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Design Space Cards: Using a Card Deck to Navigate the Design Space of Interactive Play

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The potential space of game designs is astronomically large. This paper shows how game design theories can be translated into a simple, tangible card deck that can assist in the exploration of new game designs within a broader "design space." By translating elements of game design theory into a physical card deck, we enable users to randomly sample a design space in order to synthesize new game design variations for a new play platform ("Lumies"). In a series of iterative design and testing rounds with various user groups, the deck has been optimized to merge relevant game theory elements into a concise card deck with limited categories and clear descriptions. In a small, controlled experiment involving groups of design students, we compare the effects of brainstorming with the card deck or the "Directed Brainstorming" method. We show that the deck does not increase ideation speed but is preferred by participants. We further show that our target audience, children, were able to use the card deck to develop dozens of new game ideas. We conclude that design space cards are a promising way to help adults and children to generate new game ideas by making it easier to explore the game design space.

CCS Concepts: • **Human-centered computing → Interaction design process and methods** • **Human-centered computing ~Human computer interaction (HCI)~HCI theory, concepts and models**

KEYWORDS: Design space, creativity, game design, children, design thinking methods, evaluation

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1 INTRODUCTION

A primary challenge in designing new games is dealing with the massive space of possible designs. To even consider what may be possible can be overwhelming. One value of scholarly literature on game design theory is that it can help simplify this vast space. Yet, this literature is difficult to remember, understand and apply during game design ideation. This is an issue for adult designers and even more so for children. This paper presents a solution to this general problem by addressing the case of designing new games for the Smart Lumies platform.

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Figure 1: Left: Lumies are connected toy blocks that can respond to touch, orientation, acceleration, proximity to other blocks – and respond with colored lights, sound and vibration. They are digital playthings that can be played individually or socially—with or without a phone screen (middle). The possibilities seem endless—and yet hard to imagine. To help experts and children consider gameplay possibilities, we designed a card deck for exploring the gameplay design space (right).

1.1 Lumies

Lumies are interactive play cubes that provide a non-screen-based game and play platform. Lumies were developed in response to K12 curriculum changes in Croatia [77] in order to give children a tangible and fun experience of computer science and game design [56]. In comparison to other programmable blocks [54], Lumies are far more constrained: they do not have a screen and can only produce colored lights, sounds and vibrations in response to touch, orientation, acceleration and the presence of other cubes nearby. But this small list of ingredients produces an enormous set of possible interactions in play.

To give a simple example interaction, the cube rotation can be used to control changes in the RGB values defining the colors of the cube. This simple relationship provokes pure play; it offers no goal yet it somehow motivates exploration and joy. Other Lumies programs have emergent goals: one such program responds to rapid acceleration so that when a player jerks the cube, it will "fire" like a phaser gun, with sounds and lights. Further, when the axis of the jerk aligned to the direction of another Lumies block, the other block "explodes" with sound, lights and vibration. On top of this simple interaction, a connected smartphone can track "lives" lost and announce a winner. In such a way, within the constraints of the platform, the Lumies cubes can be used to play the game of "laser tag". What other interactions might they afford?

The highly constrained platform of the Lumies poses a special challenge for designers. Even though constraints can support creativity [6][52], the possible design space of games and play with Lumies is enormous. While a simple drag-and-drop application helps children program new games for the Lumies cubes, it is a major challenge to help children to imagine the new game concepts that they might wish to program. And, apart from helping children make new games, it is also a challenge to help professional designers identify new "Killer Apps" [18] for the Lumies platform.

1.2 Paper Summary

This paper shows how game design theories can be translated into a card deck that can be useful for exploring a design space. In our evaluation, we demonstrate the utility of this method for creating novel game ideas specifically for the Lumies platform. However, we seek to contribute more than an evaluation of another card deck; by showing how theory can be translated into design spaces and then into an accessible card deck format, we aim to generalize to other

platforms and other theoretical domains. In this manner, we seek to contribute to 'intermediate level knowledge' as called for in the community of CHI and play [4].

Our game design space card deck was designed to make it easy to explore different game design variations within the context of the Lumies hardware. Each card presents a specific option or variation within larger game design dimensions like "user interactions", "game pleasures" and game "themes." By randomly drawing cards from different categories, the card deck provides inspiration that can help users imagine different game design possibilities.

A card deck was chosen as the medium for design space exploration in order to 1) offer abstract theories in small, easy-to-understand bits 2) allow for random combinations that help spark creativity 3) help users start simply (e.g., with a single category of cards) then build up to a more complete idea (e.g., by involving more card categories) and 4) stimulate discussion and social exchange between participants in physical creative sessions.

Following a literature review, this paper presents a research-through-design process [21][76] involving four iterations of design and evaluation. First, we designed a practical spreadsheet-based taxonomy of game design theory in order to support ideation. Second, to make this space of possibilities more accessible, useful and social, the taxonomy was transformed into an ideation card deck. Based on feedback and observation, the deck was redesigned for experts, then for children and finally for general use. After sharing the research-through-design results, we share the results of a controlled experiment evaluating the efficacy of the design space card deck in relation to an established brainstorming method.

2 RELATED WORK

The work in this paper touches upon several connected areas in the field of design. First, it reviews design principles and evaluation theory in the domain of "creativity support tools" and then briefly describes related work with card decks for creativity. Then, it unpacks the formal notion of a "design space" and considers it in the context of game design theory. This leads us to our design research question: How might we use card decks as a creativity support tool to explore the design space of game possibilities for a new gaming platform?

2.1 Creativity and Creativity Support Tools

Starting broadly, we adopted the following definition for creativity: "Creativity is the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" [55]. This definition emphasizes novelty and usefulness but also recognizes that creativity is often a social process.
There exist many tools for supporting creativity [19]. In fact, nearly any composition tool can be conceptualized as a support for creativity [66]. An impressive set of researchers have formulated a series of "Design Principles for Tools to Support Creative Thinking" [58]. The principles below are exemplified by the work in this paper.

- Support Exploration (easy to try alternatives)
- Low Threshold, High Ceiling, and Wide Walls
- Support Many Paths and Many Styles
- Support Collaboration
- Simple as Possible - and Maybe Even Simpler
- Invent Things You Want to Use Yourself
- Design for Designers

- Iterate, Iterate - Then Iterate Again
- Evaluate Tools

What is an appropriate way to evaluate creativity support tools? Controlled studies are not necessarily the most useful way to focus evaluation; instead, researchers suggest [30] designers ask questions like: Is it better than existing practice? Have you learned how to improve this tool based on this evaluation? How does the tool influence the creative process? Does it celebrate diversity? How does this method complement others in the family of tools/techniques? The authors also suggest several outcome metrics for evaluation:

- # of unique alternatives attempted
- Time to come up with solutions
- # of people supported by the tool/process
- Quality of solutions (e.g., using scales)
- Cultural appropriateness of the tool/process
- People's acceptance of the tool over the long term
- Ease of learning

These design principles, questions and metrics help frame our rationale for using an iterative design and evaluation cycle to develop and improve upon a game design ideation tool.

2.2 Card Decks for Creativity

Cards decks are currently a popular way to support creativity, supporting everything from imagining future scenarios [10] to general idea generation [23] to learning and applying data science theory [28]. Dan Lockton's "Design with Intent" method [38] introduces a brief history of cards for "randomized provocation", covering 20th century card decks (e.g., from Marshall McLuhan and Brian Eno) as well as the ancient Chinese I Ching: an oracular method, similar to a deck of cards, that provided randomized advice about what one should do in a challenging situation.

A recent survey of card-based design tools [71] revealed diversity in the use of cards and helped describe why they may be useful. Card decks have been applied to creative development in many areas, including "lenses" for game design [61], gamification [57], Mixed Reality game design [72][14], designing for emotion [75], designing for happiness [16]and co-designing with children [67]. Many of these card decks are notable for letting users *randomly sample* variations.

2.3 A Brief History of the "Design Space"

A design space is "a space of possibilities" [43] for a design; it is a conceptual space that refers to possible variations within the dimensions or parameters of a design. The design space of a pencil might include dimensions like length, thickness, color, hardness, type of eraser, etc. and any particular pencil can be defined as a location within this space.

The concept of a multidimensional Cartesian "parameter space" was formulated by Abraham Wald around 1939 [70] and then described in 1960 by aerospace engineer Lucien Schmit Jr as a "Design Parameter Space" [65]. Several years later, his student Richard Fox provided a clear definition of a *design space*:

> "Many modern techniques for the optimum synthesis of structures are based on the concept of a design space...[where] each Cartesian coordinate axis represents a design variable, and thus a point in this space...represents a design." [18]

In 1989, the notion of a design space was brought into the field of human-computer interaction with this definition: "The design space consists of a decision space (alternative options which might be appropriate), and an evaluation space." [44] The same authors, from Xerox PARC, later introduced a formal technique for Design Space Analysis [45]. In 1991, Stuart Card *et al* famously showed the utility of a formal design space by systematically considering the morphological diversity of the design space of computer input devices [11]. Yet, by 2006 Woodbury and Burrow wrote "Whither Design Space" to lament the lack of research on design spaces; they argued that the concept had exceptional value in computational design and artificial intelligence [73]. Since then, there have been a number of different efforts to systematically consider design spaces in design, both in computer-aided settings [8][39][40] and non-computational settings [12][41][42][37]. Recent work at Aarhus University makes an explicit call for more design space thinking [26]. A design space can be defined in terms of the direct design input parameters of a design (e.g., the number of seconds set as the time limit of a game) and in the experienced outputs of a design (e.g., the overall difficulty of a game) [39]. Mary Shaw provides a particularly clear formulation of conceptual and parametric design spaces and their various representations [64].

2.4 Game Design Theory and Game Design Spaces

There are many different game design theories that include some degree of dimensional variation; this makes it possible to define a formal game design space. For instance, Macklin and Sharp describe the elements of games as: "…actions, goals, rules, objects, and playspace" [46]. Each of these elements or dimensions represent a space of variation that can be independently combined with other dimensions. Together, these game design dimensions constitute a game design space; this space can be explored through the combination of different variations to produce particular design instances. For instance, a designer might create lists of elements within each dimension and simply combine them at random: consider how variations in game actions (like "jumping" or "throwing") could combine with variations in goals (like "accumulating points" or "passing the finish line") — and how these possibilities might be further constrained or enriched through variations in playspace (like "tabletop" or "swimming pool"). "Throwing" + "accumulating points" + "tabletop" seemingly describes the existing game of Beer Pong; while "Jumping" + "Passing the finish line" + "swimming pool" seems like a novel game challenging players to leap great distances into a pool. Although some random combinations may be nonsensical, this recombinant, dimensional approach to game design illustrates how designers might explore variations within in a broader "game design space."

Notably, the above examples are scaffolded by the elements of the above game design theory. Yet, there are many game design theories that overlap. The "MDA" framework [32], for instance, is a popular theory that describes games as consisting of Mechanics, Dynamics and Aesthetics ("game pleasures"). For instance, in a first-person shooter, the mechanics may include finding weapons and shooting while the dynamics include emergent social phenomena like hiding, sniping, gunfights, raids, etc. Aesthetics in a shooting game can vary immensely: for instance, Nintendo's *Splatoon*! (2015) is a first-person-shooter framed as a collaborative painting game. The MDA game design space extends and supplements Macklin and Sharp's theoretical game design space by, for instance, including the emotional responses to the games.

Specifically, game aesthetics, or game pleasures, describe the desirable emotional responses evoked when players interact with the game system; these pleasures are listed out in MDA theory as Sensation, Fantasy, Narrative, Challenge, Fellowship, Discovery, Expression and Submission [32].

Yet, no individual theory needs to conclusively capture all aspects of game design. For instance, Jesse Schell's "The Art of Game Design: Book of Lenses" [61] provides "lenses" intended to help designers more deeply consider important aspects of new game designs. One central framework, "The Elemental Tetrad," separately considers Technology, Mechanics, Story and Aesthetics. Schell emphasizes the importance of balancing these four essential elements until they are in a harmony and working together towards a common goal. Further, he lists a set of game pleasures like Anticipation, Competition, Delight in another's misfortune, Gift giving, Humor, Possibility, Pride in an accomplishment, Surprise, Thrill, Triumph over adversity and Wonder. These pleasures overlap with and supplement the dimensions of game pleasures in the MDA framework. Therefore, rather than choosing between theoretical approaches to define our game design space, we sought to take a broad, syncretic and practical approach to distilling game theory into our game design space exploration tool. This approach is further described in section 3.1 below and in [34].

3 DESIGN GOAL: DESIGN A CARD DECK TO HELP EXPLORE THE GAME DESIGN SPACE OF LUMIES

How might we use card decks as a creativity support tool to explore the design space of game possibilities on the Lumies platform? We were motivated to help both children and professional designers consider new game designs that could work well within the limitations of the Lumies connected blocks. Just as Pac Man and Tetris anchored early home gaming [18], we wanted to discover games that could anchor the Lumies platform. We envisioned a tool that might permit users to quickly and efficiently conceptualize game and play opportunities in different areas on the basis of the interactions afforded by the platform. We pursued this vision by attempting to transform contemporary game design theory into a usable and accessible representation of game design spaces. Through the synthesis of game design theory, user testing and reflection, the direction of the project settled on the goal of producing a card deck to playfully explore the game design space of the new Lumies platform.

Not all game design theory needs to be equally useful for inspiring new game concepts—and, to be clear, it was not our goal to attempt an accurate and comprehensive coverage of game design theory. Instead, we wanted to distill popular game design theory into a useful format that supported the exploration of the affordances of Lumies. In other words, we wanted a tool to help us explore what kinds of play and game experiences were possible on the Lumies platform. Through an exploration of such game ideas, we supposed it might be possible to find "killer apps" on the new game platform.

Our iterations of design and evaluation can be characterized as applied research in a design context with the purpose of improving the effectiveness of our tool. We evaluated each iteration with different stakeholders to answer a set of guiding design research questions. Although each iteration had a somewhat different protocol, each sought to use the card deck to create new game ideas to gather insights on the obstacles and enablers of effective game design ideation. Figure 2 depicts the different iterations of the card deck and, following a description of the four iteration cycles, we provide a short summary of each cycle in Table 1.

3.1 Design Iteration 0: Designing a Taxonomy of Game Design Dimensions

Prior to creating a card deck, we created a taxonomy of different game design dimensions. To accomplish this, we assembled theoretical game design dimensions into a spreadsheet where each column represented independent dimensions. Under each column heading, we listed out all of the variants in that dimension that we could find in the literature. For instance, one column was entitled "MDA Aesthetics" and listed the MDA game pleasures such as sensation, fantasy, etc [32]. This approach was accumulative rather than systematic; we simply did our best to mine the literature for different design dimensions and variations. We found taxonomic variation in theories of play types [27], child behavior types [22] and even in lists of emotions [15] that might be elicited by game experiences.

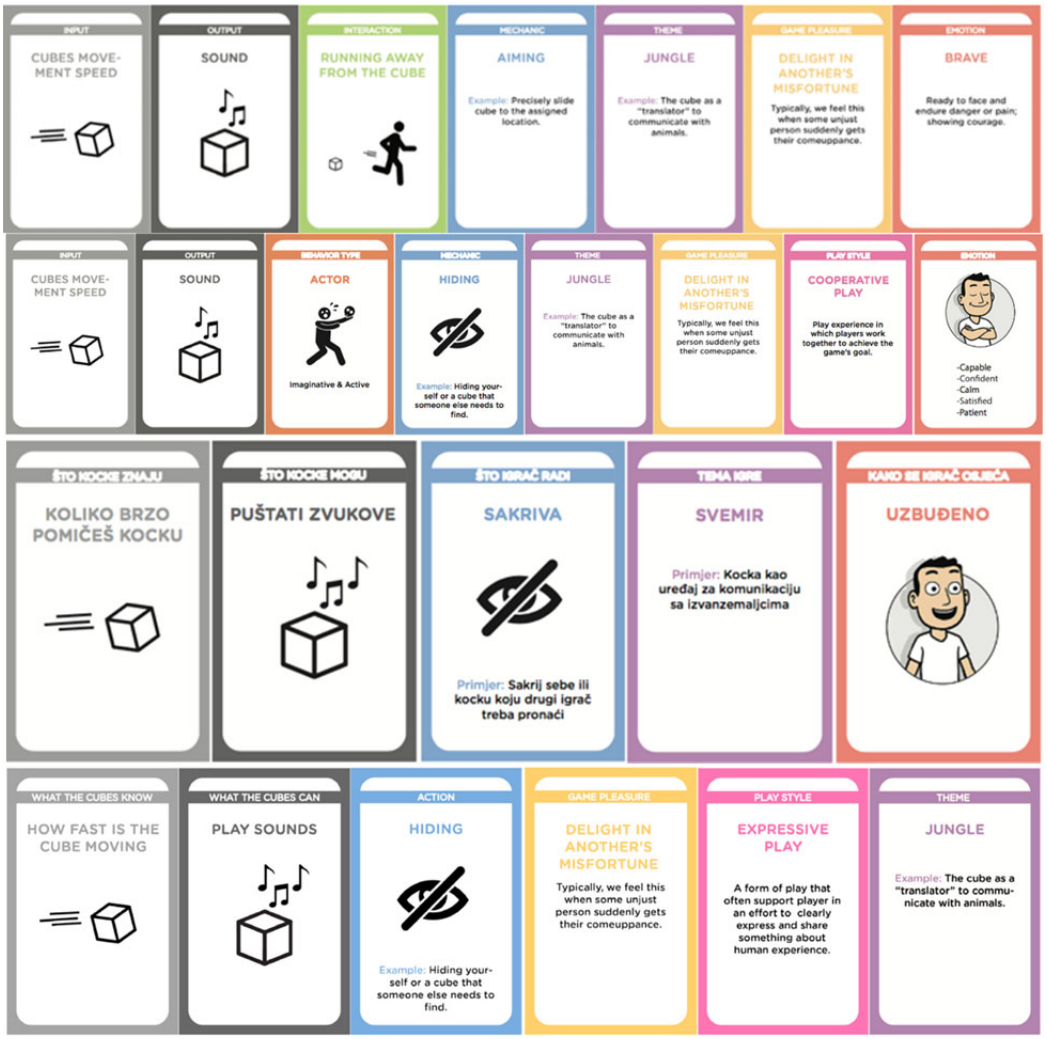

Figure 2: Each row represents a design iteration of the card deck. In each row, we show one example card for each category in the iteration. A complete set of categories and parameters can be found in the appendix.

We sought breadth and clarity over theoretical alignment; for instance, in listing out elements of "reward", we avoided the theoretical language of "Access, Facility, Sustenance, Glory, Sensory Feedback and Positive Feedback" [53] and instead listed more concrete elements like "praise, points, powers, resources, …". The rationale for this choice was that we wanted to distil the theoretical variations into a useful tool—and we felt that it would be easier to imagine how "points" could be applied to a game rather than the theoretical category of "glory." We also didn't limit ourselves to theoretical sources; for instance, we assembled lists of game themes and genres using online sources describing various types of board games, video games, card games, etc. Our spreadsheet also represented the concrete sensors and actuators of the Lumies cubes—that is, what the Lumies could sense (e.g., rotation) and how the Lumies could respond (e.g., vibration). In the end, our spreadsheet contained over 30 columns documenting different game design dimensions and their variants. A more detailed discussion of the taxonomy and its construction is available [34].

3.1.1 Iteration 0 Evaluation

After preparing the game design space taxonomy, we began game concept ideation. In our own experience, we found it relatively easy to look over different cells in the spreadsheet and imagine new game design ideas. In this manner, over several days, we created 37 new game concepts using the spreadsheet taxonomy. These new concepts were developed to explore the diversity of game designs and thus drew from almost all of the different dimensions in the spreadsheet.

3.2 Iteration 1: A Design Space Card Deck for Game Ideation

While this spreadsheet of game design dimensions helped us generate diverse games ideas, we felt it was too dull and complicated to be used by children. Though we considered the possibility of a digital tool for randomly exploring different design dimensions, we decided to focus on a physical card deck because it seemed fun (one could play with the cards), social (cards could be laid out on a table for use with others) and because it would be easy to represent different dimensions as categories of cards (e.g., the back of a card shows the dimension and the front shows a specific element in that dimension). During the creation of the physical card deck, we greatly reduced the total number of dimensions so we could focus on the ones that we found most useful during our initial ideation.

Cardboard playing cards were printed with the following game design dimensions/categories: Lumies Input (7 cards), Lumies Output (3 cards), Interaction (11 cards), Mechanics (35 cards), Theme (40 cards), Game Pleasures (22 cards) and Game Emotions (78 cards). The cards were designed based on a simple template. The front of each card provided the name of card category, the name of a specific card and the explanation of it. Each card category was designed in a different color to make them distinctive and easier to use. When possible, the cards provided examples or illustrations to support immediate explanation.

We also defined a set of game rules for using the cards. At the start, each player would receive one card from each of the five categories. One card would then be randomly placed between the players as a starting card. On their turn, each player then placed a card from their hand next to the cards that were already displayed in the middle. Each additional card thus added one more constraint to the ideation.

3.2.1 Guiding Design Research Questions

To evaluate and develop the cards, we defined the following design research question: "how might Design Space Cards be used to help generate new and useful game concepts?" To support our iterative evaluation, we defined a number of other practical questions related to the usability and experience of the cards. These questions included: How do participants use the cards to create new designs? Do participants find the cards easy to use? Were the game rules useful and could they be improved? Are the participants able to understand platform possibilities and limitations from the card set? Which card category was used most often to start the idea? Which categories do participants consider to be more or less useful for game ideation? How many cards did the participant combine in order to get to a good concept?

3.2.2 Iteration 1 Evaluation (Design for Designers)

The first session was conducted with 6 participants, all master's students at TU Delft. Participants' ages ranged from 24 to 32 years. There were three male and three female participants. The group was also diverse in nationalities: one Dutch, one German, one Mexican, one Chinese and two Croatian participants. The overall session lasted 1.5h, out of which 30 min was spent on presentation of the project and explanation of the upcoming session. This left one hour for ideating and documenting the game concepts.

During this session, the participants used the cards to play the ideation game described above. In general, the rules worked smoothly. The session resulted in about 50 game concepts, out of which 19 were new and fully usable game concepts. All participants were able to use the deck after a short demonstration and explanations. Many participants first focused on the input and output cards until they understood the cubes and then shifted to other categories to gain inspiration. In most cases, participants were able to iterate on each other's ideas after just a couple of seconds of thought. Participants agreed that they usually combined two to three cards and that this was enough to generate an idea. Having more than three or four cards in combination often caused frustration: the game concepts became too complicated to satisfy the requirements on active cards.

Participants were asked to rank the card categories from the one that they considered most inspiring to the one that they consider the least inspiring. Overall, with very small differences in the scores, mechanics were ranked as the most inspiring category, while Emotions and Game Pleasures ranked lowest. There was also a comment that the number of Emotion cards (78) was overwhelming— it took too much time to read them all.

Figure 3: Using cards (left) during a creative session to generate game ideas (middle). Combinations of cards were used to imagine potential games (right), for instance: "A roaring lion cube tries to find a hidden cube that sounds like a sheep"

3.3 Iteration 2: A Design Space Card Deck for Game Ideation

Our second iteration added two additional categories of cards: behavior type and play style. It also combined the 11 interaction cards into the mechanic category. Apart from this, the main

change was in the rules for the design of the ideation game. Now, at the start of the game, each player received one card from each of five categories (mechanic, theme, game pleasure, emotion, and play style). The small number of behavior type cards and the Input and Output cards were kept on the side for referencing. At the start of each turn, a new Behavior type card was revealed to replace the previously active one. When it was their turn, each player needed to play a card from his/her hand next to the cards that were already displayed in the middle and say a game concept that incorporated all the cards that were currently displayed. Thus, the challenge was to come up with a new game concept that contained the "ingredients" from the active cards.

3.3.1 Iteration 2 Evaluation

Participants were four members of the Lumies team: two cofounders, UI/UX designer and an operations assistant. The session lasted about 1 hour and was executed in the form of the card game described above. In the first couple of rounds, leader facilitation was essential. At the beginning of a turn, participants asked what cards they should use this turn, or whether they were supposed to build on the existing idea or come up with the fresh concept. It turned out to be effective to introduce and test one category of cards at a time, to make sure participants did not get overwhelmed by the number of cards and options. Approximately 10 novel game concepts were developed, each with multiple iterations based on the addition of each new card.

We were initially concerned that illustrations on the game mechanic cards would push participants to imagine mechanics only according to the illustration. However, we found that participants often came up with original views and associations that differed from the illustrations on the cards. On the other hand, the Behavior Type cards were not so clear at the start—a short discussion was required for all the participants to grasp how these cards worked. On the other hand, the Play Styles were clear — participants easily integrated cards from this category into the game concepts. Adding new play styles (like cooperative play or competitive play) often made the existing game concepts more concrete and interesting.

3.4 Iteration 3: A Card Deck for Game Ideation with Children.

Another iteration of the card deck was then generated to support the needs of Croatian children (7+). Based on input from the participants, we decided to rename several categories of the cards: "Theme" became "Game Theme", "Inputs" became "What the cubes know" and "Outputs" became "What the cubes can do", "Emotion" became "What the player feels" and the mechanics category became "Action"). Further, all cards were translated into Croatian. While some of these changes may diminish fidelity to game theory, we wanted to prioritize making the cards clear and easy to use. Our goal was to understand if children would be able to use the card deck in similar ways as professional designers. For this iteration, we also dramatically reduced the complexity of the brainstorming rules, as described below.

3.4.1 Iteration 3 Evaluation.

To test the updated deck, we conducted two sessions with different groups of children. The first group consisted of 4 children: an 11-year-old boy, a 7-year-old girl and two 12- year-old girls. The second group consisted of 5 children: an 8-year-old girl, a 9-year-old boy, a 10-year-old girl, a 12-year-old boy and a 12-year-old girl. Each session lasted for about 30-45 minutes and took place right after the group playtested four existing Lumies games using the prototype of the

cubes. It was decided to have them do the playtest before the ideation session so they would be familiarized with the actual product.

We dramatically simplified the rules of the ideation game in the following manner. To prompt ideas, one "Action" card (formerly "mechanics") was opened at a time and the children were asked to come up with a game concept for that included the element written on the card. For instance, "Can you tell me a game idea that includes 'Guessing' and could be played with the cubes?" The child who got the idea first started explaining his concepts while others often interrupted, trying to add something to the concept. After several rounds, we switched to the category "Theme", again pulling one card at a time. "Can you think of the game that is somehow connected to the theme "Wizards" and can be played with these cubes?" The third category to test in this single-card setup was "Emotion": "Can you think of a game that makes you feel curious?"

At one point during the ideation with emotion cards, one of the girls asked: "Can we combine multiple cards to get ideas?" Up to that point, it had seemed likely that the combination of more cards might be overwhelming and confusing for the children, so it was a pleasant surprise when they proposed it themselves. We played around with the order: e.g., in the order of Mechanic→Theme→Emotion or Theme→Emotion→Mechanic?

In about an hour, the children produced about 15 different game ideas. Ideation based on a single card went very smoothly. Children were able to think of at least one concept for every card that was tried out, although some concepts were a bit vague and underdefined. The Action category seemed the most likely to be transformed into workable game concepts. While ideating based on a Theme card, in most cases children approached it by first thinking of game scenario, players' roles and some other rules— only after that did they try to incorporate the Lumies cube and different interactions in the concept. This resulted in game concepts in which the cubes often did not have a significant role or were incorporated as an inessential addition to games that could also be played without the cubes. In the ideation based on Emotion, some of the cards instantly evoked a direct game concept, while with some cards the children responded just with a general direction in how that emotion could be achieved in a game.

Table 1: Overview of the evolution of the card deck over four iterations.

Iteration	User group	Included dimensions / changed applied
Iteration 1	Design students	Input, output, interaction, mechanic, theme, game pleasure, emotion
Iteration 2	Expert team at company	Interactions dimension was folded into mechanics, the emotion cards were illustrated, and two new categories were added: play style and play behavior type
Iteration 3	Children aged 7-12 in Croatia	Input, output and mechanics were renamed "what the cubes know", "what the cubes can do" and cards were translated to Croatian. Play styles, play behavior types and game pleasures were removed for simplicity; the emotion cards were reduced from 33 to 12.
Iteration 4	Design students	The emotion cards were removed altogether, mechanics was renamed to "action", and game pleasure, play style, and play behavior types were added back in.
Resulting final format		A total of 113 cards in 6 dimensions: "What the Cubes Know" (10 cards), "What the Cubes Can Do" (3 cards), "Action" (33 cards), "Theme" (35 cards), "Game Pleasures" (22 cards), "Play Styles" (10 cards)

The children were able to combine cards to create a new game concept with minimal guidance. When all three assigned cards were displayed together from the start, the children started ideation based on whichever card evoked some sort of idea; they then used the remaining to cards to build on that concept. Their base concepts typically started with the Mechanics category card, sometimes from the Theme cards but almost never from the Emotion cards. However, in most cases, children were able to find a place for the assigned emotions in their concepts without much effort. When revealing cards one-by-one, where participants needed to iterate on their concepts after each card was revealed, the most promising outcomes came from the sequence Mechanics→Theme→Emotion.

4 EXPERIMENTAL COMPARISON WITH DIRECTED BRAINSTORMING

These design iterations clearly showed that the ideation cards were effective for generating game ideas. But how effective? In order to quantify the effectiveness of the ideation cards, we decided to compare the cards to an established high-efficacy method for brainstorming known as "directed brainstorming" [9]. Directed brainstorming involves determining the important aspects of the problem and then writing a series of directing prompts based on these aspects. Using these prompts, participants create ideas which they then pass on to others. This method allows participants to think of new solutions based on other participants' ideas. Directed brainstorming is known to produce a large quantity of ideas, even in comparison with other creativity methods [59]. In our experiment, we only compared the *quantity* of ideas generated by each method not the quality of the ideas. While this approach is obviously limited, it is a typical approach in many studies of creativity [63] because a high quantity of ideas is considered a valid indication of creativity—it is usually a prerequisite for achieving creative combinations that lead to quality.

The design space cards also received a fourth and final iteration. The deck now consisted of 113 cards in 6 categories: "What the Cubes Know" (10 cards), "What the Cubes Can Do" (3 cards), "Action" (33 cards), "Theme" (35 cards), "Game Pleasures" (22 cards) and "Play Styles" (10 cards).

4.1.1 Participants.

12 participants were recruited from an Industrial Design Engineering bachelor program (2018-2019). To make the groups comparable, we only recruited first year students. Each student was randomly assigned to one of four groups (each with three students). 10 out of 12 said they had used the directed brainstorming while only 2 out of 12 said they used some type of ideation cards before. Group 1 and Group 3 started with the ideation cards while Group 2 and 4 started with directed brainstorming.

4.1.2 General Procedure.

An empty studio was used to host the design sessions. Groups 1 and 2 began with an introduction to Lumies and a video explaining the product. They then received an explanation of the use of the ideation cards and the directed brainstorming method. They were told that the goal in both sessions was to come up with as many game design ideas as possible. Each group used their respective method for 15 minutes before being stopped and asked to switch. When the first two groups finished their session we asked them to fill in a single-item questionnaire about their desire to use each method again (0-10 scale, from "I do not want to use this method in the future" to "I want to use this method in the future") and to rank the cards in order of their

usefulness during the session. Following the rating questionnaire and card ranking, then we continued hosting the next session with two new groups.

Ideation Card Deck Procedure. During ideation with the card deck, the different categories of cards were neatly placed on the table. Participants were told they could use the cards however they wanted. The only restriction was that they should keep the "what the cards can do" visible at all times. They were encouraged to discuss with each other but to write their own ideas on their own personally colored post-its.

Directed Brainstorming Procedure. During the directed brainstorming session, each participant was given an A3 paper sheet and a colored pen. They were told not to talk to one another during the session. These participants were first given time to write down as many ideas as possible. After 5 minutes, each participant passed their sheet to the participant on their left. They were then directed to write down ideas according to a list of prompts developed by the researchers (see appendix). Each participant had one minute to reflect on the other person's game ideas and make additions based on the criteria. After one minute the sheets were passed on again and the next prompt was given (e.g., "Make the games more competitive"). This continued until all prompts were given.

Figure 4: An image of the ideation session during the use of the design space cards.

4.2 Results

Even with just 12 participants across four groups, it was clear that significantly more ideas were generated by the directed brainstorming method (M=98.5 sd=30.1) than with the ideation cards method (M=48.5 sd=15) (p=0.044 t(3)= -3.349). Yet, the mean participant rating for ideation cards was slightly higher (M=7.5, sd=.66) than for directed brainstorming (M=7.3, sd=.97), an insignificant difference (p=0.50, t(11)=0.699). The results for each group's ranking of the usefulness of each card category is shown in figure 5.

Table 1: Counts of the number of game ideas generated by four different groups using different design methods. An asterisk (*) is used to indicate the first method that was used by each group.

	Group 1	Group 2	Group 3	Group 4
Design Space Cards	48*	63	32*	31
Directed Brainstorming	117	95*	125	56*

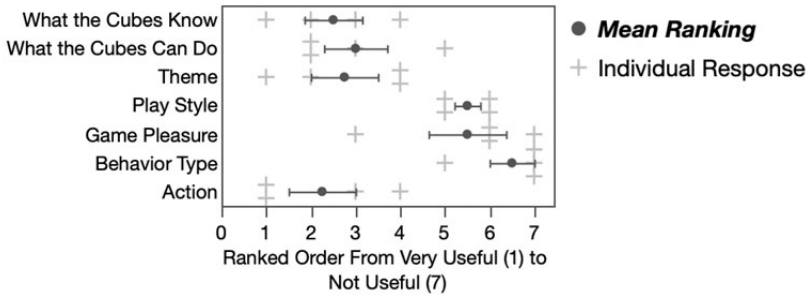

Figure 5: Ranking data indicate that all groups found the Cube Properties ("what the cubes know" and "what the cubes can do"), Theme and Action Examples more useful for ideation than categories showing Play Styles, Game Pleasures and Play Behavior Type.

5 DISCUSSION

The major contribution of the paper is an illustration of how game design theory can be distilled into playing cards that can make game design ideation more accessible to design novices and to children, particularly in the context of participatory or co-design work. The medium of a card deck was used as a low-cost and tangible mechanism for translating a set of game design theory into an accessible, fun and effective design tool.

This paper used a research-through design method to develop the card deck. We found that participants were easily able to create new ideas through game-like rules but that that the card decks were useful even in the absence of defined game rules; participants could simply play around with different combinations of random cards to discover new and interesting combinations. Even a single card could be used to generate a game idea but additional cards could provide further constraint and richness. The cards helped participants keep the platform limitations and possibilities in mind, although children were more likely to come up with game designs that ignored the constraints of the cubes. The mechanics or action card category seemed to be the most useful category for initiating a new idea.

We made a number of changes to the deck over multiple iterations. We changed around the rules of play, modified and illustrated different elements and even renamed theoretical categories. Our goal was not to synthesize game design theory with fidelity but rather to make a useful activity based on theory. Indeed, the activity was found to be useful by a diverse set of participants: multi-ethnic Dutch design students, Croatian children 7-12 and Smart Lumies company employees. While our controlled experiment showed that the method of directed brainstorming could produce ideas at a significantly faster rate, participants were just as likely to want to use the design space card deck during future design work.

Our contributions include demonstrating that a game design space card deck can serve as a creativity support tool for children, design novices and experts. We have shown that, by embodying a variety of game and play theory/frameworks in a design card set, both children and professionals could navigate the design space for interactive tangible games.

Our work has several limitations. We chose not to adhere strictly to the technical terms of existing game theory, although it may be useful to do so in the future. Further, we were not systematic in choosing which dimensions to add or drop—this was done on the basis of intuition and participant feedback. It should be further noted that Lumies is a very simple platform with limited technical capacities and it is unclear whether the cards will be useful in a more complex game design situation. For a different hardware platform with different input and output

affordances, new cards would need to be developed. Such a tool may need new categories and elements that are more relevant to the functional capacities of the game platform.

Generally speaking, we do not propose that the current card deck be adopted as a solution to conquer any interactive game design space. Rather, we suggest that designers may find it useful to create their own design space cards based on the dimensions relevant to their goals and theoretical interests. That said, we welcome use of the full printable deck [34].

Future work should investigate similar design-space-meets-card-deck approaches for other game platforms and broader design contexts outside of gaming. Evaluations of future design space exploration tools may find it useful to rate the usefulness and enjoyability of the different dimensions or elements. Further, measures of novelty, quality and relevance of the generated ideas should be added to the assessment of creativity as a complement to the count of the number of ideas. Finally, by collecting data during product engagement, it may be possible to use behavioral data and artificial intelligence to systematically optimize a design space [40].

6 CONCLUSION

This paper presents an approach to transforming a theoretical design space into a tangible card deck. This approach proved useful for generating new game design ideas for a novel game platform. Through iterative design and evaluation, we developed design space cards to help experts and children creatively generate new game design ideas for Lumies, a connected block toy. Our design space cards enabled players to randomly sample a theoretical game design space to efficiently explore variations of the dimensions of a game's design. We demonstrate the utility and limitations of this approach using evidence from a research-through-design process and a controlled study. This work illustrates an iterative design method for transforming complex theory into a low-cost tangible creativity support tool.

While our work on this design space card deck is specific to the game platform Lumies, the notion of a design space is generalizable to any design [43]. We expect that other large design spaces can be made accessible and fun for designers to explore through the production of similar ideation card decks. Our work serves as 'proof of principle' that a tangible card deck can make abstract multi-dimensional theory accessible for designers and even for young children.

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A APPENDICES

A.1 *Final Card Deck.* The final card deck was revised to represent the following categories and elements. Images are shown of each. The complete deck is available in **[34]**

Actions (Mechanics): Hiding, Shooting, Building, Guessing, Growing, Powering Up, Unlocking, Distracting, Doing Something Funny, Doing Something Scary, Looking For Something Or Someone, Choosing, Changing Roles, Convincing, Dodging, Escaping, Running, Negotiating, Running, Shaming, Fighting, Measuring, Training, Navigating, Aiming, Jumping, Touching, Throwing, Observing, Running Away, Racing, Driving, Distracting.

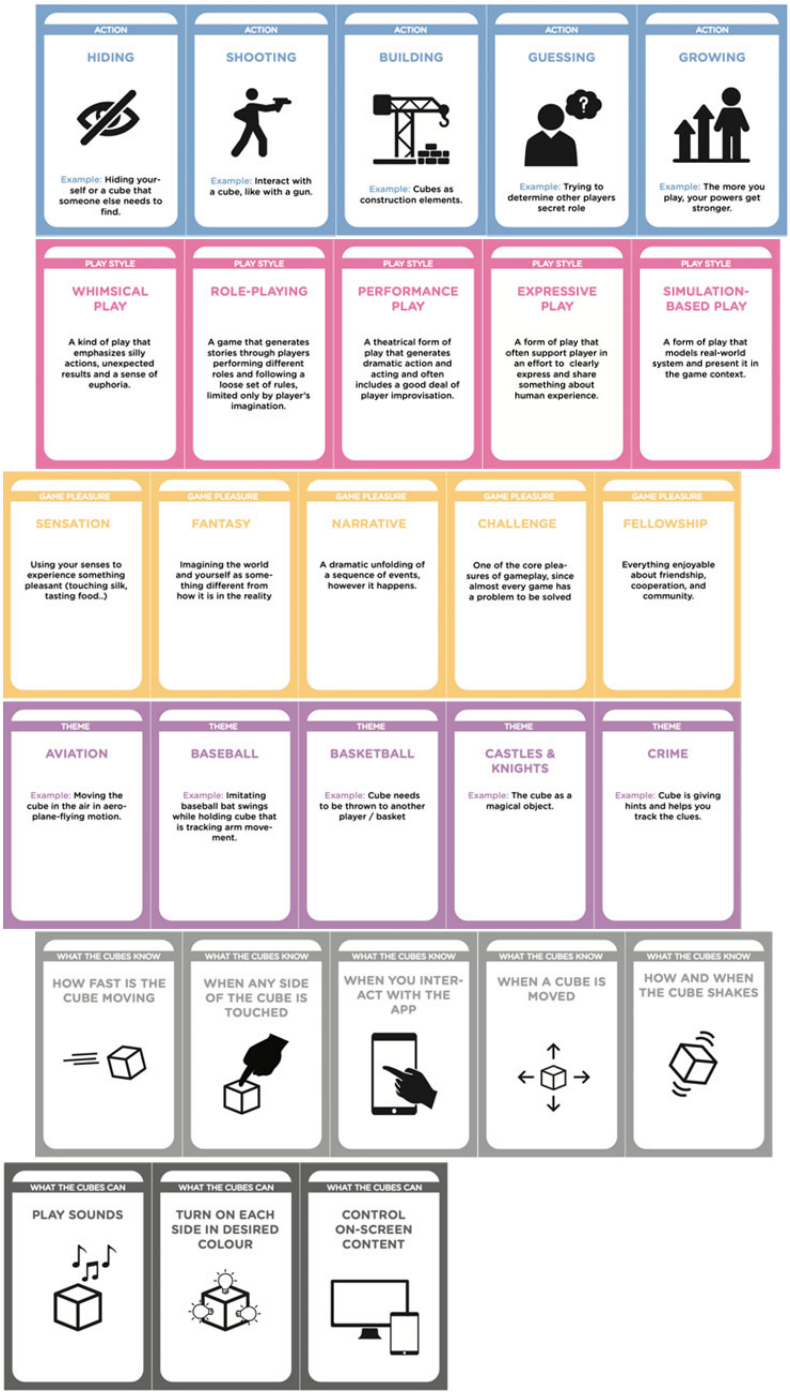
Play Styles (Dynamics): Competitive Play, Cooperative Play, Skill-Based Play, Experience Based Play, Games Of Chance, Whimsical Play, Role-Playing, Performance Play, Expressive Play, Simulation Based Play

Game Pleasures (Aesthetics): Sensation, Fantasy, Narrative, Challenge, Fellowship, Expression /Creation, Submission, Discovery / Exploration, Anticipation, Completion, Delight In Another's Misfortune, Gift Giving, Humor, Possibility, Pride In An Accomplishment, Surprise, Thrill, Triumph Over Adversity, Wonder, Mastery, Competition, Destruction

Game Themes (Story): Space, Under Water, War, Sports, Car Racing, Aviation, Baseball, Basketball, Castles & Knights, Crime, Dinosaurs, Laboratory, Food & Beverage, History, Math, Jungle, Medical, Music, Pac-Man, Art, Spy, Tennis, Space Police, Robots, Party Games, Quiz, Theatre, Rhythm & Dance, Wizards, Martial Arts, Super Heroes, Science, Animals, Monsters, Time Travel

What the Cube Knows (Input): How Far Are the Cubes From One Another, Angle Between the Cubes, How the Cube Is Rotated, How Far Is the Cube From the Phone/Tablet, How the Cube Is Orientated, How Fast Is the Cube Moving, When Any Side of the Cube Is Touched, When You Interact with the App, When a Cube Is Moved, How and When the Cube Shakes

What the Cube Can Do (Output): Play Sounds, Turn On Each Side In Desired Color, Control On-Screen Content


ACTION
HIDING
Example: Hiding yourself or a cube that someone else needs to find.
ACTION
SHOOTING
Example: Interact with a cube, like with a gun.
ACTION
BUILDING
Example: Cubes as construction elements.
ACTION
GUESSING
Example: Trying to determine other players secret role
ACTION
GROWING
Example: The more you play, your powers get stronger.
PLAY STYLE
WHIMSICAL PLAY
A kind of play that emphasizes silly actions, unexpected results and a sense of euphoria.
PLAY STYLE
ROLE-PLAYING
A game that generates stories through players performing different roles and following a loose set of rules, limited only by player's imagination.
PLAY STYLE
PERFORMANCE PLAY
A theatrical form of play that generates dramatic action and acting and often includes a good deal of player improvisation.
PLAY STYLE
EXPRESSIVE PLAY
A form of play that often support player in an effort to clearly express and share something about human experience.
PLAY STYLE
SIMULATION-BASED PLAY
A form of play that models real-world system and present it in the game context.
GAME PLEASURE
SENSATION
Using your senses to experience something pleasant (touching silk, tasting food...)
GAME PLEASURE
FANTASY
Imagining the world and yourself as something different from how it is in the reality
GAME PLEASURE
NARRATIVE
A dramatic unfolding of a sequence of events, however it happens.
GAME PLEASURE
CHALLENGE
One of the core pleasures of gameplay, since almost every game has a problem to be solved
GAME PLEASURE
FELLOWSHIP
Everything enjoyable about friendship, cooperation, and community.
THEME
AVIATION
Example: Moving the cube in the air in aeroplane-flying motion.
THEME
BASEBALL
Example: Imitating baseball bat swings while holding cube that is tracking arm movement.
THEME
BASKETBALL
Example: Cube needs to be thrown to another player / basket
THEME
CASTLES & KNIGHTS
Example: The cube as a magical object.
THEME
CRIME
Example: Cube is giving hints and helps you track the clues.
WHAT THE CUBES KNOW
HOW FAST IS THE CUBE MOVING
WHAT THE CUBES KNOW
WHEN ANY SIDE OF THE CUBE IS TOUCHED
WHAT THE CUBES KNOW
WHEN YOU INTERACT WITH THE APP
WHAT THE CUBES KNOW
WHEN A CUBE IS MOVED
WHAT THE CUBES KNOW
HOW AND WHEN THE CUBE SHAKES
WHAT THE CUBES CAN
PLAY SOUNDS
WHAT THE CUBES CAN
TURN ON EACH SIDE IN DESIRED COLOUR
WHAT THE CUBES CAN
CONTROL ON-SCREEN CONTENT

A.2 Directed Brainstorming criteria:

1. "Give the games a stronger theme (put the games in a certain context or combine it with an already acknowledged game)."
2. "Make the games more competitive. "
3. "Make the games playable with more people. "
4. "Make the games playable in the pool. "
5. "Make the games playable in the dark. "
6. "Implement throwing the cubes into the games. "
7. "Implement a chair into the games. "
8. "Implement a playing field into the games. "

A.3 Example Games

"Intruder" : At the start of the game, players stand in a circle, each holding a cube. Cubes will start blinking to signal the start of the game and give players 5 sec to run away in different directions. One player's cube will temporarily turn red and is marked as an active target. While the player is holding the red cube, he needs to run away from all the other players because if one of the players manage to approach him, he will be out of the game, and a "kill" point will be given to the player who caught him. Red light jumps between the players for the random duration in a random pattern and marks who is an active target that can be caught. If more players are involved, there can be 2 active targets at the same time.

- **Goal:** To avoid being caught, and to catch as many other players as possible.
- **Players:** 3+, 1 cube per player
- Theme: Spy
- **Action:** Catching, Chasing, Running, Escaping
- **Play styles:** Competitive play, Cooperative play
- **Type of play:** Movement play, Success and team play
- Behaviour type: Achiever
- **Game pleasures:** Thrill, Triumph over adversity, Delight in another's misfortune
- **Emotions:** Energetic, Alert, Dynamic
- **Input:** Magnetometer
- Output: Lights
- **Screen:** Start the game **&** Keep track of the score

"Curling": The game is a simple adaptation of "Curling" sport. Like in Curling, a player needs to slide his cube over the floor / flat surface and get it to stop as close as possible to the "checkpoint" cube. The distance will be registered in the app score spreadsheet. The game can be played in multiple rounds, with as many players as you like.

- **Goal:** To slide your cube closer to the checkpoint as possible
- **Players:** 1+, at least 2 cubes
- **Theme:** Sports game adaptation
- **Mechanics:** Aiming, Sliding
- **Play styles:** Skill based play, Competitive play
- Behaviour type: Achiever
- **Game pleasures:** Mastery, Competition, Triumph over adversity

- **Emotions:** Focused, Progressive, Systematic
- **Input:** Magnetometer
- Output: Lights
- **Screen:** Start the game **&** Keep track of the score

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