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# Designing a game to explore human artefact ecologies for assistive robotics

## Basing design games on an activity theoretical framework


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## ABSTRACT

This paper concerns the creation of design games made to explore and uncover the daily lives and artefact ecologies of users living with paralysis from the neck down. The paper reviews previous notable literature on making design games and presents a novel approach for basing a design game on an activity theoretical framework named the Human Artefact Model. After discussing the creation of the games, the paper reflects on the results and experiences attained whilst using the design games to gather data in the wild. Last, this paper proposes several points of attention to reflect upon when creating design games based on formal theories.



## CCS CONCEPTS

• **Human-centred computing** → Interaction design; Interaction design process and methods; Participatory design.

## KEYWORDS

Activity Theory, Design Games, Artefact Ecologies

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## 1 INTRODUCTION

This paper presents design games for use in the design of future practices of living with an exoskeleton arm. The paper takes its starting point in activity theoretical HCI and uses that as the basis for development of design games to support user studies of artefact ecologies and development of design requirements. Design games are used in interaction design as a technique to move beyond an understanding of the current practice and generate ideas for future design [33].

We are engaged in the design of an exoskeleton arm targeted at people living with paralysis from the neck and down. User studies of artefact ecologies of this target group are essential to understand not only the users' current ways of daily living with paralysis but also the future practice of living with an exoskeleton arm. An exoskeleton arm is a robot arm that is mounted directly onto the body and therefore becomes an extensive of such, hence the term exo. As this type of design is still largely found only at research departments, future users are required to engage in conversations and imagine a technology that is not yet commonly understood. We therefore develop and use design games to facilitate an exploration of these imagined futures. The repertoire of design games presented in the literature includes multiple examples related to specific design cases [15, 50]. The theoretical anchoring of design games is less developed in the literature, and this, in addition to the need for a deep understanding of the context for an exoskeleton design, has led to the current study.

Activity theory is used in HCI research as a framework for understanding the relationship between humans and artefacts. HCI researchers have contributed to the application of activity theory in HCI studies by developing analytic models [5, 23, 35]. This work provides an important theoretical anchoring beyond specific empirical cases. In this paper, we propose a way of linking activity theory to design games to provide the abovementioned anchoring of the games. The design games presented are inspired by and contribute to research that focuses on applying theoretical elements in the activity through *artefact ecologies* and the theoretical human-artefact model (HAM) [8, 10].

In this paper, we ask the following research questions: (1) How can the theoretical elements of HAM be transferred into design games to investigate artefact ecologies in the design of assistive technology for people living with tetraplegia and (2) how can design games anchored in activity theory provide insights into the daily lives and activities of people living with paralysis? The contribution of this study is methodological and to some extent empirical. Methodologically, we contribute by demonstrating the development of design games for user studies of artefact ecologies. The theoretical anchoring of the design games adds a conceptual perspective to the development of design games, and the specific games extend the repertoire of tools for studying artefact ecologies. Empirically, this study contributes insights into the complexity of investigating artefact ecologies for assistive technology, such as an exoskeleton. We first present related work on design games, the activity theoretical framework and the HAM model. Then, we show how we linked these two elements and developed design games to explore the artefact ecology for a future exoskeleton arm with future users during home interviews.




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# 2 RELATED WORK

## 2.1 Design games

The notion of what a design game is and can be used for has changed over time and has its roots in the, for the time, very exploratory future workshops of the fifties [30]. During the late 1980s and 1990s, the term design game began to appear in the literature, with notable inputs from Buur and Søndergaard [18], Muller [43], Habraken and Gross [27]. Today, design games have been widely used and developed into a variety of different games, each with their own pros and cons relating to their intended outcomes. Surveying the literature, Vaajakallio and Mattelmäki [50] identified four main rationales behind the use of design games: for research, for building design competence, for empowering users and for engaging multiple stakeholders. Whilst sharing the above notions, Brandt, Messeter and Binder [16] described the main rationales for using design games as exploring the problems and possibilities, addressing the initial specifications of design and mapping potential design spaces. Despite slight differences in the definition, most literature suggests that design games are ideal tools for understanding current and future actions, scenarios or practices. Design games have advantages over, for example, body-storming or scenario-enactment [16] in that they force the participants to take on a birds-eye perspective of their lives and activities, and thus allow for expanded reflection.

Further, design games often revolve around the practices of the user rather than a direct solution or product, which can be the tendency with methods like prototyping. This focus helps the participant to engage meaningfully in complex design processes by allowing for a "third space" [44] in which the knowledge domains of the users form the basis for conversations, and merge into the design space to allow for a collaboration on future designs [32, 50].

Brandt summarised four useful types of exploratory design games [15]: (1) Games to conceptualise design, which explore the design by creating abstract game universes; (2) games to exchange perspectives, which explore elements of change through subversion and chance to create something new and perhaps surprising; (3) games of negotiation and workflow, which explore workflow by simulating use worlds or practices to attain a common understanding of the work context; (4) scenario-oriented games, which explore scenarios by for example enacting with props as a means to understand the nuances of activities. Additionally, the work in [50] summarised three perspectives of how design games can be viewed: (1) as a mindset that the participants can employ to transport themselves into the world that is created and thereby describe and reflect on it; (2) as tools for designers to extract information and insights from the explored practice; and (3) as structures created by the design game designer to facilitate the collection of insights. It has been difficult to identify direct recommendations in the literature for design game design, mostly because a design game has to be developed for the context in which it is to be used. Therefore, recommendations for designing games cannot be broken down into specific elements. However, Brandt [15] presented some recommendations for what should be considered by a design game developer: Design games help facilitate and foster participation; therefore, (1) tangible artefacts can be useful for engaging participants in the game; (2) rules in design games can be powerful tools for structuring the kinds and amounts of data that to gather; and (3) scenarios have proven powerful for extracting narrative information from the participant.

## 2.2 Activity theory, triangles, ecologies and the HAM

Activity theoretical HCI has its roots in the Russian sociocultural research tradition of activity theory, which dates back to Vygotsky [51] and Leontiev [39, 40]. Activity theoretical HCI has been the basis of extended work since 1980 to understand and develop perspectives on human shared practice and its development as well as on the side of tools, language and societal structures [24]. Activity theory was introduced into HCI by Bødker [5] and Kuutti [38], and was followed by work by Kaptelinin [34] and Nardi [45]. In parallel, Engeström [22–24] developed a triangular understanding of activity systems which characterises activities by the mediated relationship between people carrying out the activity, the praxis/community of which they are part, the outcome of the activity, and the roles of tools, means of collaboration and division of work. Activity systems are dynamic and have a dialectic relationship with others (see refs primarily CSCW).

Activity theoretical HCI examines how the introduction of new artefacts changes practice and how practice may change the use of these artefacts; this concern is brought into the HAM with the following main points [6]: Human activity is mediated by artefacts through which the user may act on objects of interest or with other subjects. This object exists twice, first as material and second as a vision of the future. The mediator stands between users and their object and helps users act on the object in ways they could not do without it. Therefore, the mediator mediates the relation with the material as well as with the vision of ideal. A mediator causes breakdowns and draws the user focus towards the artefact when it gets in the way of the activity.

HAM, which was developed by [6, 8, 9] with inspiration from Bærentsen and Trettvik [1], is intended for analyses of current and future artefacts and provides an emphasis on understanding interaction with technology as multiple, multi-layered and dialectically supporting and preventing mediation. HAM is a crystallisation of fundamental activity theoretical concepts into a simple form that maintains focus on dialectics and the layers of activity. HAM provides a form [8] in which each field can be addressed one at a time by summarising empirical findings and by identifying particularly critical issues or findings to match or contradict those of other fields. HAM can be used to structure an analysis of human practice and to consider the consequences of adding a new feature. HAM also addresses tensions between fields, across sides and levels, e.g. in breakdowns, and makes it possible to move back and forth between a focus on one level at a time and the whole of the activity.

The analytical scheme combines analyses of action possibilities and mediators [8] on three levels reflecting the activity hierarchy: activity, action and operation. These levels provide three sets of analytical glasses, each focusing on an important aspect of human activity: motivation (by asking why), goal-orientation (by asking what) and operation (by asking how).

In addition to HAM, Engeström's triangular model points out that the use of artefacts does not happen in isolation. In various works [3, 8, 9, 11, 17], Bødker et al. developed artefact ecologies to

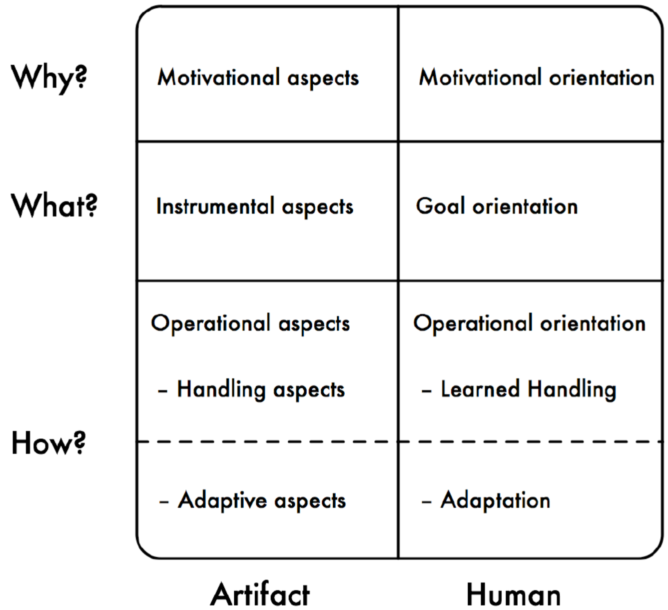


**Figure 1: The HAM (see Bødker & Klokmose, 2011)[8].**

address the ways in which multiplicities of use, users and artefacts come together within and across activities. This work was inspired by Jung et al. [29], who defined a personal ecology of interactive artefacts as a set of interactive artefacts that a person owns, has access to, and uses (p. 201), and extended to also consider communities by Bødker et al. [12–14].

Bødker and Klokmose [8] made many attempts to transform activity theory into workable models for design. Korpela [37] developed a simple model that helps designers structure their analysis of stakeholders, artefacts and division of work based on Engeström's triangular model of activity systems [22]. HAM can thus be understood as a vehicle for applying activity theory and as a mediator of design.

## 2.3 Designing with HAM

Rogers [46] pointed towards several discussions of whether and how theory may contribute to the design of new technologies. Based on her studies of how practitioners have adapted more recent theories, she pointed out that the practical impact lies mainly in singular concepts (such as affordances or personas). The processes and methods of interaction design are essential ways of moving beyond such singular concepts, even if this process of transferring theoretical concepts and insights by HCI research into HCI practice and interaction design often fails. In this spirit, cultural probes [26], participatory design strategies [5, 21] and prototyping approaches [5, 41, 42] are all part of the toolbox proposed by researchers to address interaction design. Such tools may help designers explore and characterise the design space [28] or they dress up [7] or prepare designers for action [25]. Stolterman [25] discussed the role of theoretical constructs in design to frame and explore a design space through sketching, iteration and alternatives, and Bødker and Klokmose [9] looked at how designers prepare for action through the conceptual and methodological basis of the HAM. They [9] described the HAM as (1) support for better artefacts to make prototypes and prototyping less ad-hoc; (2) stronger support for carrying insights and decisions across the analysis and design for mapping out the design space of artefacts and past practices and (3) better structured support to explore the design space in terms of design ideas and alternatives.

In an example, they [9] used HAM for an exploratory design among students (and future users) and pointed out the following: the level of motivation of users is important yet easily ignored in the analyses; the focus on motivation together with the other levels of a more standard HCI analysis are essential to the design space; the background experience of users with technologies and the focus on these past practices and artefacts are important; systematically working with alternatives at all levels of HAM and systematically reviewing prototypes and design ideas based on HAM require courage and scepticism and the will to question one's own design ideas; structured walkthroughs of elements of the future use and applying HAM keep the design space open and note which design decisions were deliberate, hence enabling backtracking if necessary to explore alternatives.

Relating to Lim et al. [41], Bødker and Klokmose [9] pointed out that the students' purposefully formed manifestations of design ideas are better rooted and understood in relation to the entire design process and use situation and not just in the purpose of the singular prototype.

# 3 THE CASE

The design games described in this paper were developed for a large interdisciplinary project at a Danish university. The purpose of the larger project is to create an exoskeleton arm for citizens that have become tetraplegic, paralysed from the neck down, as a result of a severe spinal-cord injury. The games are part of an effort to create a user-centred solution that fits not only the needs but also the wants and lives of the users, meaning that there was a need to understand the everyday lives and aspirations of the future users of the system.

The exact number of citizens living with tetraplegia globally is impossible to ascertain, as the methods of asserting prevalence differ between countries. In this study, we focus on people paralysed as a result of a traumatic spinal-cord injury. There are an estimated 236 to 1,298 per million globally [36], of which, at least in Europe, about 50 percent are diagnosed with tetraplegia rather than paraplegia, which can, and often do cause paralysis, in varying degrees, from the waist down [49]. As most tetraplegics require caregiving 24 hours a day, and as statistics show that most spinal cord injuries occur before the age of 30 [19] and that most tetraplegics live long lives as a result of excellent health care solutions, the solution could become a long-lasting investment in a better life for the citizens for whom it is intended.

Exoskeletons are future technologies with opportunities for people living with tetraplegia to regain some level of autonomy. However, the design and use of exoskeletons are complex, especially since the technology faces the paradox that the larger the disability, the greater the potential of using and exo but the harder it is to control it. If the technology is not acceptable for the user, it will not be used. Hence, our design of an exo arm is based on interdisciplinary research into how to advance interaction techniques with tongue control and computer vision [2], how to create flexible and lightweight exos [20] and control systems [47, 48], and how to integrate user requirements into the design of the exo arm.

Seven possible users were recruited to identify user requirements for an exo arm. We developed design games to facilitate one-to-one conversations with these participants because we aimed to move beyond an understanding of the current use practice and generate ideas for a future design. Recruitment was carried out in collaboration with a Danish rehabilitation centre for spinal-cord injuries and thirteen suitable participants were identified, seven of whom agreed to participate. At the time of the study, all participants lived with high-level spinal cord injuries and most had 24-hour caregiving supplied by the Danish state. One participant opted out of nightly caregiving because he was uncomfortable with strangers being in the house while sleeping. Two of the seven participants lived in specialised housing build with caregiving in mind; the rest had altered their living arrangement after their injury. The experience of living with their injury ranged from 2.5 years to 26 years.

# 4 THE STUDY

To attain an understanding of the lives and activities of potential users, we developed design games that were structured for individual interviews by setting up a dialogue with the future users, centred on understanding the present and exploring possible futures. It is central for a user-centred design to consider techniques for exploratory use situations as part of the design process in ways that allow users' hands-on experience with the future and give opportunities for feedback [4]. Design games support participants in exploring futures in such ways. The exploration of the rules in this design case, e.g. exploring what happens when an exo-arm is introduced and makes changes to the current situation of the participants lives, makes gaming a playful and powerful technique that supports a cooperative exploration of future paths in a constructive dialogue between future users and designers [33]. To understand the daily lives, activities and artefact ecologies of future users, we designed the game using HAM as the underlying framework because it offers the ability to structure the conversation around a subject with a clear focus while enabling the three abstraction levels of why, what and how to be included directly in the design of the game artefacts. Second, using such design games allows for a multi-levelled understanding of the motivations and actions of the participants. Finally, through such games, the participants enter a mindset in which reflections concerning their activities become more natural. It was decided that the design games where to apply visual, and tangible artefacts to stimulate and activate the participants [31, 33].

## 4.1 The first design game – Identifying key activities

*4.1.1 Purpose of the game.* The purpose of the first design game was to uncover specific activities in the participants' daily lives for which the exoskeleton arm should be designed and, more specifically, to understand these activities at a motivational level. As an exoskeleton arm is rather limited in its capabilities, the list of activities produced needed to be precise and prioritised to allow the engineers to assess which activities were possible and which were not. Further, a general idea of the technological ecology of the participants was needed, as the engineers had to understand with which other technologies the arm should function. Last, the game focused on the users' general understanding of assistive technologies and their preferences regarding the attributes of the future design.

*4.1.2 Structuring the game.* HAM was used as both the structure for the game and as an analytical tool after the design. Primarily, the notion of the three levels of analysis was used to guide the direction of the design. It was decided that the first game would focus on the motivational level of the model while also providing a basic understanding of the operational and instrumental aspects of the activities. To understand which activities the participants are carrying out, which technologies assist them, and who are their caregivers, three separate categories of cards were created, most of which were blank to allow the participants to fill them with their own inputs. The following cards were created:

- Activity cards to determine which activities the participants found important or frustrating throughout their daily lives.
- Artefact cards for the participants to state which technologies assisted them during their daily routines.
- Caregiver cards to list the different people that help them.

Further, we created a game board consisting of five different areas; one area was the playing area, three was used for storing cards and the last area was made to be added during a second phase of the game and contained an addition of a functional arm. The


**Figure 2: Picture of the first design game.**

main playing area featured seven spots on which cards could be placed, and an area on the left that was constant and had the text 'Me' printed above it. On the far right, a slot titled 'My activities' was created for the activity that was to be explored. The remaining six slots were divided into two categories, one for artefact cards to be placed under 'my things' and one row for caregiver cards called 'My helpers' (see Figure 2).

*4.1.3 Rules.* To understand how participants chose to prioritise activities, technologies and caregivers, we set the number of available slots for the cards to eight. While the participants were carefully instructed and encouraged to create more than eight cards, it was preferable if they placed the most important, frequent or frustrating cards on the slots to show their priorities. Further, to understand why the activity was carried out or the motivational level of the activity, the participants were asked to elaborate on their choices before and frequently during the game. When exploring the activities, and to understand the instrumental aspects, the participants were asked to add the technologies and caregivers utilised in carrying out the activity and to elaborate on the choices. The different activities were played twice, first exploring them as they are currently conducted and then while the participant envisioned having a fully functioning arm. The participants were not introduced to the purpose of the second round until the first round was finished to hinder their speculation and concerns while completing the first round.

*4.1.4 The game process.* The process of the game was carried out as follows:

- Introduction (10 min) – To establish a common understanding of why the game was to be played, the participant was introduced to the project and the purpose for the interview and design game. Consent forms were signed during this phase.
- Getting to know (10 min) – To contextualise the insights created during the game and create a relaxed and 'open' atmosphere, initial questions about the participant's life and experience with paralysis were posed.
- Presenting the game (5-10 min) – The participant was introduced to the game, the different cards to be filled out and the overall design of the game board.
- Playing the game (30-35 min) – During this phase, the game was played.
- Discussing the scenarios (10 min) – Up to three scenarios were discussed briefly with a focus on the change between activities from before to after the imagined implementation of a functioning arm. This conversation led to a common

understanding of imagined issues and positive aspects of the change.
- Discussing the arm (10 min) – A brief conversation concerning exoskeleton arms and what the participants expect from the future solution. This phase highlighted specific wishes and concerns regarding the design requirements.
- Wrapping up and giving information (10 min) – The participant was given an opportunity to state any last-minute considerations or concerns. Following this, the participant was notified of the coming procedures and invited to participate in a second round of design activities.

*4.1.5 Findings.* To extract the insights from the first round, the recordings from each design game were transcribed and coded according to categories used in the design game. Therefore, each activity, artefact and caregiver mentioned and discussed were identified and categorised as either present or future. The codes were then thematised using a coding schema, in which each activity category functioned as an organising theme with artefacts and caregivers attributed afterwards. The schema was divided into current and future activities to address the envisioned change in each activity. Based on the prioritisation made by the participants during the game, in regards to what activities were most important six main activities were identified: drinking, eating, itching, shaving, brushing teeth and reading. These six activities were chosen from 45 activities mentioned by the participants during the design games, which were mentioned alongside 69 artefacts and eight different types of caregivers. Last, 54 insights that did not necessarily fit under the predefined codes were identified; at first, we named these 'other' but we later labelled these as 'contextual'.

## 4.2 The second design game – detailed mapping of activities

*4.2.1 Purpose.* The second design game was designed to reveal the instrumental and operational aspects of the six key activities identified in the first round of design games. The game focused on breaking down the activities into their smaller components and understanding why and when technologies and caregivers are used. To further the design, the engineering staff on the project needed evaluative knowledge of the current design and a finer notion of what the participants considered aesthetically pleasing and functional. In addition, the aim of the second game was to produce more tangible design insights that could be acted upon in terms of what the system should be able to do and the things that it definitely should not do.

*4.2.2 Structure.* To further the understanding of each activity, the new design game was created as two posters on which the participant could help map out their individual activities. The main poster consisted of an area to establish the timing of activities, an area to sketch out the space of the activity, and two areas to list the positive and negative consequences of an exoskeleton implementation. We used six pre-made posters and brought two additional posters in case the participant had a new activity that needed exploring. The aim of going through the activity in a much more detailed manner than what was the case during the first game, was to spark thoughts about the current state of the activity and identify which specific elements would change. Sketching the space in which the activity would take place helped to situate the future technology within the technological artefact ecology of the user, which allowed the both the participants and designers to reflect on how the future solution would interact with current technologies. Listing the positives and negatives regarding implementation also allowed for reflection on the design requirements for a satisfactory solution.

The secondary poster consisted of two lists, one for the 'go's' and another for the 'no go's'. This list was created to allow the participants to summarise their thoughts about the exoskeleton design, which possibilities should be considered and which should not. This process allowed the participants to elaborate their thoughts in sentence structures by physically having space for writing.

*4.2.3 Rules.* To make sure that as much information as possible was extracted from this round, the participants were first asked to prioritise the posters that were pre-assigned. This was done to see whether priorities of tasks had changed over time, as almost half a year had passed since the last round. Further, the participants were told that at least two activities should be mapped out, meaning that a time limit was imposed to guide the participant towards using their intuition. The participants were also asked to produce positive and negative statements about the solution to be developed to elicit both problems and positives during the session.

*4.2.4 The process.* Similar to the first game, the interviews were divided into the following phases:

- Introduction (10 min) – To ensure all participants had the same level of knowledge for the design game that was to follow, the interviewees were introduced to a prototype of the exoskeleton arm and informed about the initiatives of the project. Participants were also able to pose questions in case of any doubts.
- Presenting the game (10 min) – The participants were introduced to the second design game via a quick walkthrough of the two posters. This phase promoted a common understanding of the purpose of the game and its possible outcome.
- Playing the game (30 min) – The activities were mapped out onto at least two posters.
- Summary (10 min) – The discussions that occurred during the game were summarised and potential questions about the scenarios and contextual understanding were posed.
- Discussing the exoskeleton arm (20 min) – The arm was discussed and the second poster was filled out. During this phase, any shortcomings in the common understanding of the design were overcome and the participants contributed their thoughts pertaining directly to the design of the arm.
- Final discussion (10 min) – A final discussion of the two posters was held to mitigate participants' concerns or misunderstandings and verify the insights produced with the participant.

*4.2.5 Findings.* Analysing the data from the second design game was done in the same manner as for the first. The findings regarding the specific activities with respect to new technologies and caregivers were added to the table, while all contextual information revolving around the activities was noted and saved in quotational form. The information that was collected in lists, i.e. the 'go's' and

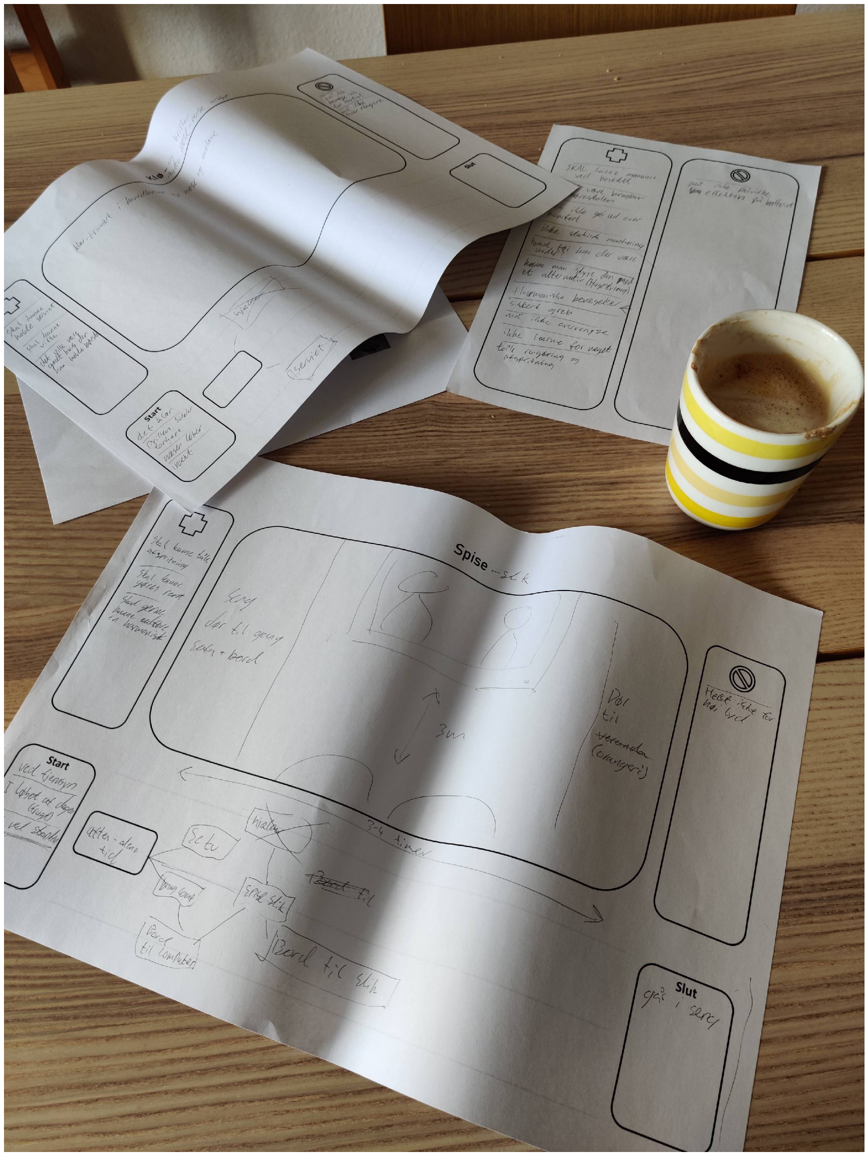


**Figure 3: Picture of the second design game.**

'no go's', were noted, listed and prioritised based on the input from the participants. The overall insights produced from the second round of the design games were an expanded knowledge of the six different activities that were being designed for. It became evident that, for example, eating not only happened indoors and it did not necessarily refer to dinners or candy; participants also took pieces of fruit to the garden to eat or snacks to eat on the go. Likewise, a deeper understanding of the attributes of the arm was attained; for example, the participants were adamant that it should produce as little noise as possible and that movements should be natural.

## 5 FINDINGS OF THE TWO GAMES

Building the study through consecutive design games allowed for a step-by-step introduction into the lives of the participants and their technological ecologies. While the first round of design games offered insights into which activities the participants conducted and the second allowed us to break down those activities into their core elements, the iterative nature of pacing the exploration of the activities allowed for a multi-faceted look into the daily lives of the users. Through the knowledge obtained from the first game, we tailored the second game to identify the specifics that we needed to elaborate to continue the design of the exoskeleton solution, while the explorative nature of the games allowed for new insights to still surface. A finding that exemplifies that exemplifies the new insights obtained in the second game relates to eating as an activity that most participants found particularly cumbersome due to the pacing of the activity. The participants experienced that it was hard to get the caregiver to deliver the food at the right pacing while maintaining both conversation and not eating too slow. However, as the games progressed, the object of eating changed with the continued reflections so that it was not the act of eating a meal that they primarily wanted to change but rather the act of eating candy and snacks. The participants stated that when watching television at night, they could either choose to do so alone or they could choose to have a snack whilst watching, but not both because snacking required the presence of a caregiver. While this in its own right is an excellent finding that helped us to shape the exoskeleton arm, our understanding of the task was nuanced further. Whilst playing the second game, it turned out that the location of the activity mattered considerably to the participants. Thus, rather than just snacking in front of the television, they wanted to take the activity into the garden and the outdoors. The thought of being able to relax on their own and enjoy a snack had stuck with the participants, and the scope of the activity subsequently changed.

During both games, the pacing allowed the participants to reflect on the questions posed and the activities being explored. We believe that having explored all the levels of abstraction, i.e. the what, why and how, in one iteration of design games would not have allowed us to attain as much knowledge about either the individual activities or the contextual information surrounding them, or the artefact ecologies that supported the activities.

# 6 REFLECTIONS ON DEVELOPING DESIGN GAMES WITH HAM

Using an activity theoretical framework as a basis for design games is not only as a positive for the design games but also as a means of analysis. Utilising the notion of analytical levels, as proposed in the HAM [8], helped to structure and force an iterative approach to the design games. It became evident early on that, although all three levels of analysis, i.e. the motivational, instrumental and operational levels, were present in the first round, further breakdown and mapping of the individual activities was necessary to obtain a deeper understanding of the users' daily lives. Such an understanding was in turn needed to develop the exoskeleton solution. Focusing on the activities that the participants prioritised enabled the engineers to understand and start designing for the activities early, which allowed them to follow the iterative process and adapt rather than start from the beginning once a deep understanding of each activity was established.

During the first round of the design game, although the participants were told that they could make more cards than the eight that spots had been prepared, the visual limitations of the game board implicitly prompted the participants to reflect on the activities they found most important. This was also the case with the artefacts that the participants were to list, meaning that, for example, the wheelchair was often omitted from the activities although, in reality, it was a vital part of anything that the participants did besides sleeping. Using two phases, i.e. the current and future practice, helped the participants reflect on their current activities while also making it easier to imagine a future scenario and envision what a good change could look like. Keeping in mind that the focus was on the motivational level of the activity (why?) helped to structure both the conversation and questions during the game and helped to make sense of the coding during the analysis. Likewise, the use of formal theory and being consistent with the categories eased the extraction of knowledge from the coded data. While the amount of insights produced was useful and easy to interpret, a large amount of information that did not fit the predefined codes was found. This information did not prove to be negative; rather, the findings drawn from the data ended up being effective for contextualising the information. However, we found that predefining codes based on theory should be done in a flexible manner so that any new findings could be used and added and not discarded due to a lack of fit with the model chosen. This finding was one reason that prompted us to add the poster for attributes to the second game; the aim was to have the game facilitate the collection of these contextual data and applicable advice given by the participants.

During the second round of design games, actively using the analytical levels of instrumental and operational aspects (what? how?) helped to structure the insights obtained from the conversations. Furthermore, being aware of which level of abstraction was being explored, i.e. the instrumental or operational level, helped when posing questions that broke the activities down into more detailed elements and mapped the activities in both time and space. While the design game posters worked well for mapping the activities, it became evident that the layout of the posters had a large impact on the conversations. As the first part of the game had been placed at the bottom of the poster, the participants continued to comment on the other parts of the poster during this phase. This commenting can be seen as both a positive and a negative because having a notion of the space in which the activity takes place cannot necessarily be separated from the activity. However, in this specific game, the commenting turned out to be a distraction in the conversation and made both the transcription and coding more difficult.

Developing the design games used during the study with the theoretical structure of the HAM and technological ecologies in mind helped us understand not only the daily lives currently lived by the users but also the imagined future scenarios in depth. Understanding the impact of technologies used currently during activities enabled the participants to explicate how the change in future technologies would also change how an activity would be carried out at the different levels of abstraction. For example, understanding the interdependencies between the motivational and instrumental level and how a change at the instrumental level could change the motivation for why the activity was carried out allowed both the participants and the designers to understand and reflect on the potential impact of envisioned change in the technological ecology of the users. An example of such a change became evident when discussing the activity of eating with the participants in which the conversation started out being about eating basic meals with the base motivation of survival and sating hunger. When the activity was changed at the instrumental level, at which point the caregiver was removed and the arm was introduced, the motivation for eating changed from a fundamental need to that of wellbeing and providing a 'cosy' time.

While having a formal theory as a basis for the design games conducted in this study helped us in both the design, conduction and analysis of our user study, certain limitations to the method should be considered. First, basing the design games on theory removes some flexibility and explorative nature for which design games are often well regarded [15, 33, 50]. That is not to say that one cannot be flexible and explorative during the developed games, but rather a part of the open-ended nature of the design game is lost due to the fixed elements that must be explored during the games presented in this paper. Further, the design games conducted in this study were done only with one participant at a time, and we cannot therefore say how this would work in a setting with multiple stakeholders present. However, the design of the games provides the opportunity for a group of people to discuss activities and artefacts. Last, basing design games on theory required a longer preparation period to understand and appropriate the theoretical components to fit the format of design games. This longer period created some issues relating to the deadlines imposed by others parties in the project. However, a positive side to this was that the time spent preparing the coding schema and performing the analysis was greatly reduced because we had specified the points of interest beforehand.

## 7 CONCLUSION

In this paper, we explored the use of an activity theoretical model, namely the HAM, as the basis for developing design games. By developing two connected design games focused on the three levels of analysis as described by the HAM, we found that the theoretical underpinnings helped not only in structuring and developing the design games developed to explore artefact ecologies but also in understanding the data and analysis. Furthermore, being aware of the analytic level of abstraction that was being activated during a design game was particularly useful for structuring the questions posed in the game, developing the games, and breaking down the insights into manageable information. During the analysis it became evident thatthe understandings attained at the different levels of abstraction and how the current technological ecologies affected each level separately allowed for understanding and reflection on how the different levels were interdependent and how a change in technology at the instrumental level could also have a large impact on the motivations for conducting the activity and how the activity was carried out at an operational level.

We found that using a two-round approach where we first focused on the motivational level of the participants' daily lives and produced a prioritised list of activities early eased the development of the second game, as we knew exactly what was to be explored. This process assisted our engineers in developing an early understanding of what features to accommodate in their design. Last, using the HAM in combination with design games gave us good results because of the positive influence they have on each other. We conclude that using HAM as a framework for design games is an effective way to ensure structure and consistency throughout the study, whilst allowing for the flexibility needed to explore the artefact ecologies and context for the activities found.

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