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The CoCe Design Space

Exploring the Design Space for Co-Located Collaborative Games that Use Multi-Display Composition

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In this paper, we map out the CoCe design space - a design space for co-located collaborative games that use multi-display composition. The design space grew out of the analysis of game instances based on the 4in1 concept. First, we did a horizontal analysis of 16 game instances with 31 corresponding gameplay design patterns (GDP), followed by a vertical analysis of 89 GDPs occurring in the description of the GDP Cooperation. Through inductive analysis, we have identified four perspectives with corresponding dimensions that span the CoCe design space. By applying the CoCe design space with game instances, we illustrate how it can be used both as an analytic tool for analysis of games and also as a generative tool in the design or re-design of cooperative games that use multi-display composition.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**.

Additional Key Words and Phrases: Collaboration; game design; design space; intermediate-level knowledge, gameplay design patterns.

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1 INTRODUCTION

The introduction of touch technology has revolutionized the way we interact with computers, and devices like tablets are gaining increasing popularity in many educational settings. However, the vast majority of applications developed for tablets are targeting one user using the device alone, and tablets are "typically perceived as a personal device, evoking the image of its owner tapping away - silently submerged in their private digital bubble" [40, p. 1405]. One way to break this 'mobile bubble' and use touch technology to support groups of people acting together in a collaborative manner on a common activity could be to instead design for, and make use of, large shared screen displays and tabletop computers. A problem with this approach is that tabletop computers are still rather expensive and cannot easily be moved or carried around. Rather the users need to gather in the place where the tabletop happens to be located. As an

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alternative, we argue that tablets could also be used to create engaging collaborative user experiences instead of being devices used to lock each individual user into his or hers mobile bubble.

Fig. 1. An example of where children arrange tablets to form the shared game area, as designed for the application StringForce [3]

This has encouraged us to investigate the combination of multiple tablets into a larger shared space for several people to interact with at the same time, as a form of multi-display composition [48]. We have been running several research-through-design [70] studies under the name *4in1* for the past five years. The 4in1 concept is defined as a co-located collaborative activity supported by 2-4 connected tablets arranged next to each other to form a shared interactive space where the activity plays out (see Figure 1). The studies have so far mainly targeted children in an educational context where tablets are common. In such tablet-dense environments, a 4in1 arrangement can in many ways function as a relatively cheap, accessible, and mobile alternative to a tabletop computer.

The goal behind the 4in1 concept is to break the mobile bubble [47, 61] and instead let people practice collaboration through engaging experiences inspired by ideas from ubiquitous computing [69], engaging ubicomp experiences [60], collective interaction [41] and interaction rituals [17]. We have so far developed 16 instances in the form of various types of collaborative games within 4in1, however, studying individual instances have not provided us with an overview of the possibilities of co-Located collaborative games that use multi-display composition.

In pursuit of this, in this paper we apply a design space approach in order to investigate these design possibilities. With *design space* we mean a dynamic conceptual space, in line with [12, 20, 33], and as opposed to e.g. a physical space [62], or a specific use context [19]. The design space is a way to systematize knowledge [15], where the result is a systematic mapping of parameters that can be used for both generating and testing the design space. In this paper, we claim that a design space can be a form of intermediate-level knowledge [36], residing between particular artifacts and general theory, with its primary origin in instances, and with the intent to inform design practice [44]. We have made a horizontal analysis of a collection of game instances, a vertical grounding in theory, and finally an inductive analysis to identify perspectives and dimensions. The result is a design space for co-located collaborative games that use multi-display composition, which can be used as both an analytic and generative tool.

2 BACKGROUND

One of the main components in 4in1 is to support co-located collaborative interaction mediated by technology in the context of games. This approach have been explored earlier, e.g. in False Prophets [52] and the Stars platform [51]; see Bergström and Björk for a more extensive overview of the field [11]. Most of these differ from 4in1 in that many screens are not used to combine into a functionally larger one, an exception being *Pac-Man Must Die* [63].

One inspiration for the 4in1 concept is Collective Interaction [57]. Collective Interaction puts focus on designing for co-experiences among co-located people by using five key elements [57]: 1. The interaction itself invites for human–human interaction beyond what is in the interface. 2. The spatial organization of people induces expectations of use. 3. A shared goal is established on the basis of sharing responsibility and negotiating control of interaction. 4. Establishing

a shared goal through negotiation is essential both in order to achieve the goal and in order to challenge it. 5. The interaction may be asymmetrical, in the sense that people take on different roles, but the efforts of all participants are accounted for and valued in the use of the system.

Another source of inspiration for 4in1 is the concept Togetherness, which can be understood as the product of successful interaction rituals. According to Collins [17], who bases his work on Goffman [29] and Durkheim [21], a successful Interaction Ritual between people creates, among others, group solidarity and a sense of membership. On an individual level it creates a "feeling of confidence, elation, strength, enthusiasm, and initiative in taking action" [17, p. 49]. This kind of interaction is potentially useful for creating a bond between children. Collins states four necessary ingredients for these interaction rituals: firstly, that people are co-located, letting them directly or indirectly notice each other's bodily presence. Secondly, there are easily noticed distinctions between those participating and those not participating. Thirdly, everybody involved focuses their attention upon the same thing or activity, and is aware that everybody else has the same focus. Finally, all participants share a common emotion or mood related to the activity. Playing collaborative games, in contrast to competitive or solo games, is an activity that incorporates all these four ingredients as has been explored by [9]. Further, the rules of games provide structure to the activity and thereby make it less difficult to understand than free play or unstructured everyday social interaction.

Recently, we have been inspired to adopt the levels of collaboration as defined in Activity Theory (AT), in order to define collaboration in an operational way in 4in1. AT provides a method of understanding and analyzing a phenomenon, finding patterns and making inferences across interactions [39]. Based on AT as a theoretical foundation, Engeström defined three levels of collaborative interaction [24], and building on this definition Bardram introduced a framework for collaborative interactions between users and mediating technology [2]. This framework consists of three different levels of collaboration, from the simplest to the most complex form: Coordination, Cooperation and Reflective Communication.

2.1 Design for Connecting Multiple Devices

The idea of combining several mobile devices to form a shared space as in 4in1 has been explored in several ways in recent years [34] [28]. Lyons et al. [48] use the term Multi-Display Composition (MDC) to denote the technique of joining several mobile displays in an ad hoc manner whenever and where-ever it's needed, a term we have adopted to label the 4in1 platform. The 4in1 MDC has some overlapping characteristics with tabletop computing, e.g. that they can let users have face-to-face interaction and have a shared user interface. However, they also differ since the set up of MDCs can be easily modified by users and they can be used in situations where no actual tables are present. For design recommendations regarding tabletop display systems, see Scott et al. [64]. A common domain explored in applications that use MDC is viewing and sharing photos, e.g.[45, 55], playing movies distributed over several devices [56], or sharing other types of information.e.g. [27, 42]. Applying MDC in projects involving children seems to be less common. One exception is Mobile Stories [26] which is a system where children can collaboratively read and create stories using 2 connected mobile devices.

From a technical perspective, creating a Multi-Display composition involves two major sub-problems: (i) connecting the devices together and (ii) arranging the devices into a shared display and making sure that the devices are aware of the arrangement. A number of approaches for handling the first approach, binding and device association of mobile devices, can be found in [16]. When it comes to arranging the devices into a shared display a number of different approaches have been tested. In principle these fall into techniques making use of the mobile devices only, and techniques that involve some kind of external technology. A popular approach not involving any external technology is to use some kind of pinch gesture [56]. This means that users first arrange the devices into their desired positions and then perform

a pinch gesture over their screens to indicate their relative positions. The pinch approach is also used in for instance [42, 55]. Another approach is to make use of cameras one way or another, e.g. [31, 43, 58]. The need for a smooth set-up procedure is stressed by Lucero et al. stating [46, p. 31] that if people are not able to join a group and start interacting with others "in a fast and easy way, they might lose interest in participating in mobile collocated interactions in the first place".

2.2 Design Space

Although design spaces are widely acknowledged in HCI, e.g. [8, 12, 14, 15, 18, 33, 50], there is no agreement on either the definition of a design space or on the method for mapping a design space. We refer to Dove et al. for an overview that highlights the diversity of interpretations of the term design space in HCI, [20], and which illustrate how liberally the term design space is being interpreted in practice, and how usage changes. Botero et al. [14] define the notion of design space as a space of potentials that the available circumstances afford for the emergence of new designs. In line with this, Beaudouin-Lafon and Mackay offer a wider definition, proposing that a design space "constrains design possibilities along some dimensions, while leaving others open for creative exploration" [8]. However, we argue that a design space is not solely a source of opportunities for new designs, or constraints along some dimensions, but also a systematized well of knowledge for both instances and theory.

As with the notion design space, there are many interpretations of methods for creating design spaces. While some approach this by defining a specific method for mapping design spaces e.g. the design space analysis method (DSAM) [32], others use more formal methods such as e.g. semantic analysis [15, 49]. As a result of a combination of the two approaches, Biskjaer et al. propose a format for mapping the main features of the design space in a parametric matrix, the design space schema approach [12], that builds upon Zwicky's [71] and Zwicky and Wilson's [72] work on morphological analysis.

In common for all approaches is that design space refers to a dynamic systematization of knowledge that is application-independent and that the design space is constructed and developed by designers through processes of framing and inquiry. This lets designers have an overview of various possible new instances of designs, and also identify "blind spots" in current design practices if existing designs are positioned in the design space.

2.3 Design Space as a Form of Intermediate-Level Knowledge

The idea behind the notion of intermediate-level knowledge is that the space in-between instances and theories is non-empty and can be filled with knowledge constructs that are more general than the particular instances, but have a different scope and purpose than universal theories [36]. This is inspired by Stolterman and Wiberg's work on conceptual constructs as a midway between a single concept and an all-encompassing theory, aimed at portraying future designs [67]. Some examples of general intermediate-level knowledge forms, roughly listed in chronological order as they appeared in HCI according to Löwgren [44] are Design methods and tools, Design guidelines, Usability heuristics, Patterns, Strong concepts and Annotated portfolios. In the present paper we claim that a *design space* is another form of intermediate-level knowledge, residing in between particular instances and general theory see Figure 2.

Annotated portfolios is an approach to communicate about design, which is basically about gathering a range of design experiments and highlighting the most interesting aspects that run through them. What is often characteristic about the instances in an annotated portfolio is that they are interrelated and partly build on each other, or are different variations of the same concerns. Strong concepts, are described as design elements abstracted beyond particular instances, which have a generative potential [36]. One example of a strong concept is social navigation based on the

observation that we tend to follow the behavior of others and that this can be used to guide the design of navigation [36]. Höök and Löwgren argue that strong concepts should be grounded both horizontally and vertically, where horizontal grounding means that the concept is related to similar concepts, focusing on similarities and differences that can help to understand the range of applicability of the strong concept. Vertical grounding means that the concept is connected to other instances, and/or to relevant theories.

Strong concepts and annotated portfolios resemble each other in the sense that they are constructed from instances and their aim is to reflect upon and inform design practice. Design space as a form of Intermediate-Level Knowledge is inspired from both. The annotated portfolio approach can be used as a method for horizontal grounding on interrelated instances, such as those in our collection (see 3.2), in order to identify the more general factors across the collection. This increases our awareness of the constraints introduced by particular design choices and qualifies our understanding of the way a design space has been filtered by design activities [20]. Following the suggestion for the creation of strong concepts we also add vertical grounding in order to challenge the constraints from the horizontal grounding and reconsider disregarded opportunities. The design space intermediate-level knowledge form we suggest is thus one that is based on an analysis of a number of instance and related theory, verified through horizontal and vertical grounding.

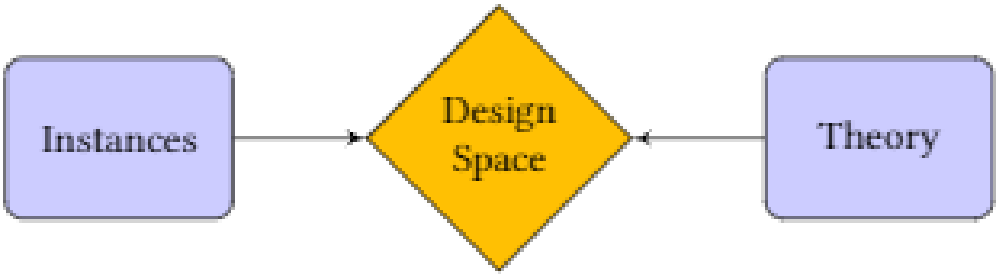


Fig. 2. Design space stemming from both instances and theory.

2.4 Gameplay Design Patterns

Patterns is an example of generative intermediate-level knowledge [36], and stem originally from architecture and urban planning [1]. Although the original intent was to create a common language to increase user involvement in design, it has become a successful way of capturing, disseminating, and coordinating best-practice knowledge. Gameplay Design Patterns collection is a design tool that can be used to both aid design practice, in the design of new games [10], to analyse and evaluate specific aspects of player experiences [5, 6, 22, 59, 65], and provide a common language to communicate with participants (e.g., children [25]) in co-design activities. GDPs form a structural framework for describing commonly recurring components of games and patterns of interaction that concern how components used by players or a system during a gameplay [13]. In this paper we mainly use the pattern collection developed by Björk and Holopainen, available on a wiki with restricted editing access [30]. The full description of a pattern in the wiki follows a template and includes an introduction assuming no knowledge of other patterns, a section on what makes it appear in a game, and a section on the consequences the pattern has on gameplay in general. In the rest of this paper, all pattern names are written using Small Caps. The blue ones are directly linked to their definitions in the

aforementioned wiki [30]. However, the patterns Complementarity and Synergies between abilities (from [59, 65]) and the pattern Symmetric Gameplay stemming from this study are not linked.

3 METHOD

Initially, we examined all the 4in1 game instances developed since 2016 (see Table 1). The major motivation behind designing 4in1 games was to support children's collaborative interactions. Thus, collaborative gameplay was central to determine the design constraints in 4in1 games and hence define the limits of the design space we investigate in this paper. In this section we first present the participants and the procedure that took place in the process to define the design space, then describe the technology that make up the 4in1 platform, and finally explain the qualitative method we conducted for the three levels of analysis and testing.

3.1 Data Collection: Participants and Procedure

To date, more than 50 developers have been involved in designing and building 4in1 games. In this paper, we will use the term "developers", which here is defined as researchers or university students (bachelor and master level) in the role as designers, programmers and developers of 4in1 games. The majority of these have been BSc (computer science and software engineering) students working in groups on their thesis projects. Eight such game development projects have been carried out by on average 6 students per project. All of these student groups were supervised by one of the authors. The student groups were given the task to design and develop a collaborative activity for primary school children based on the 4in concept. The games developed in 2019 and 2020 explicitly base their design process on the use of GDPs, whereas the earliest games did not. The students were introduced to GDPs through recommendations to literature, e.g. [13, 30, 59, 65]. The StringForce game was designed by researchers and implemented by a programmer [3]. A second version was later implemented by one of the researchers. Quadropong, which is the most recent game, was developed by a professional team consisting of one interaction designer and 2 programmers based on instructions from 2 of the authors.

The students were encouraged to include user testing in their development process, and the researchers in some cases helped to establish contact to the intended user group. The observational notes extracted from the playtests with children were used to analyse and describe the player interactions related to game components. However, the data in this study largely consisted of the mechanical game components of 4in1 games. Thus, only the collaborative player interactions related to game components and children's use of game design patterns were taken into account in our analysis, and the data about children pertaining to their skills, requirements, views and ideas were beyond the scope of this study.

In sum, the main sources for collecting data for this paper stem directly from the developers themselves: from documentation of games, documentation of children participating in participatory design and/or play tests of the applications as found in research papers ([3, 6, 7, 25]), student reports, and the games themselves.

3.2 Materials: Collection of 4in1 games

All the game instances are listed in Table 1 with a title, year, and short description. The description also contains information on if the application was developed by bachelor students, master students or researchers, what platform has been used for development, and finally if the application has been user tested or not. The 4in1 applications are designed to be used by groups of 2-4 children with individual tablets in a classroom context. The original aim of the applications was to understand how technology can be designed in order to stimulate collaboration among pupils. Each

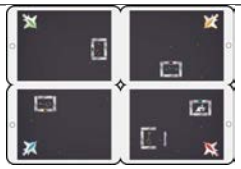
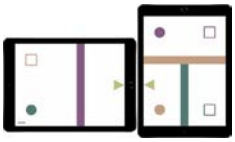
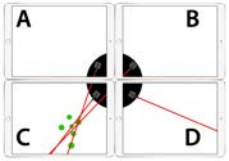
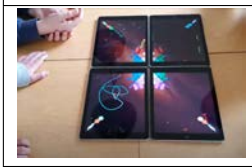
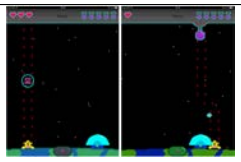
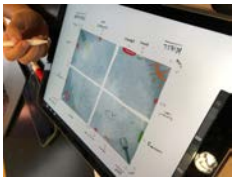
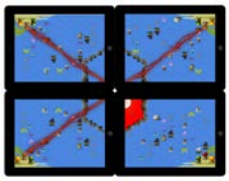
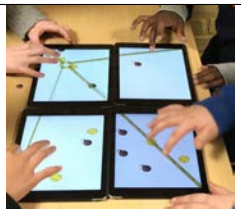
THUMBNAIL	DESCRIPTION	THUMBNAIL	DESCRIPTION
	**Subventure 2019:** Four unique abilities control a submarine and capture items for points. *Unity, BA Student, User tested.*		**Prism 2017:** Four individual laser beams release keys to free astronaut. *iOS, BA Student, User tested*
	**Mathforce 2019:** a shared cursor connected to four strings to collect numbers in a math table and avoid wrong numbers. *iOS, MA Student, User tested*		**Cirkva 2016:** puzzle, move each circle to the color matching square. Walls are removable obstacles and the triangles are portals. *iOS, BA Student, User tested*
	**CogWheel 2019:** asymmetric, each player control a robot with two buttons to move the matching gears in the middle. *iOS, BA Student, User tested*		**Tilt 2017:** players roll a ball through a maze to the goal. Each player controls a direction of the plane from each of their corner. *Unity, BA Student, User tested*
	**Slime Attack! 2018:** Enemies move towards the target in the middle, where each player controls a cannon. *Unity, MA Student, User tested*		**Laser Lunacy 2020:** direct a laser beam from one point to another by exchanging blocks and avoid obstacles. *Unity, BA Student, User tested*
	**Space Control 2020:** land spaceships on a color matching runway, and avoid collisions and obstacles. *Unity, BA Student, User tested*		**Earth Defense 2016:** two players defend earth from space attack using asymmetric abilities. *Ionic2, BA Student, User tested*
	**Deep Blue 2020:** Four unique controls of a submarine to travel and collect items for points. *iOS, Researcher, Not tested*		**StringForce2 2018:** players move a shared cursor connected to four strings to collect coins and avoid bombs. *iOS, Researcher, User tested*
	**Quadropong 2020:** Destroy bricks with ball bouncing on paddles which can be placed anywhere using two fingers. Edges act boundary for balls. *Unity, Researcher, User tested*		**Solve IT 2019:** puzzle, the pieces are spread across devices and moved by dragging. *iOS, Researcher, User tested*
	**Pearls'n'Pirates 2018:** defeat pirates and avoid obstacles by moving ships and control powerful pearls. *Ionic2, Researcher, Not tested*		**StringForce1 2016:** players move a shared cursor connected to four strings to collect coins and avoid bombs. *Ionic2, Researcher, User tested*

Table 1. Overview of all 4in1 collaborative games developed by either students or researchers.

group of children should be able to perform the activity together, without interfering with other groups who are using their tablets at the same location. The children should be able to initiate a 4in1 session by themselves at any time. This implies that the interface for starting a session should guide the children without depending on text, since reading can be found difficult to some children, and that the solution should use the same procedure, independent of how many tablets are connected so that the children only have to learn the procedure once.

In order to establish communication between devices, the tablets must be connected into one session, and the children have to make sure that their tablets are connected to the same session. The session will rely on some kind of server-client setup where the server keeps the connected tablets in sync and manage the application state, but from the children's perspective all tablets should appear to have equal roles. In order to carry out a 4in1 activity it is necessary for the players to arrange the tablets correctly to form the shared game area, see example in Figure 1. The positions of the tablets are not interchangeable.

3.2.1 Platform and Communication. From a technological perspective all applications share the design that one tablet acts as a server managing the 4in1 game and the other tablets connect to the server and become clients. The applications have been implemented using three different solutions: Ionic2, iOS and Unity.

The first 4in1 games were based on the platform-independent web framework Ionic2 [38] and made use of Bluetooth for communication between the devices. This worked fine but had the disadvantage that it was not based on any existing game engine. However, as iPads dominate the school market strongly in [Country] it was decided that it was acceptable to focus on a solution that would work on iOS only. This lead to that our first attempt at creating an application framework for 4in1 activities is built upon Apple's Multipeer Connectivity Framework [54], which enables easy to set-up direct communication between devices and automatically selects the best available communication channel (Bluetooth, Wi-fi etc), and the game engine SpriteKit [66]. Finally, the aim of the Unity [68] solution is to provide a platform for creating network games including an error handling system and the possibility to handle multiple rooms, the users can join. A shell game has been developed that can be used as a template to build networked games that uses the displays on multiple devices as one big canvas. The connection between the tablets is coded using Unity3D's UNET networking code and Mirror Networking with Unity3D. A difference compared to the other platforms is that it requires all tablets be connected to wi-fi.

3.3 Data Analysis: Understanding 4in1

3.3.1 Phase 1: Horizontal analysis. We used horizontal analysis to start our mapping strategy. Horizontal analysis means to relate similar concepts, focusing on similarities and differences that can help to understand the design space. At first we listed all the instances of 4in1 games including both concepts and implemented prototypes. The 4in1 games that we know have been developed, constitute a total of 16 game instances, see overview in Table 1.

We used Gameplay Design Patterns (GDPs) [30] as a vocabulary for identifying and analysing the commonality between different games instances. We extracted all the GDPs that have been annotated by the developers of the 4in1 game instances. This resulted in 31 GDPs in total namely Abilities, Asymmetric Gameplay, Attention Demanding Gameplay, Capture, Challenging Gameplay, Controllers, Complementarity, Dexterity-Based Actions, Focus Loci, Experimenting, Game Items, Levels, Maneuvering, Movement, Obstacles, Real-Time Games, Tactical Planning, Synergies Between Abilities, Symmetric Gameplay, Avatars, Collaborative Actions, Functional Roles, Mutual Goals, Resources, Social Skills, Stimulated Planning, Symbiotic Player Relations, Tension, Teams, Enemies, and Cooperation. For each pattern addressed by the developers, we analysed how these patterns have

PHASE 1: HORIZONTAL ANALYSIS
Include 16 game instances
Extract 31 GDPs from developers
Analyse 31 GDPs across 16 instances
Decide on Cooperation as filter for the design space
PHASE 2: VERTICAL ANALYSIS
List 89 GDPs as mentioned in Cooperation [30]
Exclude 22 GDPs due to missing description in [30]
Exclude 13 non-cooperative GDPs
Exclude 4 GDPs not supporting co-location
Identify 12 GDPs shared in both Include 15 GDPs from Cooperation overlooked by developers
25 GDPs only in Cooperation and unexplored in 4in1 27 GDPs existing in both that define cooperation in 4in1 17 GDPs only in 4in1 and unexplored in Cooperation
PHASE 3: INDUCTIVE ANALYSIS
Identify *perspectives*: Game Space, Social Interaction, Game Components, Aesthetics
Identify *dimensions* for the perspectives: Game Space - Set-up, Mechanics Social Interaction - Roles and Skills, Actions, Goals and Planning Game Components - Roles and Skills, Actions, Goals and Planning Aesthetics - Game Space, Social interaction, Game components
PHASE 4: TESTING
Testing the design space on three instances

Table 2. Short overview of the different steps in the method in chronological order from top to bottom.

been applied across 16 various instances of 4in1 games. Through the horizontal analysis, we identified Cooperation as described in the GDP collection [30] as the most pertinent pattern across all the instances to create an overview of the potential components. We decided to have this pattern as a focus to delimit our design space, and for describing manipulable components of 4in1 games and for encapsulating a space of design opportunities.

3.3.2 Phase 2: Vertical Analysis. In the next step, we used vertical analysis, which means making connection to theory. We used vertical analysis by listing all the 89 GDPs mentioned in the pattern Cooperation in the wiki [30]. We compared the GDPs pronounced by the developers with the ones listed in Cooperation that have a definition in the wiki [30]. We identified 12 GDPs listed in both Cooperation and listed by the developers in common: Avatars, Tension, Collaborative Actions, Teams, Functional Roles, Enemies, Mutual Goals, Resources, Social Skills, Stimulated Planning, Symbiotic Player Relations, Asymmetric Gameplay. Therefore, in sum 108 GDPs.

We excluded 22 GDPs mentioned in Cooperation that are listed in the pattern suggestion list albeit have no definition in the GDP collection in Wiki yet [30]: Competition, Conflicts, Trading, Unmediated Social Interaction, Timing, Coordination, Alliances, Uncommited Alliances, Dynamic Alliances, My Enemy's Enemy is my Friend, Inherent

Mistrust, Traitors, Negotiation, Public Interfaces, Alternate Reality, Social Interaction, Constructive Gameplay, Social Organizations, Game-Based Social Statuses, Asymmetric Abilities, Asymmetric Information, Perspective Taking, resulting in remaining 86 GDPs.

We excluded patterns described in Cooperation that were not deemed relevant for 4in1. The exclusion criteria was a) non-cooperative patterns: Non-Player Help, Ragequitting , Playing to Lose, Actor Detachment, Dedicated Game Facilitators, Betrayal, PvP (player-versus-player), Individual Rewards, Player Unpredictability, Delayed Reciprocity, Strategic Knowledge, Tied Results, Social Dilemmas, and b) patterns not supporting co-location Drop-In/Drop-Out, Late Arriving Players, Communication Channels, Chat Channels, resulting in 69 remaining GDPs in total which we present in this paper.

Studying Cooperation thoroughly helped us to find relevant patterns pertaining to both Cooperationand 4in1 games in common, however overlooked by the developers. Thus, we included 15 more patterns in the 4in1 game instances namely: Multiplayer Games, Mediated Gameplay, PvE, Continuous Goals, Supporting Goals, Asymmetric Goals, Asynchronous Collaborative Actions, Parties, New Abilities, Non-Player Characters, Shared Rewards, Shared Resources, Internal Conflicts, Transferable Items, Gameplay Mastery. The exclusion and inclusion of patterns in Cooperation were mainly based on our observations of the playtest videos and experiences with the 4in1 games, nevertheless may be conceived as a limitation for the analysis.

In sum, we categorized GDPs that are shared in Cooperation and either addressed by the developers of 4in1 games or identified as existing in 4in1 by the authors (a total of 27 GDPs), patterns that exist in 4in1 but not in Cooperation (17 in total), patterns that only exist in Cooperation and that could be unexplored possibilities for future development of 4in1 games (25 in total), see overview in Table 3.

3.3.3 Phase 3: Inductive analysis. The remaining 61 patterns resulting from the horizontal and vertical analysis were scrutinized by the three authors. To maintain an accuracy for our inductive approach, the authors reviewed and studied the patterns independently. After all authors had grouped the patterns in relevant clusters individually, we went through the clustering of patterns in detail together and discussed how we understood and interpreted the related pattern clusters. To calibrate the internal consistency and reach a conclusion for identifying the major categories, we reiterated the clustering in several affinity diagrams in the Miro online whiteboard platform together [53]. Thus, we conducted a qualitative consensus coding in our inductive analysis rather than measuring a quantified agreement. By doing so, we identified the main perspectives Game space, Social Interaction, Game components and Aesthetics, and dimensions related to each of the perspectives through inductive coding. This is what makes up the Design space for co-located collaborative games that use multi-display composition with a focus on cooperation.

3.3.4 Phase 4: Testing the design space. After mapping out the design space for co-located collaborative games that use multi-display composition, we tested its usefulness as analytic and generative tool for analysis and (re-)design, by applying it to instances in the 4in1 collection of collaborative games. For this paper, three instances were chosen for visualizing this step, based on their different characters. First, Cirkva, which is a puzzle type of game, secondly StringForce as one of the first instances ever created, and finally Quadropong which is the latest instance. We analysed the three games using the properties and dimensions in the design space. The result outline the differences between the three games, and when comparing to the design space mapping in Table 8 the possible ways to move forward in further development and re-design become clear.

Two authors were responsible for the first phase (the horizontal analysis), all three authors were involved in the second and third phases of the data analysis (the vertical and inductive analysis), and two of the authors were involved in the fourth phase (applying the design space to the instances). Results from the analysis are described below.

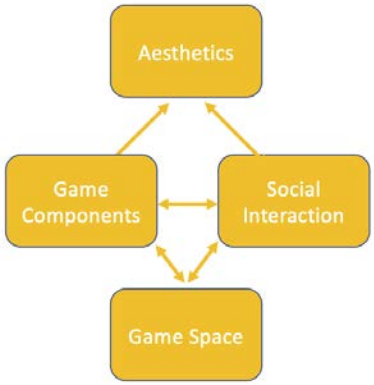


Fig. 3. The four perspectives of the design space deriving from 4in1 games.

4 RESULTS FROM ANALYSIS

The result of the analysis is a design space for co-located collaborative games that use multi-display composition. The design space is spanned by patterns that can support cooperation deriving from game instances as well as from the description of Cooperation in the wiki [30]. By testing the design space as an analytic and generative tool, we have been able to compare games for similarities and differences, and discover unexplored design possibilities for future work. Finally, deriving from this work, we can suggest new GDPs that can inform the development of the definition of the GDP Cooperation .

The design space is organized into 4 perspectives: *Game Space*, *Game Components*, *Social Interaction* and *Aesthetics*, see Figure 3. Each perspective provides a look at the 4in1 space from a specific angle. The Game Space perspective deals with set-up of game sessions and basic mechanics. The Game Components presents a number of patterns relevant for designing the components of a collaborative 4in1 game. The Social Interaction perspective looks into patterns that enhances the opportunities for creating interaction and communication. Finally, the Aesthetics perspective contains patterns that describe characteristics emerging from the use of the other patterns during a game session. The figure illustrates how the perspectives depend on and relate to each other.

4.1 Game Space

The *Game Space* perspective is quite specific for the 4in1 platform, and is defined by the base components. Patterns appearing in this perspective are typically building blocks that the designer has full control over, and that exist before the user so to speak, quite similar to the low-level patterns belonging to 'Mechanics' in the Mechanics-Dynamics-Aesthetics (MDA) framework [37]. The perspective is spanned by the dimensions *Set-up* and *Mechanics*, see Table 4. The Set-up dimension lists patterns dealing with basic requirements and initiating a game session. A cornerstone of the 4in1 platforms is that several players work to gather and all games are therefore instances of Multiplayer Games, letting

	GDPs in 4in1 & Cooperation	GDPs in 4in1 but not in Cooperation	GDPs unexplored in 4in1 from Cooperation
GAME SPACE			
Set-up	Multi-player Games	Real Time Games	Split-Screen Views Invites
Mechanics	Mediated Gameplay PvE Assymmetric Gameplay	Experimenting Attention-Demanding- -Gameplay Symmetric Gameplay*	
SOCIAL INTERACTION			
Roles & Skills	Teams Functional Roles Avatars Social Skills Parties	Abilities Synergies-Between- -Abilities*	Social Roles Roleplaying Characters Priveliged Abilities Entitled Players Companions
Actions	Collaborative Actions Symbiotic Player Relations Asynchronous-Collaborative- -Actions		Altrustic Actions
Goals & Planning	Mutual Goals Continuous Goals Supporting Goals Asymmetric Goals Stimulated Planning	Tactical Planning	Preventing Goals
GAME COMPONENTS			
Roles & Skills	New Abilities		Improved abilities Competence Areas Social Dilemmas Team combos Handles
Actions		Game Items Focus Loci Dexterity based Actions Maneuvering Capture Movement	Area Control Controllers
Goals & Planning	Resources Enemies Non-player Characters Shared Reward Shared Resources Internal Conflicts Transferable Items	Obstacles Levels	Agents Game System Player Free Gift Inventories Algorithmic agents Landmarks Geospatial Game Widgets
AESTHETICS			
Game Space	Tension	Challenging Gameplay	Complex Gameplay
Social Interaction		Complementarity*	Reflective Communication
Game Components	Gameplay Mastery		

Table 3. Overview of the design space for co-located collaborative games that use multi-display composition. Patterns marked with * have been mentioned by the developers of 4in1 games, but stem from other sources than from Cooperation in the wiki [30]

GAME SPACE	
Set-up	**Mechanics**
	Mediated gameplay
	PvE
Multi-player games	Symmetric gameplay
Split-screen views	Assymmetric gameplay
Invites	Experimenting
Real Time games	Attention demanding gameplay

Table 4. Overview the perspective *Game Space* with the two dimensions *Set up & Mechanics*, and patterns.

the players have social interaction before, during and after game sessions. In the cases where the progression of the game is tied to the progression of real time, the games can be classified as Real-Time Games. Two examples of this are StringForce and Quadropong. Examples of games where time is not important are the puzzle games CirKva and Solve IT!. The Set-up dimension also contains a couple of patterns that have not been explored yet. Invites would enable starting up the game alone or with only few players, and these could then perform game actions that result in new players being invited to join the game and thereby completing the full gameboard. Also, Split-Screen Views has not been explored although it provides players with an alternative where they can have better overview of each other's actions.

The *Mechanics* dimension consists of the rules and basic actions the player can take in the game. An import choice to make is whether a game should have Symmetric Gameplay or Asymmetric Gameplay. Both have been explored in the existing games, e.g. StringForce is symmetric while Subventure is asymmetric. When the asymmetric approach is used the players are given different abilities, which might be beneficial for cooperation since they need to make use of each others skills and opportunities. The combination of Multiplayer Games and Real-Time Games typically leads to Attention Demanding Gameplay where players can easily suffer bad consequences for being inattentive at any given point. The consequences can for instance be caused by using PvE ('Player versus Environment'), where the game systems rather than other players, provide challenges to players. Finally one way to force cooperation and coordination between players is to make use of the pattern Experimenting, where the players have to figure out how the game works by trial-and-error. Experimenting is used in most of the 4in1-games, an exception is CirKva, which has a tutorial that walks the player through the game in a single-player mode.

4.2 Social Interaction

In the *Roles & Skills* dimension, see Table 5, all 4in1 games developed so far are designed so that the players work together in one Team towards reaching a common goal. The player skills are defined by the Abilities assigned to each player. In symmetric games like StringForce these are the same for each player. In asymmetric games e.g., Subventure, Quadropong, and CogWheel, players have different Functional Roles visible through Avatars which create Synergies Between Abilities [59, 65]. The interdependence between roles and skills invite players to engage their Social Skills throughout the gameplay which is valuable for cooperative games. Other ways for cultivating the cooperative gameplay environment in 4in1 could be to design different Characters such as Entitled Players or other types of Companions that attribute different Social Roles to the players or agents in the game. Roleplaying or Privileged Abilities could open varying alternatives for increasing the individual differences between players capabilities and extending the *Roles & Skills* dimension in 4in1 Games.

SOCIAL INTERACTION		
Roles & Skills	**Actions**	**Goals & Planning**
Teams		
Functional Roles		
Avatars		
Social skills		
Synergies between abilities		
Parties		
Social roles		Mutual goals
Roleplaying		Continuous goals
Characters		Supporting goals
Priveliged abilities	Collaborative actions	Asymmetric goals
Entitled players	Asynchronous collaborative actions	Stimulated planning
Companions	Symbiotic Player Relations	Preventing goals
Abilities	Altrustic actions	Tactical planning

Table 5. Overview the perspective *Social interaction* with the three dimensions *Roles &Skills, Actions, Goals & Planning*, and patterns.

The *Actions* dimension in 4in1 games is built around the Collaborative Actions combining the players' efforts in compound actions. Further, there are Symbiotic Player Relations found in all the 4in1 games in that everyone act together and win or lose the game together. All players need to act together albeit, some games also allow players Asynchronous Collaborative Actions. For instance, in some levels of Quadropong, players complete their tasks on their own screen and they do not necessarily act simultaneously with the other players. One way of alternating Collaborative Actions could be Altruistic Actions which benefit the other players rather than the one who actually performs the action. This type of action could add an individual character to the action while maintaining the overall cooperative intentions amongst the players.

The *Goals & Planning* dimension consists of the patterns towards which the *Actions* are performed along with the *Roles & Skills* by the players. In all 4in1 games players act upon their Mutual Goals e.g., winning the game together through coordinating their activities which is achieved through a subset of Continuous Goals e.g., collecting all coins while avoiding the bombs in StringForce, and Supporting Goals e.g., capturing all trash in order to clean the ocean in Subventure. Moreover, in asymmetric games like Subventure and Quadropong where players have different roles and skills, the players need to do Tactical Planning in which they coordinate their actions in the most feasible way for the current state of the gameplay. They might also need to do Stimulated Planning in order to plan the steps further ahead through predicting what the game state could turn into. Some levels of Quadropong also provide Asymmetric Goals for the players in that they need to complete different tasks on their own screen to reach the shared goal. Tactical Planning is found as a pattern offered by 4in1 games which can be used to further inform the definition of the Cooperation pattern. A pattern that has not been explored yet is Preventing Goals that could possibly be applied in two Teams or Parties of players or by agents in the game by competing simultaneously against each other.

4.3 Game Components

The Game Components perspective, see Table 6, deals with matters related to the basics of gameplay and contains several patterns that are of a more general nature. The *Actions* dimension patterns Game Items, Focus Loci and Movement describe basics for using various kinds of items to form game worlds and move around to perform actions. For instance in StringForce the Focus Loci are the ring and the ropes the players use to perform Movement in order to Capture the Game Items coins and avoid the bomb Obstacles. In Real-Time Games, basically all the 4in1 games

except for Cirkva, Pearls 'n' Pirates, and SolveIT, controlling the Movement of game elements through Maneuvering is central to play the game. When the movements require some level of skill for direct control and physically challenge the players, typically in hand-eye coordination, they are examples of Dexterity-Based Actions. The Actions dimension also contains properties like Area Control and Controllers related to actions that can only be found or performed in certain locations that have so far not been explored in the presented 4in1 games. These patterns could possibly be utilized through designing different game worlds within a game which incite the players to move, explore and gain access to a certain set of *Actions*.

In the *Roles & Skills* dimension the only pattern that has been explored so far is New Abilities, which can be found in QuadroPong, and which provides players with new actions to be performed. This dimension lists patterns related to things like how the skills of the players can change (e.g. Improved Abilities), how they can be identified on screen (Handles) or how they can combine their efforts to perform actions they would otherwise not be able to do using Team Combos. That several of the properties/patterns have not been explored in any 4in1 game yet indicates directions for new possibilities indicated by the design space.

GAME COMPONENTS		
Roles & Skills	**Actions**	**Goals & Planning**
		Levels
		Resources
		Shared Resources
		Shared Rewards
		Transferable Items
	Game items	Landmarks
	Focus loci	Geospatial Game Widgets
	Movement	Free Gift Inventories
	Maneuvering	Enemies
Handles	Obstacles - moved	Non-Player Characters
New abilities	Capture	Agents
Improved abilities	Dexterity based actions	Game System Player
Competence areas	Area Control	Algorithmic agents
Team combos	Controllers	Internal conflicts

Table 6. Overview the perspective *Game Components* with the three dimensions *Roles &Skills, Actions, Goals & Planning*, and patterns.

The dimension *Goals & Planning* lists quite a few patterns that span the space for components dealing with possible ways to create goals and incentives for planning within 4in1-games. A very common approach is to divide games into Levels, often with increasing difficulty. This has been explored in several 4in1 games, e.g. Tilt, Laser Lunacy and QuadroPong. Obstacles and Enemies have been explored in several 4in1-games for instance there are walls in Tilt that blocks the way and the basic element in Slime Attack! is to stop invaders. To handle these the players need to set up goals and together make up a plan. Shared Rewards can be used to create a sense of achievement when a group reaches their goal, and to reach the goal they might need to make use of their Shared Resources. A first exploration of Non-Player Characters has been done in Laser Lunacy where a dwarf walks around and disturbs the players' intentions. Laser Lunacy also makes use of Transferable Items when the players need to exchange laser re-directing blocks to find a joint solution to the game. One way to design for cooperation might be using Internal Conflicts to create a situation that requires the players to rethink their strategies. A group of patterns that have been rather little explored so far are patterns related to the use of agents, with variants like Algorithmic Agents and Game System Player. Accordingly, this creates room for further explorations in the design space with many possibilities for

future work, where game components can be introduced that force the players to create goals and make plans. Further, patterns such as Free Gift Inventories, Landmarks and Geospatial Game Widgets generate occasions in gameplay environments to set *Goals* and stage *Planning* for players and offer unexplored possibilities for design.

4.4 Aesthetics

AESTHETICS		
Game Space	**Social Interaction**	**Game Components**
Tension Complex Gameplay Challenging Gameplay	 Complementarity Reflective Communication	 Gameplay Mastery

Table 7. Overview the perspective *Aesthetics* with the three dimensions *Game Space, Social Interaction, Game Components*, and patterns.

The perspective *Aesthetics* is here defined with inspiration from the Mechanics-Dynamics-Aesthetics (MDA) framework [37], meaning Aesthetics are the responses evoked in the player. The patterns in aesthetics are a result of the mechanical patterns implemented, and which dynamics that have occurred, meaning what users do when they use the system. The player responses can either be as emotional responses such as Tension or behavioural responses such as e.g. Reflective Communication. The perspective is spanned by gameplay design patterns related to the dimensions *Game space, Social interaction, Game components*, see Table 7.

Through playtests of various games (e.g. Quadropong, Stringforce), we have studied how those games which allow players to become skillful in repeatedly succeeding with challenges posed by the game allow players to develop Gameplay Mastery in them. This is a consequence of that the game provides new challenges, learning opportunities, or experiences when played again. By using the three levels of collaborative interaction from Activity Theory (AT) [2, 24] as a frame of reference (coordination, cooperation and reflective communication), different types of collaborative interaction that children engaged in when playing co-located collaborative games have been studied in StringForce, Subventure and a non-digital collaborative board game, Forbidden Island. The results show that the children indeed can be engaged in coordination and cooperation activities in all three games. However, engagement in the highest level of collaboration, Reflective Communication, is scarce, and appeared only in the traditional board game [5]. Furthermore, having different *Roles and Skills* in performing the *Actions* enhance the sense of Complementarity amongst the players in accomplishing their *Goals* which also aligns with the findings by El-Nasr et al. [65] for cooperative gameplay design patterns.

Through playtests, we can conclude that some of the games offer the players Challenging Gameplay (Quadropong and Laser Lunacy) in that players experience the gameplay as difficult or challenging their abilities and skills. However, we have not yet explored Complex Gameplay where planning or performing actions is complex, or understanding the consequences of actions are.

5 TESTING THE DESIGN SPACE

The design space can be used as both an analytic and generative tool in several different ways for both analysis and (re-)design. For analysing and comparing games one can map out the patterns found in the games as done in Table 8. An analysis like this does for instance seem to indicate some similarities as follows: Multiplayer Games setup along

	StringForce	Cirkva	Quadropong
GAME SPACE			
Set-up	Multi-player games Real Time Games	Multi-player Games	Multi-player Games Real Time Games
Mechanics	Mediated Gameplay PvE Symmetric gameplay Attention-Demanding--Gameplay Experimenting	Mediated gameplay Symmetric Gameplay	Assymmetric Gameplay Mediated Gameplay PvE Attention-Demanding--Gameplay Experimenting Symmetric Gameplay
SOCIAL INTERACTION			
Roles & Skills	Teams Abilities Characters AVatars Social Skills	Teams Abilities Social Skills Avatars	Teams Abilities Functional Roles Synergies Between Abilities
Actions	Collaborative Actions		Collaborative Actions Asynchronous-Collaborative--Actions
Goals & Planning	Mutual Goals Tactical Planning	Mutual Goals Stimulated Planning	Mutual Goals Continuos Goals Supporting Goals Asymmetric Goals Tactical Planning Stimulated Planning
GAME COMPONENTS			
Roles & Skills			New Abilities
Actions	Game Items Focus Loci Movement Maneuvering Capture	Game Items Focus Loci Movement	Game Items Movement Maneuvering Dexterity-Based Actions
Goals & Planning	Levels Enemies Shared Rewards Obstacles	Levels Transferable Items Obstacles	Levels Transferable Items Obstacles Shared Resources
AESTHETICS			
Game Space	Tension	Challenging Gameplay	Challenging Gameplay
Social Interaction			Complementarity
Game Components			Gameplay Mastery

Table 8. The design space applied to the three games StringForce, Cirkva and Quadropong with a focus on Cooperation .

with Mediated Gameplay mechanics are common in the Game Space perspective. Besides, Teams and Abilities are commonly used as defining the Roles & Skills while Mutual Goals are utilized to design Goals & Planning in the Social Interaction perspective in common in these games. Moreover, Game Items and Movement occur customarily as part of Actions dimension and Levels and Obstacles are regularly used for designing the Goals & Planning dimension in the Game Components perspective. Thus, these patterns across the related dimensions and perspectives can be interpreted as the fundamental components found in the design space and regarded as the basics for implementation. Even with these several similarities it is possible to observe a variety of Aesthetics across the three 4in1 games. On the other hand, the table also indicates that the Roles & Skills dimension in Game Components is largely unexplored. Furthermore, the Roles & Skills dimension of the Game Components perspective has been weakly explored, and Quadropong is the only instance for applying the New Abilities pattern in this dimension among other 4in1 games. Another inference could be seen when looking at the similarities between StringForce and Cirkva where both games are designed by utilizing many similar patterns including Avatars and Focus Loci, however in StringForce Goals & Planning are shaped through Tactical Planning in which players know the current state of the game from the PvE as such, and bombs as Obstacles create Tension for the players as an Aesthetics, whereas in Cirkva players are required to plan their actions according to some goals that are not immediately obvious to them in the PvE so they do Stimulated Planning which creates a Challenging Gameplay experience for the players.

The design space can also be used as a generative tool for design and re-design. One way to do this could be to pick some patterns from the different dimensions and use them as starting points for design. A variation of this could be to start with an inspiring collaborative game and take the patterns it uses as a starting point. For instance if one wants to develop an instance of Attention Demanding Gameplay and PvE that allows Experimenting to the players then looking at the patterns commonly used in e.g., StringForce and Quadropong might be a useful starting point. This could lead to that one for instance decides to design the Actions dimension based on Collaborative Actions for Social Interaction, and Maneuvering for Game Components. Besides, for designing the Goals & Planning dimension Tactical Planning for Social Interaction and Shared Rewards or Shared Resources can be utilized from the Game Components perspectives.

Finally, the design design space could be used for design and re-design. One way to do this could be to look at patterns from the various dimensions that are missing and examine if the current designing could be improved by using them. As an example, some Levels of Quadropong are designed almost the same on purpose where only their mechanics are different to provide the players with both Symmetric Gameplay and Asymmetric Gameplay experiences within the same game. A re-design of StringForce could introduce Shared Rewards when one of the Levels is cleared that lead to Improved Abilities. A similar approach could also be applied to other games.

6 DISCUSSION

In this paper, we have defined a design space for co-located collaborative games that use multi-display composition. We have done so by analysing design outputs in the form of 16 collaborative game instances. This work has provided us with the opportunity to revisit a range of instances and prompt reflection on prior design activity within the 4in1 concept, activities important in undertaking research through design [70].

One weakness with design spaces in general, and the design space in focus in this paper, is that it is not possible to include all the factors that have an impact on design. There will always be a certain focus in the mapping of a design space, which means that important parameters might be filtered away. We acknowledge that 4in1 is much more complex than just related to cooperation, and more complex than the design space as defined in this paper. There are more

patterns to include, more factors that have an impact on design, further technical possibilities etc. The design space as defined here is an instance of the 4in1 conceptual space, and as so, there are potentially many more possible design space instances within 4in1. However, identifying such is not in the scope of this paper.

Another factor that might influence the results is that there are gameplay design patterns that have rather open and ambiguous definitions. This means that it is not always clear cut if a certain pattern is present in the gameplay of a particular game or not. As an example, we have decided in our analysis that so far there are no 4in1 games that show Complex Gameplay. The definition of the pattern describes it as gameplay "where planning or performing actions is complex, or understanding the consequences of actions are" [30]. Typical examples mentioned are Chess and Go. Of course, deciding what is actually complex is subjective. For instance, in the 4in1-game Solve IT!, the game is very basic, since it's just a simple puzzle where the task is to shuffle around the pieces until they are in the correct order, so in this respect the gameplay is not complex. On the other hand, finding the solution can be quite difficult, which means that planning and understanding of actions is complex. In the end we decided not to classify Solve IT! as exhibiting Complex Gameplay based that we judged the game to be too simple to match the description, but there is no obvious right or wrong when it comes to interpreting this and others patterns.

6.1 Multi-Display Composition vs. Tabletops

As mentioned above, the 4in1 MDC has similarities to tabletops. Both have the shape of a flat rectangular area where several uses can use touch to interact with the system simultaneously. In both cases 4 persons could gather around the space and carry out a collaborative activity. A notable difference is that the MDC is flexible and portable and could in principle be used anywhere, anytime where a group of people meet. Another difference is that tabletops may allow extra interaction possibilities like understanding physical markers placed on the table.

The CoCe design space is the result of work with the 4in1 MDC but the similarities with tabletops indicate that the results can be applicable for these as well. Indeed, an interesting path for future work could be to look at collaborative tabletop games through the lens of the CoCe design space. This could both open up for new possibilities regarding design co-located collaborative games for tabletops and be valuable for evaluating and improving the design space.

6.2 Design Space as a New Form of Intermediate-Level Knowledge

In this paper we claim that design spaces are a form of intermediate-level knowledge residing between instances and theory, see Figure 2. With this, we mean that the design space derives from instances but is more specific than theories, as there is no claim of universality. The design space in focus here has been defined by applying horizontal grounding on a number of instances and by vertical grounding using theory from [30]. The method is inspired from the method described for identifying strong concepts, another form of intermediate-level knowledge [36]. However, it is not just the method itself that makes us claim that design space is a new form of intermediate-level knowledge, it is rather a result of the claimed contributions. The design space can be used as a generative tool in the design and re-design of co-located collaborative games. However, in addition, the design space clearly point to possible GDPs that can be of interest to consider when further developing the definition of the GDP Cooperation, and as such also contribute to theory. That is why the arrows in Figure 4 points in two directions - to illustrate the design space as a result of instances and theory, and with possibility to generate both new instances and new theory with inspiration from the design space.

The main motivation for working with intermediary knowledge forms such as design spaces and patterns is that they can have generative power [35]. That is, when we are faced with a new design challenge we can turn to the existing system of parameters in the design space and use them as a starting point for design. The grounding behind the

parameters as well as the example instances give possibilities to function both as inspiration and reference. Although we do not claim to know whether the design space described here has generative power beyond our own work, we can conclude that it can be a useful starting point for the future development of our own work and the work of our students. Interesting future work would be to explore how others can make use of the design space as a generative tool. Our approach is based on the encapsulation of a design space to identify and examine further design opportunities in different games. The extensibility of the approach lies in encapsulating another design space, and an interesting topic for future work would be to apply the approach on GDP:s for other types of games.

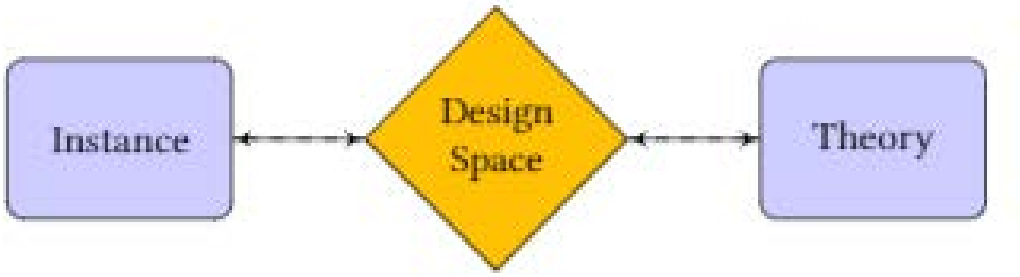


Fig. 4. Design space with double arrows - stemming from and contributing to both instances and theory.

6.3 Method for Defining Design Space

As presented earlier, there is not one single method settled on for defining design spaces. Rather, it is quite scattered between developing specific methods for mapping design spaces e.g. [32], more general methods such as e.g. semantic analysis [15], or a combination of both e.g. [12]. In this paper we have applied horizontal and vertical analysis in combination with the language of gameplay design patterns as an approach to developing a design space, with promising results. The horizontal and vertical analysis as method has previously been applied to developing strong concepts, e.g. [4, 36], however, we have not seen it be used for developing design spaces. We therefore claim that this method could be useful for others who venture into defining design spaces.

One limitation with the method might be the reliability. The inclusion and exclusion criteria for patterns in cooperation have been decided on by the authors themselves, who have been involved in 4in1 for many years, either as developers themselves or as supervisors to student developers for all the game instances. This means that there is possibly a high level of subjectivity. However, one of the authors has only been involved in the development of one game, why it has been possible to keep some degree of objectivity and holistic approach. A further limitation might be that the design space emanate from our own design-oriented research and the work of our students. However, this might be natural since the articulation of intermediate-level knowledge requires deep familiarity with the original instances and their properties [36].

In the mapping of the design space of co-located collaborative games that use MDC, we have chosen to focus on the collaborative aspects of 4in1, by using Cooperation as a focus for vertical analysis. However, we acknowledge that there are many other filters we could have used, which would have had a broader impact on the result. The focus for 4in1 has always been on collaboration, however, neither collaboration or coordination exist as a pattern in the wiki [30].

Collaborative Actions is a pattern we could have chosen as an alternative filter, although it was our judgement that this would be too limited to actions, while Cooperation was considered as broader and cover more aspects. Another interesting path to pursue in the future could be to focus on Reflective Communication, which is a possible design goal in line with Cooperation. Reflective communication is the highest level of collaboration as defined in Activity Theory [23].

Using Cooperation as a filter when mapping out the design space might have limited possible future explorations. One example to illustrate this is for instance that the patterns New Abilities and Abilities are listed in Cooperation, however Decreased Abilities is not, why we have only included New Abilities and Abilities . Snowballing related patterns for each pattern could most certainly have provided a richer design space, however, we chose to stay with the constraint of using Cooperation as filter. Investigating what the results from such an extended mapping would be could be an interesting path for future work.

7 CONCLUSION

In this paper, we have used a three phase analysis on 16 game instances, which resulted in the CoCe design space for co-located collaborative games that use multi-display composition. The design space is filtered around cooperation, and defined by gameplay design patterns. The process consists of a horizontal analysis of 16 games, vertical grounding in the gameplay design pattern Cooperation, inductive analysis to define the perspectives and dimensions that make up the CoCe design space, and finally testing the design space through the analysis and re-design of 4in1 games. The results indicate that the CoCe design space support further explorations of 4in1, and thereby point towards that the CoCe design space has the more general power to act both as an analytic and a generative tool for co-located collaborative games that use multi-display composition. We further acknowledge the potential of the CoCe design space to inform further development of the description of the Cooperation gameplay design pattern.

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