deformTable: *A Design Inquiry and Long-Term Field Study into Creative and Contingent Appropriations of a Shape-Changing Artifact*

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In this paper, we propose that a materiality approach can sustain creative and contingent appropriations of a particular shape-changing artifact in everyday settings over time. We support this proposal by designing and deploying five deformTables to five households for approximately one year to gather empirical insights. deformTable is a shape-changing artifact that can go up with the change in weight or pressure applied to its top surface. Findings suggest that participants adopted the shape-changing artifact for routine exercises and ludic purposes in the early months of living with deformTable. Some further decorated the shape-changing interface with tools in their homes, while others sketched and performed music with deformTable. Over time, deformTable provoked rich experiences of creative actions across different homes. Reflecting on these empirical findings contributes implications for further explorations on designing for ludic appropriation, individual improvisation, and shape-changing interfaces to be shaped through use.

Keywords **–** Shape Change, Appropriation, Improvisation, The Materiality of Interaction, Research through Design.

Relevance to Design Practice **–** This paper offers an exemplar of adopting the concept of the Materiality of Interaction as a frame to support long-term appropriations of a shape-changing artifact. It contributes practical insights such as implicit manipulability and resourcefulness to promote further implementations of computational and dynamic physical forms.

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Introduction

Design researchers and practitioners have had a growing interest in crafting unique shape-changing artifacts to support novel interactions and experiences over the past two decades (Alexander et al., 2018; Qamar et al., 2018; Rasmussen et al., 2012). They have created many unique morphing materials (Yao et al., 2013, 2015) and installations (Fortin et al., 2014; Kan et al., 2017; Ludwig et al., 2019) to explore design opportunities of shape change. As these novel objects were crafted to enhance the interactivity of computing (Roudaut et al., 2013, 2016) and augment the communication of information (Haulrik et al., 2017), design researchers have conducted short-term user experiments to evaluate the designed qualities of shape-changing devices (Gomes et al., 2013; Ramakers et al., 2014; Robinson et al., 2016; Schorr & Okamura, 2017). However, most of these studies were initiated to test in-situ shape change per se.

The rapid emergence of these artifacts in everyday settings may pose challenges to the design research community. As computing pervades everyday lives (Bødker, 2006), users may not intend to interact with a shape-changing artifact in a predefined way. They may creatively appropriate the shape-changing artifact to meet individual needs in their everyday routines (Wakkary & Maestri, 2007, 2008). The accumulation of their ongoing creative actions may transform the manifestation of the shape-changing artifact (McCarthy & Wright, 2004). Therefore, Rasmussen et al. (2012) have been encouraged to adopt design-oriented approaches to blend shape-changing artifacts into people's everyday lives in a unique way. More specifically, Alexander et al. (2018) suggested exploring long-term appropriations of shape-changing artifacts.

Along these lines of inquiry, we propose that a materiality approach can frame creative and contingent appropriations of a shape-changing artifact in everyday settings over time. As the notion of the Materiality of Interaction has been suggested as an approach to address the challenges of the form aspects of interaction (Wiberg, 2018), there might be an opportunity to adopt this approach to inform the design implementation of a dynamic physical form. In this paper, we ask, how the experience of ongoing appropriations and improvised intentions can be better supported through the design of a particular shape-changing artifact. And, how the Materiality of Interaction, as a novel

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approach for form-oriented interaction, can catalyze ongoing interactions, intersections, and entanglements with the designed dynamic physical form in the context of everyday.

To explore these questions, we designed the *deformTable*, a shape-changing artifact that can linearly change its dynamic physical form. deformTable is highlighted by a counterfactual feature: it can go up with the increase of weights applied on the table surface, and vice versa. The input interface of deformTable is a load cell, which can detect weights or equivalent pressures ranging from 0 kg to 5 kg. The output device of the deformTable is a linear actuator, which can linearly deform a piece of white-coloured spandex upholstered with the form enclosure. The table surface and the base of the deformTable were crafted with solid wood. With the programmed digital materials and fabricated physical parts, we batch produced five deformTables as shape-changing resources for this long-term field study.

We deployed deformTables to five households simultaneously for approximately one year (see Figure 1). The findings reveal that the materiality approach successfully provoked participants to adopt deformTables with different intentions and adapt deformTable with surrounding materials in their homes. They initially triggered the dynamic physical form in-situ in the early weeks of living with deformTable. Their incremental interactions with deformTable suggested how they adopted a shape-changing resource to meet routine activities and ludic purposes. Tensions emerged when they were intended to adapt deformTable to meet individual purposes with resources in their homes. However, utilizing the temporal expressions as resources helped them to address the challenges of sketching on and decorating deformTable. The accumulation of these interactions dynamically transformed the originally designed dynamic physical form and successfully blend the deformTable into the background of their homes.

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Figure 1. Participant Daniel-H4's cat Cocona standing on deformTable to lift her up.

This paper makes two main contributions to facilitate design-oriented research and practices: Firstly, it contributes a case to reveal how the notion of the Materiality of Interaction can nurture ongoing appropriations of a shape-changing artifact for diverse individual purposes across different homes. Secondly, it offers a long-term field study to unpack how participants accepted a shape-changing artifact that has been adapted by themselves with materials in their own contexts. Next, we will discuss the related work of the study to frame the field study of deformTable.

Background

The theoretical background of this paper consists of three sections: empirical studies on shape-changing artifacts, appropriation and design, as well as the materiality of a dynamic physical form.

Empirical Studies on Shape-Changing Artifacts

Shape change refers to the physical change of shape or materiality as input or output of computing (Rasmussen et al., 2012). Over the past decades, design researchers have conducted in-situ user experiments to explore the controllability and interactivity of shape changes (Burstyn et al., 2016; Steimle et al., 2013). Some aimed to test the accuracy of manipulating shape-changing mobile objects (Robinson et al., 2016). For instance, Lo & Girouard (2017) invited 12 participants to rate the controllability of a mobile game device. To investigate users' innate abilities to interact with shape-changing interfaces (Lee et al., 2010; Ramakers et al., 2014), design researchers have employed participants to manipulate newly crafted shape-changing bottoms (Harrison & Hudson, 2009), toys (Follmer & Ishii, 2012), fingertip skin (Schorr & Okamura, 2017), musical instruments (Troiano et al., 2015), and origami artifacts (Niiyama et al., 2015). With these foundations, Vallgårda et al. (2015) invited domain experts to freely control temporal form installations, which refers to dynamic movements on shape-changing interfaces. Findings suggest that the temporal form can trigger richer experiences than the static form.

In addition to designing shape-changing artifacts for supporting novel interactions in-situ, design researchers were motivated to investigate situated experiences of shape change in the wild. Grönvall et al. (2014) deployed coMotion to a hall foyer, an airport hall, and a shopping mall for five days to explore how a shape-changing bench may affect social behaviors. Park and colleagues (2015) explored how Bendi, a shape-changing mobile phone, can enhance visual-tactile conversations in a coffee shop for three days. Furthermore, Everitt and other researchers (2016) designed ShapeCancas to explore users' novice behaviors with shape change over 2.5 days in a café. Like these studies, design researchers have discussed the materiality of shape-changing interfaces by applying them to architectures and games (Green, 2016; Walz & Deterding, 2015). With these foundations, there are growing calls to investigate shape-changing artifacts by conducting long-term field studies that collect rich empirical data on use (Alexander et al., 2013, 2018). For example, Rasmussen et al. (2012) claimed it is still unknown how use context may impact the performance of and preference for shape-changing interfaces.

To tackle this issue, they encourage design researchers to explore shape-changing artifacts by utilizing design-oriented approaches (Rasmussen et al., 2012). While recent research has explored the lived experience with a deformable lamp for around two months (Zhong et al., 2020), more work is needed to investigate how people might creatively adopt and adapt shape-changing artifacts to meet improvised and individual intentions. Our work aims to explicitly contribute to this underexplored area by conducting a long-term field study of deformTable.

Appropriation and Design

Appropriation describes how digital artifacts are adopted and adapted to unintended uses that are not envisioned by designers (Dix, 2007; Dourish, 2003). Considering users' ongoing maintenance and reuse of interactive artifacts may pose challenges to sustainability (Huh et al., 2010), researchers have been encouraged to investigate how users may appropriate design artifacts over periods (Salovaara et al., 2011). Findings suggest that appropriation can foster long-term communications (Krischkowsky et al., 2015) and collaborations (Muller et al., 2016) among the team, group, and community members. To facilitate design implementations, researchers have asked to develop theoretical and conceptual notions to connect user studies and design (Belin & Prié, 2012; Salovaara et al., 2011). To address this challenge, Derboven et al. (2016) proposed a semiotic approach to reveal how technologies can mediate appropriation in use.

On the practical level, another thread of investigating appropriation was the research on *everyday design* (Karana et al., 2020; Kim & Lee, 2014; Tanenbaum et al., 2012; Wakkary & Maestri, 2007; Wakkary & Tanenbaum, 2009). It refers to the "resourceful appropriation of artifacts and surroundings, the ongoing adaptation of systems and routines through design-in-use that allows emergent properties to arise and addresses individual needs" (Wakkary & Maestri, 2007, p.163). Recently, Kim et al. (2021) claimed that former explorations on the appropriation of everyday design could enhance the understanding of stockholders' creative behaviors in interaction design practices.

In addition to enriching the understanding of appropriation from theoretical and practical aspects, design researchers have investigated the phenomenon of appropriation from a cognitive perspective. Within this context, appropriation refers to "an interpretation process in which the user perceives in a tool a new opportunity for action" (Salovaara, 2008, p. 209). Similarly, they have proposed the notion of *ludic engagements* to describe people's interpretive and explorative activities toward designed objects motivated by curiosity (Gaver et al., 2004; Morrison et al., 2007; Nam & Kim, 2011). To sustain these behaviors, The Drift Table was designed for open-ended appropriations by leveraging the weight of detected items as the input factor (Gaver et al., 2004).

Accordingly, *designing for appropriation* illustrates the intentionality of designing interactive objects for supporting ongoing adaptations of end-users (Tchounikine, 2017). Mäkelä and Vellonen (2018) further claimed that designing for appropriation can enhance teachers' motivations and performances in the context of a special education school. To have an in-depth understanding of the non-conventional use of technologies, Gibson et al. (2019) have developed the notion of bricolage to unfold how the adjustment of technologies with everyday tools and materials can promote dementia care. In addition, as users may respond to contingencies of a situation, Biasutti (2017) was encouraged to support spontaneous activities and extemporaneous creativity by *designing for improvisation*. To do this, researchers have developed novel instruments to promote the performance of musicians (Bowers et al., 2014; Griffin & Jacob, 2013; Kang et al., 2018), robot controllers (Mikalauskas et al., 2018; Savery, 2021), and dancers (Berman & James, 2014; Wallace et al., 2021) by addressing shortcomings of responsiveness. Yet, little work has discussed appropriation and improvisation in relation to lived experiences of a shape-changing artifact. Our study aims to build on and extend these concepts through a long-term field study.

More generally, former studies on appropriation have generated rich user experiences through the design of unique 3D printers (Ludwig et al., 2014; Shewbridge et al., 2014), mobile devices (Dalton et al., 2012), public installations (Fortin et al., 2014; Jacob, 2017), and tangible games (Segura et al., 2017; Unbehaun et al., 2020). However, it remains unclear how users may contingently appropriate a shape-changing resource in the mundane context of everyday (Alexander et al., 2018). Our work aims to expand former user studies on appropriation by contributing high-quality empirical insights to the design research community.

The Materiality of a Dynamic Physical Form

As users' creativity of actions may transform over time (McCarthy & Wright, 2004), this opens the possibility of investigating ongoing creative appropriations by drawing on the notion of the *materiality of interaction* (Wiberg, 2018). This notion describes how a purposefully designed shape-changing artifact with a particular form of materiality can support three intertwined processes: "1) the processes of interaction; 2) the processes of computing; and 3) the materiality of interaction as an ever-changing process that reflects the entanglement of the other two processes" (Wiberg, 2018, p.132). However, little research has adopted this approach, especially regarding the design of shape-changing artifacts.

In addition to the notion of Materiality of Interaction, design researchers have developed many alternative approaches to inform the design of computational forms (Hobye & Ranten, 2019; Vallgårda & Sokoler, 2010; Wiberg & Robles, 2010). For instance, Jung et al. (2017) proposed a morphologic perspective to illustrate the importance of hybrid materialities in designing interactive forms. However, as the core character of the Materiality of Interaction is its ever-changing state and form, its dynamics, and how it performs (Wiberg, 2018), grounding this approach through a design study requires a design implementation that supports this type of dynamism. Our work aims to build on this concept to frame the design implementation and field study of the deformTable.

In summary, the strands of these contributions indicate that the temporal form can trigger high-quality empirical data on shape-changing artifacts, and the experience of appropriating a shape-changing artifact can be better supported through the design of a particular form of materiality. Previous studies also reveal the opportunity to expand discussions on designing for appropriation and improvisation by reflecting on the collected empirical insights. This study aims to connect these threads. We plan to explore how the designed qualities of a shape-changing artifact can support ongoing appropriations and adaptations in everyday settings over time. We also want to investigate how a particular form of materiality might be accepted and blend into people's everyday lives in an intuitive way. In so doing, we aim to conduct a field study by deploying five deformTables in five different homes over 11 months.

Methodology

In previous articles, (Zhong et al., 2021, 2022) have conducted reflective inquiries to illustrate how they attended to the materiality and temporality of deformTable through small batch production (see Figure 2). However, it remains unclear how the purposefully instantiated form of materiality can engender ongoing appropriations of a shape-changing artifact across different homes. In this section, we provide a rationale for the design of the deformTable, and we unpack how related design concepts informed its implementation through realizing and instantiating aspects of the Materiality of Interaction. In addition, the design of the deformTable was broadly informed by previous design-oriented investigations of the Drift Table (Gaver et al., 2004) and the table-non-table (Wakkary et al., 2016).

Design Implementation and Rationale

We designed the inputs and outputs of deformTable during the process of instantiating a particular form of materiality (Wiberg, 2018). Specifically, we adopted Arduino IDE as the software platform to frame the process of interaction and the process of computing. For the threads of interaction, we utilized a 5 kg load cell as the input device of deformTable after testing 3 kg, 10 kg, and 20 kg load cells, respectively. Because we found that most everyday items can trigger shape changes with the calibrated load cell. In terms of the processes of computing, an actuator was programmed to linearly deform a piece of upholstered spandex.

To sustain long-term relations with deformTable, we intentionally calibrated the temporal expressions of deformTable (Vallgårda et al., 2015). Considering how slowing down the actuation speed may trigger critical reflections on ongoing appropriations of deformTable (Odom et al., 2018), we adjusted the actuation speed from 5 mm/s to 10 mm/s. However, slowing down the speed might adversely affect the novel attraction of shape change. This challenge motivated us to set the actuation speed at 10mm/s. We also designed the response time of shape change as 500 milliseconds to meet the pace of daily routine. In addition, we defined the minimal detective weight of deformTable as 15 grams to meet the weight of most everyday items in the home. These decisions demonstrate how we aimed to design a particular form of materiality that can express a concrete temporal form at a given moment and instantiate concrete materiality when weight changes on the table surface.

DeformTable was also conceptualized by related theories for promoting design-oriented inquiries: the unselfconscious interaction (Wakkary et al., 2015) and material speculation (Wakkary et al., 2016). Unselfconscious interaction refers to designed artifacts with open-ended and lived-with qualities that can support creative and contingent appropriations. Material speculation requires highlighting the counterfactual feature of designed shape-changing artifacts to embody proposed research questions. Given this, our intention in crafting the form enclosure of deformTable was to embody these higher-level concepts rather than approach functional and utilitarian purposes. We did this by using solid wood to fabricate the table surface and leaving a hollowed space between the elastic spandex and the form enclosure. Additionally, we programmed the actuator to design the counterfactual feature of deformTable: it can go up with the increase of weights or equivalent pressures applied on the table surface, and vice versa. We call deformTable a research product as it can be independently deployed to everyday sittings for supporting field inquiry (Odom et al., 2016).

The collection of these endeavors successfully created a resource for supporting deployment investigations on creative and contingent appropriations of shape change. People who lived with the deformTable might interact and intersect with the dynamic physical form when they place an object on the table surface and change the shape of the elastic fabric. The instantiated materiality of the deformTable might cultivate people to entangle with the dynamic physical form. The hollowed space between the form enclosure and shape change can support ongoing creative actions and entanglements with deformTable. The temporal expressions on the surface of the dynamic physical form can cultivate critical reflections on people's creative behaviors and experiences. The accumulation of entangling with the deformTable at different homes might engender new and unknown experiences on appropriation. The maximum weight detection capacity of deformTable is 5 kg with a 100 mm actuation length. deformTable is portable throughout a home though it requires AC power. We ultimately small batch produced five deformTables by assembling the crafted physical parts and programmed digital materials together. Next, we will discuss the research settings of the field study.

Figure 2. deformTable is a shape-changing artifact upholstered with a piece of elastic fabric (rendered image). From left to right: deformTable in a static state; a book placed on the table surface of deformTable; deformTable goes up higher as more books are placed on the table surface.

Recruitment and Participants

We recruited five everyday households as participants in the study during the pandemic period. We initially emailed 25 invitation flyers to dwellers who were living in Greater Vancouver. Six replied to us, and five agreed to join this study. None of them dropped out over 11 months, while one of the households completed the study at the end of the 8th month because they moved to another city. We see limitations of our approach as we did not invite as many participants to the study through our collection of the home that was sufficiently varied. Similar to previous research on long-term deployment study of the computational artifacts (Gaver et al., 2013; Odom et al., 2019; Wakkary et al., 2018), we wanted to collect situated and reflective experiences of independent homes from a diverse sample. We use pseudonyms to describe all the participating households:

Household 1 (H1) consisted of Jessie (aged 41, user experience designer) and Owen (42, electrical engineer), a married couple who moved from a townhouse to an apartment during the deployment period (see Figure 6). Household 2 (H2) consisted of Oliva (28, UX designer) and Jack (30, software engineer), a couple who lived in an apartment for around four years (see Figure 7). Household 3 (H3) consisted of Sophie (43, independent writer), Noah (45, algorithm engineer), and their son Lucas (3, preschooler), a couple who lived in a house where they had just moved in (see Figure 3). Household 4 (H4) consisted of Emma (30, bank clerk) and Daniel (31, real estate broker), a young couple who lived with their cat Cocona in an apartment for around one year (see Figure 4). Household 5 (H5) consisted of Lydia (27, mechanical engineer), a music enthusiast who had just graduated with a master's degree and lived with her landlady in a house (see Figure 5).

Data Collection and Analysis

We conducted four semi-structured interviews at the start, interim, and end of the field study (Seidman, 2006). We used Zoom (an online conference platform) to conduct each interview to keep social distancing. We dropped five deformTables with informed consent at the front door of participants' homes. After they received the artifacts, we asked them to take photos of the deformTable by including the surroundings of their homes. We wanted to have a deeper understanding of everyday items and materials in their places. We conducted the second interview at the end of the third month to collect details of creative actions. In the six-month interview, we asked them to report on their ongoing and transformable experiences with deformTable. We conducted the last interview at the end of the study to capture long-term relations with the form of materiality. The interviews created about 710 minutes of recorded conversations or approximately 38,000 words.

A closed Facebook group was created for participants to post recorded photos, videos, and comments. As a platform where group members can share their experiences, including all the stakeholders in the online platform can reduce barriers between participants and researchers (Medley-Rath, 2019). We clarified how all involved participants could check their posts in the consent form to protect their privacy. The group was deleted immediately after withdrawing the deformTable from the participants' places (Franz et al., 2019). We also briefly introduced the research background during our first interview. We expected that participants could develop their appropriative and adaptive behaviors autonomously across the process of living with deformTable (Judge et al., 2010). At the end of the field study, the online platform accumulated 36 posts with 24 photos, eight videos, and 32 comments.

We adopted the constructivist grounded theory to analyze the transcribed data from each interview (Charmaz, 2014). We wrote memos to engage empirical findings in time right after each interview. We used initial coding to preserve the fluidity of participants' experiences. Constructing emerged themes was a dynamic process, which required us to work back and forth to frame codes to fit participants' long-term experiences. We then adopted axial coding to categorize discrete annotations as a coherent whole. Themes emerged after we used theoretical coding to analyze selected data. In the following, we present the constructed themes to highlight selected examples.

Findings

The field study aims to address the challenge of appropriating a shape-changing artifact in everyday settings over time (Alexander et al., 2018). In the early weeks, the participants were curious about the shape-changing feature of the deformTable. After they were familiar with the counterfactual feature, they used the deformTable for relaxation and physical exercises, while some of them leveraged the deformTable for ludic activities. Participants gradually accepted deformTable as part of their homes by sketching on and decorating the shape-changing surface. Interestingly, one of the participants performed music by adapting deformTable as a drum. These experiences suggest how a particular form of materiality engendered ongoing experiences of creative and contingent appropriations: from adoptions to adaptations.

Getting Familiar with deformTable through Creative Actions

In the early days of living with deformTable, participants appreciated the robustness and aesthetics of shape change. Sophie-H3 mentioned how the form enclosure with actuality and deformability was friendly to her son: "I would say the wood has good quality. And the fabric was very soft, which was very gentle for my son." Jack-H2 reported how the hollowed patterns on the fabric surface invited him and Olivia-H2 to interact with deformTable: "I think the fabric stood out more to us because it's something that we can kind of wave around and attach things to it." Daniel-H4 described how he was satisfied with the physical form of deformTable: "I think the overall design can fit the decoration style of my apartment." The open-ended and high-finished qualities of deformTable also stimulated Lydia-H5 to creatively interact with deformTable: "My original feeling was the design of deformTable. I didn't consider it as something functional at the beginning."

Figure 3. Sophie-H3's son placed his toy on the sketched table surface of deformTable.

Furthermore, Participants engaged in the dynamic physical form to familiarise themselves with deformTable. Jessie-H1 motioned how her partner Owen-H2 explored the actuation mechanism by triggering shape change repetitively: "He was full of curiosity to explore technical things… It's easy for him to observe embedded electronics by looking through the hollowed dots of the fabric when deformTable went up and down." Similarly, Jack-H2 was also interested in activating shape change by dynamically plugging and unplugging deformTable: "At the moment when I unplugged it… I expected that [the height] would go back to its default position after losing power… I was sort of curious about how that might work." For Sophie-H3's son Lucas-H3, he would like to place different materials on the wooden surface of deformTable: "He was curious about everything and he touches everything around him… He wanted to see how the table would respond to him if he placed a metal piece on top of it." Interestingly, Daniel-H4's cat Cocona was also curious about deformTable by clawing at the spandex: "I saw she scratched at the fabric and then moved her paw away."

After performing in-situ interactions with deformTable for a few weeks, participants started to move deformTable to different rooms. Oliva-H2 described how she took the deformTable from her living room to her bedroom: "We initially put it in our living room. And I remember later, somehow, I put it in our bedroom." However, Sophie-H3's son would like to roll deformTable over spaces in their house: "I moved deformTable to my living room… He rolled the table back and forth between the kitchen and the bedroom." Daniel-H4 mentioned how he intentionally moved the deformTable next to a cushion on the patio of their apartment: "It was in the living room when the MUJI cushion was there. … I tried to put deformTable on the patio for a short period." In terms of Lydia-H5**,** she placed deformTable to all the rooms of her house except the bathroom: "I moved it from my bedroom to dining room to living room."

As the study progressed, the incremental interactions with deformTable evolved to more situated uses that led to appropriations of the artifact. For Oliva-H2, she decided to conduct physical exercises with deformTable: "It's very interesting because it's new, and we wanted to figure out what we can do about it. … I found it would be useful for my exercising." However, Sophie-H3 would like to place her books on deformTable while sitting on the floor and read: "I tested different things in the daytime… Now I use it as a tool to assist my reading." Like Oliva-H2, Daniel-H4 adopted deformTable as his armrest: "I found it was very comfortable if I put my arm on top of it [deformTable] while watching TV." As Lydia-H5 has experience playing a hand drum, she would like to adopt deformTable as a drum pad: "After I touched it and saw how it changes, I realized it's kind of a drum pad for me."

Generally, these findings indicate how participants got familiar with deformTable in the early weeks of the field deployments. They initially performed engaged activities to familiarize themselves with deformTable. The collected insights also reveal how they were curious about the instantiated materiality of a shape-changing artifact. Interestingly, we found participants initiated to appropriate deformTable for personalized aims that evolved from their day-to-day experiences. Next, we will describe how they adopted deformTable to meet diverse interactive needs at their places.

Figure 4. Daniel-H4's cat Cocona sniffed and clawed on the spandex of deformTable.

Performing Everyday Activities with deformTable in the Home

deformTable is highlighted by its counterfactual feature that is designed to nurture ongoing creative actions in the home. Over the months, we found participants not only conducted physical exercises with deformTable but also adopted deformTable for ludic activities. These experiences resulted in the adaption of deformTable for individual purposes at different homes.

Relaxing and Exercising with deformTable

Three months later, most of the participants moved deformTable to different rooms for relaxation. For example, Jessie-H1 mentioned how she placed her legs on the wooden surface of deformTable: "This made me very comfortable. You know, when you put your legs on this table, it would go up and down. And then you can relax your legs." For Olivia-H2, she would like to apply forces on the table surface to deliberately trigger shape change: "I would like to apply a different amount of force with my legs each time." However, Daniel-H4 preferred to place his arm on the deformTable to take a rest: "When I sit on the MUJI cushion while watching TV… I like to put my arm on deformTable."

In addition to utilizing deformTable as a resource for relaxation, participants also conducted exercises with deformTable. For Oliva-H2, she used deformTable to assist her lunge exercise: "For the lunge exercise, I would like to place my feet on the surface of deformTable. It's harder for me to keep balance if the deformTable rises higher… I have to apply pressure to deformTable to make it higher." Similarly, Sophie-H3 mentioned how Lucas-H3 dynamically adjusted the height when playing with deformTable: "After he climbed up the table, the table got higher… He liked to hang his feet here and there while he was holding the fabric with his hands. He kept singing when sitting at the table… And he tried to make the table up and down." Interestingly, Daniel-H4 remarked on how the cat jumped to the wooden surface of deformTable at the moment: "She has a cat tree on the right side of deformTable. I found she put her paws on the floor and then jumped to the top of deformTable."

Leveraging deformTable for Ludic Activities

After participants were more familiar with the counterfactual feature, they began to adopt deformTable to meet playful interactions. Oliva-H2 enjoyed her experiences of making deformTable up and down: "Therefore, I moved my leg up and down, up and down... it's hard to keep balance essentially just because I wasn't used to it… But it was fun to try it out." For Daniel-H4, he describes how he would like to use deformTable to play with his cat: "If Cocona can overcome her fear of the machine [deformTable], she would like the teaser… That's why I placed the teaser there [wooden surface]. She's brave enough to get it and try to finish every single play." Similarly, Lydia-H5 also reported her pleasurable experiences of beating deformTable with drumsticks: "I used it to place my drum pad. It's quite fun to play with it [deformTable] with my drumsticks."

These experiences stimulated participants to reconsider the role of deformTable in their everyday lives. After attempting to place different items to trigger shape change, Jessie-H1 reported how she placed her toy on the table surface for several days: "Yeah, I tried many ways to use it. I put my toys on it." Similarly, Sophie-H3's son Lucas-H3 played with deformTable by placing toys on the table surface: "He would like to put plastic donuts on the table. He did that again, again and again. The table would get higher or lower when he puts items on the table each time… He was very happy about it.". After interacting with deformTable in different ways, Daniel-H4 used it as a digital toy for his cat: "I have tried to place different things on deformTable, such as a table for my mug… In the end, it would be the toy of my cat." For Lydia-H5, she considered deformTable as a non-functional object by comparing it with other tables in her house: "For my dining table or my desk, they have specific purposes… I didn't use it [deformTable] as a functional table. Instead, I had more fun with it as something like a toy."

Transitioning from Adoptions to Adaptions

After living with deformTable for around half a year, we found the participants started to adapt deformTable with surrounding materials in their places. For example, inspired by the hollowed patterns on the shape-changing surface, Jack-H2 and Oliva-H2 decorated deformTable with Christmas ornaments in the living room of their apartment. Jack-H2 shared with us:

> I like all fabric technically has holes in it… But the ones on this are bigger than normal clothes, which I think was kind of interesting. Because it's like the sort of inviting you to put things on it…that sort of [hollowed patterns] gave us a hint to put like Christmas balls and lights and stuff on it, which I think it's interesting. (Jack-H2)

Olivia-H2 also specified how she began to decorate deformTable during Christmas: "I adopted its function of raising while pressing… I used it as an exercise tool. Now, I use it for decoration. We adapted it to calculate the 'correct' height of hooking ornaments."

We also found that participants intended to adjust deformTable to meet their purposes. For example, Jessie-H1 reported how she wanted to draw on the shape-changing interface of deformTable: "Actually, I want to sketch some smiley faces on the soft cloth as I want to use deformTable to record the growth of my plants." And Lydia-H5 also used deformTable as a hand drum to play with it: "I think deformTable encouraged me to get my old hobbies back. It was a drum stand at the very first beginning. And then it became a hand drum for me."

These collective insights suggest how participants creatively appropriated a shape-changing artifact for sustaining daily interactive needs. Findings also reveal how deformTable has been adopted to meet ludic activities at different homes. However, transitioning from adoptions to adaptions transformed the dynamic physical form of deformTable. Next, we will describe how participants adapted deformTable to meet personalized purposes in the last few months of the field deployment.

Figure 5. After using deformTable to perform music for several weeks, Lydia-H5 trimmed the spandex to store her drum stick.

Adapting deformTable to Meet Individual Purposes

McCarthy and Wright have claimed that designed artifacts would be in unfinished states as users' creativity of actions is always potential and always becoming (McCarthy & Wright, 2004). Users may interact, intersect, and entangle with computational artifacts in untended ways that go beyond envisions of designers (Mäkelä & Vellonen, 2018). As the study progressed, we found that participants employed surrounding materials and resources to adapt deformTable to meet different purposes. Over time, the incremental of their activities transformed the originally designed shape change to fit the surroundings of everyday (Wakkary et al., 2016).

Adjusting and Decorating deformTable with Materials at Homes

As different participants have different backgrounds and preferences, they adapted deformTable for different purposes with resources in their homes. To facilitate her experiences of using deformTable as a hand drum, Lydia-H5 described how she trimmed the unholstered spandex on the enclosure: "I trimmed the fiber, which allowed me to have faster interactions with the side of the table. And it allowed me to have good control of the pace and speed when I use it like a hand drum."

Interestingly, we found some participants leveraged temporal expressions as resources to decorate deformTable. Olivia-H2 described how she used dot patterns on the spandex surface to decorate deformTable:

> I thought about different ways to decorate it [deformTable]. I tried to arrange ornaments to different [hollowed] patterns many times. I made the final decision by moving the table up and down repetitively… I figured out which distances [between each ornament] were best for me. (Olivia-H2)

Similarly, Jack-H2 also dynamically leveraged the temporal form of deformTable to arrange his ornaments: "We attached it [deformTable] to weight or sitting on top of the table. When we put more ornaments on it, we would add more weight. And then hold on the table [at a specific position] until we hooked the ornaments on the fabric."

Sketching, Drawing, and Performing Music with deformTable

Other participants adjusted the deformTable with pens and markers in their homes. To observe the growth of her plants, Jessie-H1 depicted how she collaborated with one friend to draw smiley faces on the shape-changing interface: "To observe the growth of plants more vividly, my friend and I drew a rounded smiley face on the fabric surface of deformTable. The deformation of the smiley face reminded me whether I have over-watered." She also described how the sketched face changed over time: "After a few weeks later, the plants grew up, and the smiley face turned into an odd face." Similarly, Sophie-H3's son also sketched on the wooden surface of deformTable: "He was learning how to use a pen in recent… He sketched on the wooden surface at the beginning." In addition, we also found how participants employed the temporal form of deformTable to assist their sketching practices. Both Jessie-H1 and Sophie-H3 described how they entangled with the temporal form in detail. Jessie-H1 shared: "When she (her friend) was drawing on the fabric of deformTable, I pressed the deformTable because I wanted to observe what would happen." And then Sophie-H3 added:

> He [Lucas-H3] tried to press and interact with the table when he was painting on it each time. … the table would respond to him. It's so sensitive to his painting. He liked to thump on the table repetitively… He's very happy about it. (Sophie-H3)

Unlike Jessie-H1 and Sophie-H3, Lydia-H5 would like to perform music with deformTable:

> When I was listening to a slow-paced song at a time, I wanted to use different parts of my hands, like my fingertips, palm, and wrists, to develop a sense of rhythm. There were several ways to change the rhythm of the song. I could beat the side of the table to create different tones when the height of the table was changing. (Lydia-H5)

Interestingly, after the response time of shape change cannot meet Lydia-H5's expectations, she switched the music to fit the temporal pace of deformTable: "I expected that the sound pace would change immediately when I used with it like a hand drum. However, as it took around half a second in responding to my behaviors… I played deformTable with slow-paced music."

These experiences reveal how participants contingently adapted a shape-changing artifact to meet different individual purposes. Our findings also reveal how the accumulation of adaptions dynamically transformed the manifestation of the originally designed shape-changing interface. In the following, we will describe how participants reported on their long-term experiences of living with deformTable.

Figure 6. Jessie-H1 sketched a smiley face on the fabric surface to observe the growth of her plant.

Eleven-Month Lived Experiences with The deformTable

At the end of the field deployment, participants accepted deformTable as a cherished item in their places. Jessie-H1 mentioned how she routinely watered the plant on deformTable: "I watered the plant each morning after I placed the flowerpot on deformTable." Jack-H2 and Olivia-H2 accepted the decorated deformTable as part of their living room, Jack-H2: "We like what we decorated. It [deformTable] just stayed by the Christmas tree. …We haven't taken Christmas decorations off the deformTable yet." After adopting deformTable for ludic intentions, Sophie-H3's son used it in his everyday life: "Over the past months, my son interacted with it almost every day and it became my child's toy." For Daniel-H4, his cat Cocona got familiar with deformTable placed next to a cat tree: "She didn't feel nervous anymore… she used it as an elevator to access her cat tree somehow."

Over time, deformTable seamlessly fades into the background of participants' homes. For instance, Both Jack-H2 and Olivia-H2 mentioned how the decorated deformTable became part of the Christmas theme in their living room. Jack-H2: "Basically, it's sort of like a natural part of our home now. I would like to imagine it was sort of right there…Yeah, because it seems so nice, kind of in that position beside the Christmas tree." Olivia-H2: "I think after we turned into decoration it became that corner. It's blended with the environment now." For Daniel-H4, he described the possible ensemble of intersecting deformTable with a digital table:

> I'm planning to get an adjustable table. I want that [table] to be part of my home. Because now everything was fixed and only itself [deformTable] is moving… I want to see what will happen if other digital furniture interacts with deformTable. (Daniel-H4)

Taken together, these examples highlight how deformTable was dynamically accepted by participants at different homes. Over time, deformTable became part of the real material context of everyday.

Figure 7. Oliva-H2 and Jack-H2 used Christmas ornaments to decorate the deformTable in their living room.

Discussion and Implications

Design researchers have claimed the need to generate more high-quality empirical data to better understand "how use context may impact the performance of and preference for shape-changing interfaces" (Rasmussen et al., 2012, p. 743). Our work responds to this call by contributing a long-term field study of the deformTable in the context of everyday. Along with a previous study on lived experiences with a deformable lamp (Zhong et al., 2020), this study explicitly expands the investigation in this direction by offering a case to shed light on how the ongoing lived experiences of creative and contingent appropriations can be sustained by highlighting temporal expressions of a particular form of materiality. Accordingly, we see opportunities that future research can leverage materiality and temporality as resources to design novel relations with computational artifacts. Next, we aim to discuss implications in terms of ludic appropriation, individual improvisation, and shape-changing artifacts by critically reflecting on the constructed empirical themes and collected insights.

Designing for Ludic Appropriation

From the field study, the involved participants appropriated the deformTable for diverse ludic intentions across different homes. Initially, the deformTable design invited participants to explore the counterfactual feature of a shape-changing artifact. For example, Oliva-H2 reported on how her adjustment of height with her legs can throw her off balance. This intimate experience stimulated them to explore how to use deformTable as a toy for convivial purposes. For instance, Daniel-H5 placed a cat teaser on deformTable to play with the cat. While participants deliberately used deformTable for nonutilitarian intentions, these behaviors became more intuitive as time went by. However, we find that previous initiatives on developing appropriation-related concepts might not fully encapsulate these empirical findings. Accordingly, we would like to introduce the concept of *ludic appropriation*: the contingent behaviors of adopting and adapting temporal and computational material forms for explorative and convivial purposes rather than utilitarian goals.

The extended understanding of appropriation offers rich opportunities for future research to contribute reflective and empirical insights to the design research community. Our initiative of instantiating a particular form of materiality to foreground entanglement possibilities with shape change successfully engendered the experience of ludic appropriation. For example, our participants intuitively adopted deformTable to entangle with the digital toy, drumstick, and cat teaser for timely amusement. However, this experience emerged in the early period of living with the deformTable. Therefore, future research could investigate the subtle changes and transformation of such an experience and, further, how this playfulness could be extended over longer periods through the design of other forms of material interaction. Theoretically, we also find a need to further enrich the understanding of this concept by conducting more design-oriented studies. As people's creativity of actions may transform over time (McCarthy & Wright, 2004), we imagine *modular design thinking* may facilitate future explorations in this direction, for example, by clustering simple and small product components into more complex subassemblies (Ma & Kremer, 2016). This could build on our finding that the table surface of deformTable enabled Sophie-H3's son Lucas to disassemble it and play around with it.

Another opportunity could be to investigate the designed qualities of computational aspects of shape change to further support ludic appropriation. Dix (2007) claimed that exposing visual elements of information can develop meanings and intentions of appropriations. A recent study on table-non-table suggests that highlighting the open-endedness of designed material forms can trigger new and unexpected appropriations (Wakkary et al., 2016). Our findings contribute to the explorations in this direction by revealing that a purposefully designed particular form of materiality with *implicit manipulability* successfully fosters the experiences of ludic appropriation. This quality of deformTable explicitly stimulated participants to conduct different experiments and alternative uses of the deformTable across different rooms, from relaxing to exercising to pleasurable activities. We conclude this quality as how a computational form without explicit functions and open-ended interfaces cultivates users' curiosity to adopt it for pleasurable, explorative, and even unintentional purposes in their everyday lives.

However, discussing the quality of manipulability is not new in the design research community, Kim et al. (2021) claimed that manipulability is a trigger for everyday design, which refers to fixing and fastening. In our case, the manipulability of deformTable was manifested by participants' curiosity and intentions they would like to achieve. Jessie-H1 manipulated the height of the deformTable to assist her physical exercise while Daniel-H4's cat would like to adjust the height as a stair. Moreover, Boon et al., (2020) proposed the notion of constructive play to describe how users manipulate designed objects as building materials for play in a short-lived manner. However, our participants would like to contingently manipulate the deformTable as a resource for different ludic plays. The behavior of manipulating and entangling with deformTable is part of the play. For example, Sophie-H3 mentioned: "The table would get higher or lower when he puts items on the table each time… He was very happy about it." With these foundations, future research can approach the implicit manipulability of designed computational things to generate more diverse experiences on ludic appropriation.

Designing for Individual Improvisation

Drawing on the notion of the Materiality of Interaction, we also find that the deformTable design engendered the experience of *individual improvisation*, which refers to ongoing practices of leveraging a temporal and computational form to achieve creative potential in individual endeavors. After getting familiar with the counterfactual feature, participants used surrounding resources and tools in their homes to adapt deformTable to meet personalized needs. For example, Olivia-H2 collaborated with Jack-H2 to decorate deformTable by themselves with Christmas ornaments to fit their living room. These intimate behaviors motivated them to further adjust deformTable to achieve their

creative abilities. However, they met difficulties in fulfilling individual expectations, such as redesigning the aesthetic gestalt of shape change. The entanglement between the deformTable and creative interactions unpacked how they developed the experience of individual improvisation. For example, leveraging the temporal expressions of deformTable as resources helped them to balance the constraints of sketching and music performing.

These findings open a space where further research can explore the design of novel interactive artifacts that *activate* everyday items to be used in combination with the interactive artifact. Previous design research encouraged using impermanent materials to cultivate improvisation in use (Tsaknaki & Fernaeus, 2016), such as a pile of white papers (Wakkary et al., 2016). However, our field study reveals that the resourceful everyday items at different homes can foster the experience of individual improvisation. For instance, Lydia-H5 utilized her drum pad, drumstick, and scissors in their homes to redesign deformTable to support her musical performance. As everyday items provided rich resources for participants to develop their experiences of individual improvisation, there is an opportunity to investigate how the designed qualities can invite more intuitive, ongoing, and creative activities of using everyday things in combination with designed computational forms. While our field study shows how the temporal form of deformTable can support the experience of individual improvisation in a long-term period, only some of the participants adapted the deformTable for improvised intentions. To tackle this issue, design researchers can explore what alternative approaches could evoke a wider spectrum of spontaneous behaviors.

In addition, our study also suggests how the predesigned temporal expression of deformTable cultivated ongoing experience on individual improvision. Considering the linearly manifested temporal form changed Lydia-H5's music-listening habit while playing with the deformTable as a hand drum, there is an opportunity to engender more diverse improved behaviors through the design of novel temporal forms. For instance, design researchers can configure the actuation speed of a shape-changing device to cultivate an individual's creativity in improvised sketching. Over time, Lydia-H5 redesigned the deformTable by trimming the elastic fabric to meet her expectation of a desired hand drum. From this, future research can design online toolkits for individuals to bespoke temporal and computational forms by themselves. With these resources, researchers can contribute empirical insights to the design research community by inviting participants to self-report their improvised experiences. More specifically, we find our choice of using white-coloured spandex with hollowed dot patterns provoked Olivia-H2's and Jack-H2's improvised creativity in decorating the deformTable with Christmas ornaments. Over time, the proliferation of hooking the ornaments on the hollowed patterns of the temporal form met their expectations and ultimately blended the deformTable into the background of their homes. To sustain long-term improvised relations with computational things, designers and researchers can purposefully explore the design space of temporal forms in designing with digital and physical materials.

On a broader level, we expect our empirical findings on individual improvisation to encourage further research to investigate novel felt experiences by designing qualities to extend the life circle of research artifacts. For instance, researchers can explore what novel experiences, such as self-reminiscence or storytelling, may exist during the long-term bricolage of temporal and computational forms at different homes. As deformTable design has supported everyday dwellers to develop nuanced experiences of spontaneous and contingent creativities, we see our work extends former research on individual improvisation among group members (Magni et al., 2009). Considering Fukasawa's *without thought* design theory from product design for supporting spontaneous behaviors, there is the possibility to investigate and discuss the experience of individual improvisation through such a perspective (Fukasawa, 2007; Fukasawa & Morrison, 2007; Suri, 2003).

Designing Shape-Changing Interfaces to be Shaped Through Use

The core aim of the long-term field study is to explore how the deformTable design can sustain creative and contingent appropriations of a shape-changing artifact. Although participants were initially unsure about how to interact with the shape-changing interface, moving deformTable to different rooms helped them engage with a particular form of materiality being designed. However, their understanding of deformTable was dynamically transformed as they appropriated the shape-changing interface to meet different purposes. Over time, the reconfigured shape-changing interface of deformTable was accepted by all the participants and blended into the background of different homes.

deformTable design successfully triggered participants to reflect on their long-term interactions, intersections, and entanglements with a shape-changing interface. It also illustrates how the accumulation of ongoing creative actions reshaped the manifestation of the shape-changing interface itself. This finding may pose a challenge to the ongoing discussions on the alternative affordance notions of the shape-changing interface, such as the material affordance (Parkes & Ishii, 2010), dynamic affordance (Grönvall et al., 2014), and spatial affordance (Everitt et al., 2016), which describe how the transformation of dynamic shape change can provide information to users (Petersen et al., 2020) because designers might not fully envision how a particular shape-changing interface can be experienced in a specific context. Therefore, future research can design novel shape-changing interfaces to better support situated, unexpected, and mundane interactions and experiences. Reflecting on the empirical findings of these interfaces may contribute intermediate-level knowledge to the design research community, such as higher-level propositions.

Nevertheless, design researchers and practitioners may need to address technical and theoretical frictions during the process of designing new and unexpected uses for shape-changing interfaces. In our study, the purposefully designed deformTable successfully engendered the experiences of adopting and adapting a dynamic physical form for diverse individual purposes. Given

this, highlighting the *resourcefulness* of shape-changing interfaces might fulfill unexpected interactions and entanglements, that is leaving dynamic and temporal expressions of computational forms as resources for uses and reuses in living. To do so, future research can derive retrospective insights by designing for supporting daily entanglements with shape-changing interfaces, such as bricolage. Our choice of batch-producing five deformTables accumulated a wide spectrum of ongoing experiences on appropriation. Yet, design researchers might make their decisions on the deployment number of shape-changing interfaces to fit specific samples.

The long-term field study also reveals an underexplored space where researchers can generate critical insights through the design of novel shape-changing things. Deploying deformTable for 11 months promoted the accumulation of rich experience on appropriation. Building on our work, future research can conduct long-term deployments to generate more organic and high-quality empirical insights rather than evaluate the validity of shape-changing interfaces in situ. Moreover, we see our work, as a case, builds on and expands the prior user study paradigm of the shape-changing interface in the laboratory and public settings (Alexander et al., 2018; Rasmussen et al., 2012). Generally, we expect these endeavors can inspire design researchers to ground their discussions of critical, speculative, and discursive insights about dynamic and temporal forms in everyday settings.

Conclusion

This article investigates how a particular form of materiality can support long-term creative and contingent appropriations of shape change in the context of everyday. Findings reveal that deformTable design triggered rich creative actions toward a shape-changing artifact in participants' homes over time. It also cultivated engaged and ludic appropriations in the early months of living with a dynamic physical form. Over time, participants adapted deformTable with surrounding materials and resources to meet their creativity and fit their homes. Our work investigates high-quality empirical data of a shape-changing artifact and rich implications to inform further explorations on designing for ludic appropriation, individual improvisation, and shape-changing interfaces to be shaped through use.

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References

1. Alexander, J., Brotman, R., Holman, D., Younkin, A., Vertegaal, R., Kildal, J., Lucero, A. A., Roudaut, A., & Subramanian, S. (2013). Organic experiences: (Re)shaping interactions with deformable displays. In *Proceedings of the conference on human factors in computing systems* (pp. 3171-3174). ACM. https://doi.org/10.1145/2468356.2479639
2. Alexander, J., Roudaut, A., Steimle, J., Hornbæk, K., Bruns Alonso, M., Follmer, S., & Merritt, T. (2018). Grand challenges in shape-changing interface research. In *Proceedings of the conference on human factors in computing systems* (Article No. 299). ACM https://doi.org/10.1145/3173574.3173873
3. Belin, A., & Prié, Y. (2012). DIAM: Towards a model for describing appropriation processes through the evolution of digital artifacts. In *Proceedings of the designing interactive systems conference* (pp. 645-654). ACM. https://doi.org/10.1145/2317956.2318053
4. Berman, A., & James, V. (2014). Towards a live dance improvisation between an avatar and a human dancer. In *Proceedings of the international workshop on movement and computing* (pp. 162-165). ACM. https://doi.org/10.1145/2617995.2618026
5. Biasutti, M. (2017). Teaching improvisation through processes. Applications in music education and implications for general education. *Frontiers in Psychology, 8*(911). https://doi.org/10.3389/fpsyg.2017.00911
6. Bødker, S. (2006). When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordi conference on human-computer interaction* (pp. 1-8). ACM. https://doi.org/10.1145/1182475.1182476
7. Boon, B., Rozendaal, M. C., Van den Heuvel-Eibrink, M. M., van der Net, J., van Grotel, M., & Stappers, P. J. (2020). Design strategies for promoting young children's physical activity: A Playscapes perspective. *International Journal of Design*, *14*(3), 1-18.
8. Bowers, J., Taylor, R., Hook, J., Freeman, D., Bramley, C., & Newell, C. (2014). HCI: Human-computer improvisation. In *Proceedings of the companion publication on designing interactive systems* (pp. 203-206). ACM. https://doi.org/10.1145/2598784.2598799
9. Burstyn, J., Carrascal, J. P., & Vertegaal, R. (2016). Fitts' law and the effects of input mapping and stiffness on flexible display interactions. In *Proceedings of the conference on human factors in computing systems* (pp. 3649-3658). ACM. https://doi.org/10.1145/2858036.2858383
10. Charmaz, K. (2014). *Constructing grounded theory.* SAGE.
11. Dalton, N., MacKay, G., & Holland, S. (2012). Kolab: Appropriation & improvisation in mobile tangible collaborative interaction. In *Proceedings of the designing interactive systems conference* (pp. 21-24). ACM. https://doi.org/10.1145/2317956.2317960
12. Derboven, J., Geerts, D., & Grooff, D. D. (2016). The tactics of everyday practice: A semiotic approach to appropriation. *Interaction Design & Architecture(s) Journal*, 99-120. https://doi.org/10.55612/s-5002-029-005
13. Dix, A. (2007). *Designing for appropriation*. https://alandix.com/academic/papers/HCI2007-appropriation/HCI2007-appropriation-draft.pdf

14. Dourish, P. (2003). The appropriation of interactive technologies: Some lessons from placeless documents. *Computer Supported Cooperative Work*, *12*(4), 465-490. https://doi.org/10.1023/A:1026149119426
15. Everitt, A., Taher, F., & Alexander, J. (2016). ShapeCanvas: An exploration of shape-changing content generation by members of the public. In *Proceedings of the conference on human factors in computing systems* (pp. 2778-2782). ACM. https://doi.org/10.1145/2858036.2858316
16. Fisher, T. H. (2004). What we touch, touches us: Materials, affects, and affordances. *Design Issues*, *20*(4), 20-31. https://doi.org/10.1162/0747936042312066
17. Follmer, S., & Ishii, H. (2012). KidCAD: Digitally remixing toys through tangible tools. In *Proceedings of the conference on human factors in computing systems* (pp. 2401-2410). ACM. https://doi.org/10.1145/2207676.2208403
18. Fortin, C., Neustaedter, C., & Hennessy, K. (2014). The appropriation of a digital "speakers" corner: Lessons learned from the deployment of mégaphone. In *Proceedings of the conference on designing interactive systems* (pp. 955-964). ACM. https://doi.org/10.1145/2598510.2598534
19. Franz, D., Marsh, H. E., Chen, J. I., & Teo, A. R. (2019). Using facebook for qualitative research: A brief primer. *Journal of Medical Internet Research*, *21*(8), e13544. https://doi.org/10.2196/13544
20. Fukasawa, N. (2007). *Naoto Fukasawa*. Phaidon.
21. Fukasawa, N., & Morrison, J. (2007). *Super normal: Sensations of the ordinary*. Lars Muller Publishers.
22. Gaver, W., Bowers, J., Boehner, K., Boucher, A., Cameron, D. W., Hauenstein, M., Jarvis, N., & Pennington, S. (2013). Indoor weather stations: Investigating a ludic approach to environmental HCI through batch prototyping. In *Proceedings of the conference on human factors in computing systems* (pp. 3451-3460). ACM. https://doi.org/10.1145/2470654.2466474
23. Gaver, W., Bowers, J., Boucher, A., Gellerson, H., Pennington, S., Schmidt, A., Steed, A., Villars, N., & Walker, B. (2004). The drift table: Designing for ludic engagement. In *Proceedings of the conference on human factors in computing systems* (pp. 885-900). ACM. https://doi.org/10.1145/985921.985947
24. Gibson, G., Dickinson, C., Brittain, K., & Robinson, L. (2019). Personalisation, customisation and bricolage: How people with dementia and their families make assistive technology work for them. *Ageing and Society*, *39*(11), 2502-2519. https://doi.org/10.1017/S0144686X18000661
25. Gomes, A., Nesbitt, A., & Vertegaal, R. (2013). MorePhone: A study of actuated shape deformations for flexible thin-film smartphone notifications. In *Proceedings of the conference on human factors in computing systems* (pp. 583-592). ACM. https://doi.org/10.1145/2470654.2470737
26. Green, K. E. (2016). *Architectural robotics: Ecosystems of bits, bytes, and biology.* MIT Press.
27. Griffin, G., & Jacob, R. (2013). Priming creativity through improvisation on an adaptive musical instrument. In *Proceedings of the conference on creativity & cognition* (pp. 146-155). ACM. https://doi.org/10.1145/2466627.2466630
28. Grönvall, E., Kinch, S., Petersen, M. G., & Rasmussen, M. K. (2014). Causing commotion with a shape-changing bench: Experiencing shape-changing interfaces in use. In *Proceedings of the SiIGCHI conference on human factors in computing systems* (pp. 2559-2568). ACM. https://doi.org/10.1145/2556288.2557360
29. Harrison, C., & Hudson, S. E. (2009). Providing dynamically changeable physical buttons on a visual display. In *Proceedings of the SiIGCHI conference on human factors in computing systems* (pp. 299-308). ACM. https://doi.org/10.1145/1518701.1518749
30. Haulrik, N., Petersen, R. M., & Merritt, T. (2017). CADLens: Haptic feedback for navigating in 3D environments. In *Proceedings of the ACM conference companion publication on designing interactive systems* (pp. 127-131). ACM. https://doi.org/10.1145/3064857.3079132
31. Hazlewood, W. R., Dalton, N., Marshall, P., Rogers, Y., & Hertrich, S. (2010). Bricolage and consultation: Addressing new design challenges when building large-scale installations. In *Proceedings of the 8th conference on designing interactive systems* (pp. 380-389). ACM. https://doi.org/10.1145/1858171.1858244
32. Hemmert, F., Hamann, S., Löwe, M., Zeipelt, J., & Joost, G. (2010). Shape-changing mobiles: Tapering in two-dimensional deformational displays in mobile phones. In *Proceedings of the 4th international conference on tangible, embedded, and embodied interaction* (pp. 3075-3080). ACM. https://doi.org/10.1145/1709886.1709936
33. Hobye, M., & Ranten, M. F. (2019). Behavioral complexity as a computational material strategy. *International Journal of Design, 13*(2), 39-59.
34. Huh, J., Nathan, L. P., Silberman, S., Blevis, E., Tomlinson, B., Sengers, P., & Busse, D. (2010). Examining appropriation, re-use, and maintenance for sustainability. In *Proceedings of the conference on human factors in computing systems* (pp. 4457-4460). ACM. https://doi.org/10.1145/1753846.1754173
35. Jacob, M. (2017). Towards lifelong interactive learning for open-ended embodied narrative improvisation. In *Proceedings of the conference on creativity and cognition* (pp. 502-507). ACM. https://doi.org/10.1145/3059454.3078699
36. Judge, T. K., Neustaedter, C., & Kurtz, A. F. (2010). The family window: The design and evaluation of a domestic media space. In *Proceedings of the conference on human factors in computing systems* (pp. 2361-2370). ACM. https://doi.org/10.1145/1753326.1753682
37. Jung, H., Wiltse, H., Wiberg, M., & Stolterman, E. (2017). Metaphors, materialities, and affordances: Hybrid morphologies in the design of interactive artifacts. *Design Studies*, *53*, 24-46. https://doi.org/10.1016/j.destud.2017.06.004
38. Jurmu, M., Goncalves, J., Riekki, J., & Ojala, T. (2014). Exploring use and appropriation of a non-moderated community display. In *Proceedings of the 13th international conference on mobile and ubiquitous multimedia* (pp. 107-115). ACM. https://doi.org/10.1145/2677972.2677986

39. Kan, V., Vargo, E., Machover, N., Ishii, H., Pan, S., Chen, W., & Kakehi, Y. (2017). Organic primitives: Synthesis and design of pH-Reactive materials using molecular I/O for sensing, actuation, and interaction. In *Proceedings of the conference on human factors in computing systems* (pp. 989-1000). ACM. https://doi.org/10.1145/3025453.3025952
40. Kang, L., Jackson, S. J., & Sengers, P. (2018). Intermodulation: Improvisation and collaborative art practice for HCI. In *Proceedings of the conference on human factors in computing systems* (Article No. 160). ACM. https://doi.org/10.1145/3173574.3173734
41. Karana, E., Barati, B., & Giaccardi, E. (2020). Living artifacts: Conceptualizing livingness as a material quality in everyday artifacts. *International Journal of Design, 14*(3), 37-53.
42. Kim, H., & Lee, W. (2014). Everyday design as a design resource. *International Journal of Design, 8*(1), 1-13.
43. Kim, S., Christiaans, H., & Kim, C. (2021). Understanding everyday design behavior: An exploratory experiment. *International Journal of Design, 15*(1), 33-50.
44. Krischkowsky, A., Tscheligi, M., Neureiter, K., Muller, M., Polli, A. M., & Verdezoto, N. (2015). *Experiences of technology appropriation: Unanticipated users, usage, circumstances, and design*. https://reurl.cc/V8Qel5
45. Lee, S.-S., Kim, S., Jin, B., Choi, E., Kim, B., Jia, X., Kim, D., & Lee, K. (2010). How users manipulate deformable displays as input devices. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1647-1656). ACM. https://doi.org/10.1145/1753326.1753572
46. Lindley, C. A. (2004). Ludic engagement and immersion as a generic paradigm for human-computer interaction design. In *Proceedings of the conference on entertainment computing* (pp. 3-13). Springer. https://doi.org/10.1007/978-3-540-28643-1_1
47. Lo, J., & Girouard, A. (2017). Bendy: Exploring mobile gaming with flexible devices. In *Proceedings of the 7th international conference on tangible, embedded, and embodied interaction* (pp. 163-172). ACM. https://doi.org/10.1145/3024969.3024970
48. Ludwig, T., Döll, M., & Kotthaus, C. (2019). "The printer is telling me about itself": Supporting the appropriation of hardware by using projection mapping. In *Proceedings of the conference on designing interactive systems* (pp. 331-344). ACM. https://doi.org/10.1145/3322276.3322342
49. Ludwig, T., Stickel, O., Boden, A., & Pipek, V. (2014). Towards sociable technologies: An empirical study on designing appropriation infrastructures for 3D printing. In *Proceedings of the conference on designing interactive systems* (pp. 835-844). ACM. https://doi.org/10.1145/2598510.2598528
50. Ma, J., & Kremer, G. E. O. (2016). A systematic literature review of modular product design (MPD) from the perspective of sustainability. *The International Journal of Advanced Manufacturing Technology*, *86*(5), 1509-1539. https://doi.org/10.1007/s00170-015-8290-9
51. Magni, M., Proserpio, L., Hoegl, M., & Provera, B. (2009). The role of team behavioral integration and cohesion in shaping individual improvisation. *Research Policy*, *38*(6), 1044-1053. https://doi.org/10.1016/j.respol.2009.03.004
52. Mäkelä, S., & Vellonen, V. (2018). Designing for appropriation: A DIY kit as an educator's tool in special education schools. *International Journal of Human-Computer Studies*, *118*, 14-23. https://doi.org/10.1016/j.ijhcs.2018.05.004
53. McCarthy, J., & Wright, P. (2004). Technology as experience. *Interactions*, *11*(5), 42-43. https://doi.org/10.1145/1015530.1015549
54. Medley-Rath, S. (2019). Using facebook secret groups for qualitative data collection. *The Qualitative Report*, *24*(7), 1765-1777. https://doi.org/10.46743/2160-3715/2019.3963
55. Mikalauskas, C., Wun, T., Ta, K., Horacsek, J., & Oehlberg, L. (2018). Improvising with an audience-controlled robot performer. In *Proceedings of the conference on designing interactive systems* (pp. 657-666). ACM. https://doi.org/10.1145/3196709.3196757
56. Morrison, A. J., Mitchell, P., & Brereton, M. (2007). The lens of ludic engagement: Evaluating participation in interactive art installations. In *Proceedings of the 15th international conference on multimedia* (pp. 509-512). ACM. https://doi.org/10.1145/1291233.1291358
57. Muller, M., Neureiter, K., Verdezoto, N., Krischkowsky, A., Al Zubaidi-Polli, A. M., & Tscheligi, M. (2016). Collaborative appropriation: How couples, teams, groups and communities adapt and adopt technologies. In *Proceedings of the 19th conference on computer supported cooperative work and social computing companion* (pp. 473-480). ACM. https://doi.org/10.1145/2818052.2855508
58. Nam, T.-J., & Kim, C. (2011). Design by tangible stories: Enriching interactive everyday products with ludic value. *International Journal of Design*, *5*(1), 85-98.
59. Niiyama, R., Sun, X., Yao, L., Ishii, H., Rus, D., & Kim, S. (2015). Sticky actuator: Free-form planar actuators for animated objects. In *Proceedings of the 9th international conference on tangible, embedded, and embodied interaction* (pp. 77-84). ACM. https://doi.org/10.1145/2677199.2680600
60. Odom, W., Wakkary, R., Bertran, I., Harkness, M., Hertz, G., Hol, J., Lin, H., Naus, B., Tan, P., & Verburg, P. (2018). Attending to slowness and temporality with olly and slow game: A design inquiry into supporting longer-term relations with everyday computational objects. In *Proceedings of the SIGCHI conference on human factors in computing systems* (Article No. 77). ACM. https://doi.org/10.1145/3173574.3173651
61. Odom, W., Wakkary, R., Hol, J., Naus, B., Verburg, P., Amram, T., & Chen, A. Y. S. (2019). Investigating slowness as a frame to design longer-term experiences with personal data: A field study of Olly. In *Proceedings of the SIGCHI conference on human factors in computing systems* (Paper No. 34). ACM. https://doi.org/10.1145/3290605.3300264
62. Odom, W., Wakkary, R., Lim, Y., Desjardins, A., Hengeveld, B., & Banks, R. (2016). From research prototype to research product. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2549-2561). ACM. https://doi.org/10.1145/2858036.2858447

63. Park, Y.-W., Park, J., & Nam, T.-J. (2015). The trial of bendi in a coffeehouse: Use of a shape-changing device for a tactile-visual phone conversation. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2181-2190). ACM. https://doi.org/10.1145/2702123.2702326
64. Parkes, A., & Ishii, H. (2010). Bosu: A physical programmable design tool for transformability with soft mechanics. In *Proceedings of the 8th conference on designing interactive systems* (pp. 189-198). ACM. https://doi.org/10.1145/1858171.1858205
65. Petersen, M. G., Rasmussen, M. K., & Trettvik, J. (2020). Affordances of shape-changing interfaces: An information perspective on transformability and movement. In *Proceedings of the conference on designing interactive systems* (pp. 1959-1971). ACM. https://doi.org/10.1145/3357236.3395521
66. Qamar, I. P., Groh, R., Holman, D., & Roudaut, A. (2018). HCI meets material science: A Literature review of morphing materials for the design of shape-changing interfaces. In *Proceedings of the SIGCHI conference on human factors in computing systems* (Article No. 374). ACM. https://doi.org/10.1145/3173574.3173948
67. Ramakers, R., Schöning, J., & Luyten, K. (2014). Paddle: Highly deformable mobile devices with physical controls. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2569-2578). ACM. https://doi.org/10.1145/2556288.2557340
68. Rasmussen, M. K., Pedersen, E. W., Petersen, M. G., & Hornbæk, K. (2012). Shape-changing interfaces: A review of the design space and open research questions. In *Proceedings of the SIGCHI conference on human factors in computing system* (pp. 735-744). ACM. https://doi.org/10.1145/2207676.2207781
69. Robinson, S., Coutrix, C., Pearson, J., Rosso, J., Torquato, M. F., Nigay, L., & Jones, M. (2016). Emergeables: Deformable displays for continuous eyes-free mobile interaction. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 3793-3805). ACM. https://doi.org/10.1145/2858036.2858097
70. Roudaut, A., Karnik, A., Löchtefeld, M., & Subramanian, S. (2013). Morphees: Toward high "shape resolution" in self-actuated flexible mobile devices. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 593-602). ACM. https://doi.org/10.1145/2470654.2470738
71. Roudaut, A., Krusteva, D., McCoy, M., Karnik, A., Ramani, K., & Subramanian, S. (2016). Cubimorph: Designing modular interactive devices. In *Proceedings of the international conference on robotics and automation* (pp. 3339-3345). IEEE. https://doi.org/10.1109/ICRA.2016.7487508
72. Salovaara, A. (2007). Appropriation of a MMS-based comic creator: From system functionalities to resources for action. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1117-1126). ACM. https://doi.org/10.1145/1240624.1240794
73. Salovaara, A. (2008). Inventing new uses for tools: A cognitive foundation for studies on appropriation. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *4*(2), 209-228. https://doi.org/10.17011/ht/urn.200811065856
74. Salovaara, A., Höök, K., Cheverst, K., Twidale, M., Chalmers, M., & Sas, C. (2011). Appropriation and creative use: Linking user studies and design. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 37-40). ACM. https://doi.org/10.1145/1979742.1979585
75. Savery, R. (2021). Machine learning driven musical improvisation for mechanomorphic human-robot interaction. In *Proceedings of the international conference on human-robot interaction* (pp. 559-561). ACM. https://doi.org/10.1145/3434074.3446351
76. Schorr, S. B., & Okamura, A. M. (2017). Fingertip tactile devices for virtual object manipulation and exploration. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 3115-3119). ACM. https://doi.org/10.1145/3025453.3025744
77. Segura, E. M., Isbister, K., Back, J., & Waern, A. (2017). Design, appropriation, and use of technology in larps. In *Proceedings of the 12th international conference on the foundations of digital games* (pp. 1-4). ACM. https://doi.org/10.1145/3102071.3106360
78. Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. Teachers College Press.
79. Selander, S. (2008). Designs for learning and ludic engagement. *Digital Creativity*, *19*(3), 145-152. https://doi.org/10.1080/14626260802312673
80. Shewbridge, R., Hurst, A., & Kane, S. K. (2014). Everyday making: Identifying future uses for 3D printing in the home. In *Proceedings of the conference on designing interactive systems* (pp. 815-824). ACM. https://doi.org/10.1145/2598510.2598544
81. Steimle, J., Jordt, A., & Maes, P. (2013). Flexpad: Highly flexible bending interactions for projected handheld displays. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 237-246). ACM. https://doi.org/10.1145/2470654.2470688
82. Suri, J. F. (2003). The experience of evolution: Developments in design practice. *The Design Journal*, *6*(2), 39-48. https://doi.org/10.2752/146069203789355471
83. Tanenbaum, J., Tanenbaum, K., & Wakkary, R. (2012). Steampunk as design fiction. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1583-1592). ACM. https://doi.org/10.1145/2207676.2208279
84. Tchounikine, P. (2017). Designing for appropriation: A theoretical account. *Human–Computer Interaction*, *32*(4), 155-195. https://doi.org/10.1080/07370024.2016.1203263
85. Troiano, G. M., Pedersen, E. W., & Hornbæk, K. (2015). Deformable interfaces for performing music. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 377-386). ACM. https://doi.org/10.1145/2702123.2702492
86. Tsaknaki, V., & Fernaeus, Y. (2016). Expanding on Wabi-Sabi as a design resource in HCI. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 5970-5983). ACM. https://doi.org/10.1145/2858036.2858459

87. Unbehaun, D., Aal, K., Vaziri, D. D., Tolmie, P. D., Wieching, R., Randall, D., & Wulf, V. (2020). Social technology appropriation in dementia: Investigating the role of caregivers in engaging people with dementia with a videogame-based training system. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1-15). ACM. https://doi.org/10.1145/3313831.3376648
88. Vallgårda, A., & Sokoler, T. (2010). A material strategy: Exploring material properties of computers. *International Journal of Design*, *4*(3), 1-14.
89. Vallgårda, A., Winther, M., Mørch, N., & Vizer, E. E. (2015). Temporal form in interaction design. *International Journal of Design, 9*(3), 1-15.
90. Vasalou, A., Khaled, R., Gooch, D., & Benton, L. (2014). Problematizing cultural appropriation. In *Proceedings of the 1st symposium on computer-human interaction in play* (pp. 267-276). ACM. https://doi.org/10.1145/2658537.2658689
91. Wakkary, R., Desjardins, A., & Hauser, S. (2016). Unselfconscious interaction: A conceptual construct. *Interacting with Computers*, *28*(4), 501-520. https://doi.org/10.1093/iwc/iwv018
92. Wakkary, R., & Maestri, L. (2007). The resourcefulness of everyday design. In *Proceedings of the 6th conference on creativity & cognition* (pp. 163-172). ACM. https://doi.org/10.1145/1254960.1254984
93. Wakkary, R., & Maestri, L. (2008). Aspects of everyday design: Resourcefulness, adaptation, and emergence. *International Journal of Human-Computer Interaction, 24*(5), 478-491. https://doi.org/10.1080/10447310802142276
94. Wakkary, R., Odom, W., Hauser, S., Hertz, G., & Lin, H. (2015). Material speculation: Actual artifacts for critical inquiry. *Aarhus Series on Human Centered Computing, 1*(1), 12. https://doi.org/10.7146/aahcc.v1i1.21299
95. Wakkary, R., Oogjes, D., Lin, H. W., & Hauser, S. (2018). Philosophers living with the tilting bowl. In *Proceedings of the SIGCHI conference on human factors in computing systems* (Article No. 94). ACM. https://doi.org/10.1145/3173574.3173668
96. Wakkary, R., & Tanenbaum, K. (2009). A sustainable identity: The creativity of an everyday designer. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 365-374). ACM. https://doi.org/10.1145/1518701.1518761
97. Wallace, B., Martin, C. P., Tørresen, J., & Nymoen, K. (2021). Learning embodied sound-motion mappings: Evaluating AI-generated dance improvisation. In *Proceedings of the conference on creativity and cognition* (Article No. 43). ACM. https://doi.org/10.1145/3450741.3465245
98. Walz, S. P., & Deterding, S. (2015). *The gameful world: Approaches, issues, applications.* MIT Press.
99. Wiberg, M. (2018). *The materiality of interaction: Notes on the materials of interaction design.* MIT Press.
100. Wiberg, M., & Robles, E. (2010). Computational compositions: Aesthetics, materials, and interaction design. *International Journal of Design*, *4*(2), 65-76.
101. Yao, L., Niiyama, R., Ou, J., Follmer, S., Della Silva, C., & Ishii, H. (2013). PneUI: Pneumatically actuated soft composite materials for shape changing interfaces. In *Proceedings of the 26th annual symposium on user interface software and technology* (pp. 13-22). ACM. https://doi.org/10.1145/2501988.2502037
102. Yao, L., Ou, J., Cheng, C.-Y., Steiner, H., Wang, W., Wang, G., & Ishii, H. (2015). bioLogic: Natto cells as nanoactuators for shape changing interfaces. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1-10). ACM. https://doi.org/10.1145/2702123.2702611
103. Zhong, C., Wakkary, R., Chen, A. Y. S., & Oogjes, D. (2021). deformTable: Crafting a shape-changing device for creative appropriations over time. In *Proceedings of the conference on designing interactive systems* (pp. 1253-1265). ACM. https://doi.org/10.1145/3461778.3462112
104. Zhong, C., Wakkary, R., Odom, W., Chen, A. Y. S., Yoo, M., & Oogjes, D. (2022). On the design of deformTable: Attending to temporality and materiality for supporting everyday interactions with a shape-changing artifact. In *Proceedings of the conference on designing interactive systems* (pp. 1555-1564). ACM. https://doi.org/10.1145/3532106.3533501
105. Zhong, C., Wakkary, R., Zhang, X., & Chen, A. Y. S. (2020). transTexture lamp: Understanding lived experiences with deformation through a materiality lens. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1-13). ACM. https://doi.org/10.1145/3313831.3376721