systems [28,29,30,31]. However, successful interactive technologies are not simply usable, rather they should provide engaging experiences that are highly sensitive to the use context, particularly the expectations, goals, motivations, and needs to be possessed by their users [32]. Perceived value and ease-of-use are critical factors in the successful adoption of a mHealth system that is used to self-manage health conditions [29]. It is then critical that the mHealth intervention is simple, intuitive and achieves its goal of enabling users to improve self-management of the health condition [33]. End-user involvement in the design and implementation of mHealth systems is an important determinant to the eventual success and for enabling optimum clinical impact [34]. As previously discussed, involving end users throughout the development lifecycle brings new insights for customising the technology to provide a better fit to requirements. Trust in relation to users' concern over the security of personal data can influence the intention to use [28]. Low acceptance, adoption, end-user levels of technical literacy are also barriers and can impact upon the efficacy of the mHealth system [29]. Lastly, negative perceptions toward mHealth systems can significantly reduce users' willingness to adopt new technology [29].

Tables 4-5 summarise the critical success factors in each use case.

Table 4. The determinant factors for success using AT and UCD in Use Case 1.

Critical Success Factor	Description within the use case: <i>MHSF</i>
Ease-of-use	Users rated usability in relation to perceived usefulness and perceived ease-of-use scales and were then able to provide richer feedback via open-ended interviews. AT facilitated an 'activity-oriented interactive flow' to the design of the system, which users commented helped contribute to the ease-of-use of the system. The iterative feature of UCD facilitated feedback from users that could be implemented for the next design iteration of <i>MHSF</i> . Given that the system may be required to monitor more serious health conditions, it is essential that the system is designed to ensure ease-of-use to reduce the complexity of user managing these conditions.
User satisfaction	Using AT provided a richer analysis of user needs and activities, which helped in designing a system that affords increased user satisfaction. <i>MHSF</i> was evaluated by potential end users to ensure that user needs were met. Ease-of-use and user satisfaction are strongly connected. Where optimum ease-of-use is enabled, users are more likely to be satisfied with the system [34]. User satisfaction was also measured during the evaluation of the system design using interviews informed by the constructs AT.

Motivation & acceptance	Using the AT and UCD approach helps to increase the likelihood of user motivation and acceptance by collaborative decision making and to place the users at the forefront of the design. The evaluation of <i>MHSF</i> enabled users to provide feedback on the acceptance. Acceptance was analysed using constructs that includes perceived usefulness and perceived ease of use.
Trust	Trust is critical to the success of a mHealth system [28]. Evaluating user perspectives of the system during interviews highlighted that users were concerned about the security of their personal information. These concerns can then be implemented and evaluated in the next iteration of the project design.
Confidence in use	AT coupled with UCD enabled a broad understanding of user needs which also includes assessing aspects of technical literacy. The UCD approach helped to understand how well users who lack technical literacy were able to use the system. <i>MHSF</i> was designed to be intuitive with good ease-of-use to enable usage by people with limited computer proficiency. Intuitive and user-friendly designs could help to increase user confidence.

Table 5. The determinant factors for success using AT and UCD in Use Case 2.

Critical Success Factor	Description within the use case: <i>MomConnect</i>
Efficiency	Using AT in an observational ethnographic study, coupled with the interview, the results from the deployment evaluation study indicated that the registration process on the <i>MomConnect</i> system did not afford optimum efficiency, leading to complaints from pregnant women to the clinic because they had not been registered. By taking the perspective and practices of the staff, AT helped to describe how <i>MomConnect</i> can be used in the clinic, by presenting a series of nested activity system with different goals. AT helped break down goals to improve the operation of the clinic to enable effective registration on <i>MomConnect</i> . Breaking down the goals will then inform the redesign of the <i>MomConnect</i> system by allocating resources in a way that promotes efficiency.
Motivation & acceptance	Using AT to evaluate the system in use, interviews highlighted that acceptance was driven by motivation from not only the main users but clinic managers themselves. The analysis showed that these clinic managers who are not involved in the registration process, do in fact have some influence over the practice of using <i>MomConnect</i> to register pregnant women. The study demonstrated that motivation to use the <i>MomConnect</i> could be influenced by the level and type of clinical management. Women would use the system if it were recommended and benefits are promoted by more senior members of staff because they are more likely to be assigned as 'experts'.
Trust	A UCD approach to evaluating the system in use enabled users to identify confidentiality concerns during the interviews and ethnographic observational studies. This was important to address in the redesign of <i>MomConnect</i> to help increase the future success of the system. Users' perception of the confidentiality of their data, needs to be considered in context to inform the next iteration of UCD design, the requirement stage.
Confidence in use	The ethnographic observational studies, as well as interviews, helped identify issues relating to technical literacy in both staff and the pregnant women. Lack of technical literacy will impact upon user's confidence. This analysis will help in the design of a more intuitive system in future iterations.

4. Discussion

mHealth technologies must be designed to meet the wide spectrum of end-user needs, as well as enable optimum acceptance and clinical impact, where relevant. There are several examples of how the interdisciplinary field of HCI has been instrumental in providing the necessary tools in designing these technologies [7,15,35,36]. The application of HCI in mHealth has seen the employment of multidisciplinary theoretical frameworks including activity theory, as well as others including distributed cognition and cognitive ergonomics. HCI has also given rise to the development of design frameworks such as UCD which makes use of several user centred methods used within the reiterative project life cycle. UCD has been shown to be an effective framework in the design of mHealth interventions by linking Activity Theory to provide a theoretical lens during various stages of the project lifecycle [26,27]. Activity theory can help provide a broader framework for understanding human computer interaction. The elements within Engestrom's model of activity help to provide a multifaceted analysis of users, their activities and the relationships between them. The use cases presented in this chapter illustrate how AT combined with UCD can be applied throughout the different stages of the intervention lifecycle for the mobile intervention, from analysis through to deployment. The use cases also illustrate how the application of AT and UCD can help maintain or solve success or failure factors of mHealth systems. Whilst the benefits of using this approach have been illustrated, some discussion around its limitations can help in providing a critically balanced argument for its use in mHealth.

Whilst AT can provide valuable insights into understanding user needs and their activities, the theory itself can be difficult to comprehend, particularly for system designers that are not from a cultural-historical/psychology background. It is not a rigid theory and does require some understanding of its historical context to be able to utilise its principles in practice. Engestrom's model of activity (Figure 3) highlights the complexity of understanding human activities however, it can be difficult for those involved with system design to decompose the model to specific focal points in the design [36]. AT can also be a time-consuming process and care needs to be taken to ensure that this process does not impact negatively upon time constrained subjects.

There are however many examples in healthcare and other domains, where it has been advantageous to complement AT with other methods. For example, combining AT with cognitive load theory and flow experience theory to enable the development of a more integrated framework for analysing internet-mediated experiences of children, as well many examples of AT combined with distributed cognition theory to provide a conceptual framework for Computer Supported Collaborative Work (CSCW) research [37]. The application of AT does enable a broader understanding of conceptualising human in context, which is particularly relevant when trying to understanding how humans will interact with systems. The importance of undertaking a comprehensive user analysis cannot be understated. If users' needs and expectations are not met, then this will inevitably impact upon the success of a system. mHealth systems that are designed for users to help manage their healthcare, not only need to be usable but must also enable clinical impact where relevant. Acceptance of the intervention and providing a positive user experience are then key. Linking AT to a UCD framework that involves users throughout the project lifecycle of a mHealth system can help to achieve these goals.

Teaching questions for reflection

1. How can AT be used as a conceptual framework in UCD to gain a better understanding of user needs in the design of mHealth healthcare systems?
2. How can we increase the likelihood of user acceptance of mHealth systems?
3. Critically evaluate the strengths and weaknesses of using Activity Theory as a theoretical lens in a UCD approach.
4. What are some of the critical success factors of mHealth interventions, and how can an AT and UCD approach help?

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