Analyzing Artifact Interaction Complexity

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ABSTRACT

The underlying motivation for our research is the need for a deeper understanding of human-computer interaction that can speak to the increasingly varied and intricate forms of interactivity and interfaces that are present in everyday life. With this purpose in mind we have examined and 'tested' an already existing theoretical framework on interaction complexity. We have done this by applying an analytical, *artifactist* methodological approach. Our studies have led to both support and criticism of the existing framework, and allowed us to develop and extend it further. Our conclusion is that an artifactist approach has potential and that there is much to explore and learn by studying interaction and interactivity based on such an approach.

Author Keywords

HCI, interfaces, complexity, interaction design

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

In modern Western society, digital interactive artifacts are ubiquitous in people's everyday lives. Interactive artifacts are becoming more diverse in terms of their interactivity due to new forms of interaction, and the overall level of interactivity in everyday life seems to increase. These interactive artifacts provide functionality and usages that make them valuable, used, and loved. But they also challenge people with difficult-to-use interfaces and interaction requirements that sometimes lead to frustration.

Our research is based on the assumption that there is a need for a deeper understanding of human-computer interaction that can speak to the increasingly varied and intricate forms of interactivity that are present in everyday life. However, such an understanding requires analytical tools and theoretical frameworks that can support a more structured and nuanced analysis of interactive artifacts.

Problem and Purpose

Interactive artifacts present themselves to users as artifacts or systems with some form and kind of inner mechanism, as an interface, and as a way of interacting. What could or should be defined as an interface is today not easily determined. New technologies, new materials, and new form possibilities have led to highly diverse types and forms of interfaces. This diversity has, however, not been accompanied with enough attempts in our field aimed at developing concepts, theories and frameworks that can be used for detailed descriptive and analytical studies of artifacts, interactivity and interaction.

To achieve this we have examined or 'tested' an already existing theoretical framework about interaction complexity [7]. At the same time, we also had the purpose of exploring and experimenting with a more analytical *artifactist* research approach.

We will in the next section discuss our basic research approach and then give a background to the framework we have used and some core definitions. Following that, we will present our three studies. We will then discuss some findings and insights from the studies and what they mean in relation to our overall purpose. The paper ends with some conclusions regarding what this research could mean for the field of HCI research.

APPROACH

The constantly evolving new interactive reality with its new forms of interactive artifacts can be analyzed and studied in many different ways. Maybe the most dominant perspective in HCI research today is to approach it as a matter of usability or user experience. Within this perspective the user constitutes the starting point and the position from which analysis and measuring of quality is performed [5, 8, 10, 13]. This perspective is of course highly suitable if the purpose is to understand a particular artifact and its potential for real usage in a particular context.

There are also a large number of other approaches used in the field that are suitable for the study of interactive artifacts. Artifacts can be studied, for instance, as cultural artifacts, as organizational components, as social agents, as

communication channels, or as media. Each of these approaches lends itself to descriptions and explanations of interactive artifacts that accord with certain specific perspectives and purposes.

In our research we have chosen to engage in an approach that can be described as *analytical*. Such an approach has a focus on the interactive artifacts themselves—an *artifactist* approach [9, 14, 7]. In other words, it places the artifact and its specific qualities, character, properties and possibilities for interaction at the center of analysis.

Our purpose with taking such an approach is to explore the possibility of developing concepts that can be used to carefully describe, analyze and evaluate certain aspects of existing artifacts with a degree of 'objectivity'. The notion of 'objectivity' in any analysis of artifacts is, however, problematic, and to make a full account of and a well-formed argument for such an approach requires substantial elaborations. In this paper we will only briefly make that argument while hoping that our presented research will make the approach clear and compelling.

An artifactist approach means in a simplified way that the artifact itself is in focus and that it is analyzed objectively based on its intrinsic and formal qualities—not on how it is perceived and experienced by users in a use context (although of course this is related to some extent). The approach is similar to what is common in architectural practice where buildings are analyzed based on intrinsic qualities such as space, light, shapes, size, and relationships of elements. It is also related to what is sometimes called the study of 'formal' qualities of works of art: that is, taking the observable elements (e.g. length of lines, color, shape, weight, material, balance, proportions) as a starting point for a conversation about the 'nature' of a certain artifact. By creating some consensus about the 'formal' elements (what they should be, how to define them, how to apply them), it is then possible to build an argument for less obvious and more subjective interpretations or criticisms.

There is, of course, no such thing as objective or formal intrinsic properties in a philosophical sense, but if such an approach is combined with the idea of the *perspective of a designer* it makes more sense. When examining an artifact from the perspective of the designer, there are certain aspects or qualities of the artifact that a designer can control and manipulate, and others that the designer cannot. For instance, while user experience is an emergent quality that cannot be easily manipulated in any direct way by the designer, there are many other qualities that the designer can control, such as the choices of material, form, functionality, structure, etc. Our approach is based on the assumption that it is possible to objectively and productively analyze interactive artifacts when using an established conceptual framework and taking a designer's perspective when approaching artifacts.

In our attempt to analyze interactive artifacts, we have, as mentioned earlier, decided to focus on the notion of *interaction complexity*, particularly as it has been defined in [7]. Of course, when considering interaction in any form or shape, we cannot fully avoid to some extent constructing a user and envisioning how this user might interact with a given artifact; and as we do this, we draw on our own experiences and observations of such artifacts in use. This means that our analysis is never artifactist in any 'pure' sense. However, the *goal* of this activity is to develop concepts and frameworks that can make it possible to describe artifacts as objects and to examine their intrinsic formal qualities from a design perspective. Our hope is that this would also lead to a better understanding of what it is that makes certain interactive artifacts similar in some sense even though they may give rise to very different user experiences, or vice versa, why seemingly very different artifacts may lead to very similar experiences. It can become a way for the field to be able to develop typologies of interactive artifacts that could support a better understanding of interactivity and be useful in education of designers.

In [7], Janlert and Stolterman proposed a theoretical framework on how to analyze complex interaction and interactivity when it comes to digital interactive artifacts. Their approach is one example of an artifactist approach. However, the theoretical framework they propose is accompanied by very few empirical examples and even less by any organized study. We have therefore in our research conducted some empirical studies in order to 'test', critique, and potentially extend or develop the proposed framework, as well as to develop a sense of what methods might be appropriate for these kinds of analytical studies of artifacts.

COMPLEX INTERACTION—DEFINITION AND FRAMEWORK

The approach presented in [7] examines interactivity and interaction based on the notion of complexity. The authors' chosen core analytical concept is *complex interaction*. The argument is made that it is possible to analyze interactivity by assessing or 'measuring' complexity. It is important to note that the authors state clearly that complexity is only *one* aspect of interaction out of many [7]. They argue, however, that complexity is a crucial aspect of interactivity since it seems to influence qualities that are related to ease of use, control and automation, all which are relevant when it comes to human computer interaction.

The term *complexity* has many definitions; and in order to engage in careful analysis we need to have a deeper, more nuanced understanding of what we mean when we use the term. On an everyday level, *complex* might be understood as the opposite of *simple*. It also has a more scientific meaning in the context of complex systems science, which studies complexity as it exists in dynamic real-world systems such as biological systems, stock markets, and social networks [1].

Definitions of complexity usually revolve around having multiple parts and relationships. We can see this in the noun

form, as in an 'entertainment *complex*', as well as in the adjective. In addition to defining *complex* as consisting of various connected elements, the Oxford English Dictionary defines it as: "*Consisting of parts or elements not simply co-ordinated, but some of them involved in various degrees of subordination; complicated, involved, intricate; not easily analysed or disentangled.*"

This definition also points to the challenge of analyzing complexity and it emphasizes the importance and nature of the connection between elements, which may influence each other. When considering complexity, then, it is necessary to recognize its constituent *parts* and also the presence and nature of the *connections* between them. We have found both of these senses to be useful when trying to identify, tease apart and analyze various aspects of artifact interaction complexity.

There is of course nothing new in the idea of analyzing interaction. This has been done for a long time by influential researchers in our field. It is also not a new idea to approach interaction and interfaces as an issue of complexity, for instance, recently in [12]. It is quite obvious that the strong emphasis on usability [10, 11, 13] and later on user experience [8, 4, 5] is the result of a recognition that many interactive artifacts are complicated and difficult to use. The problem has been recognized as being related to human cognition and some research has been focused on finding the mental models that humans use in their interaction with complex artifacts and searching for potentially more appropriate models [11, 6, 2].

However, these approaches all establish their stance by taking the perspective from or via the *user*. Most of these approaches, if not all, do not in any detail describe or analyze the properties of the artifact, except from a secondary or consequential level. There are, however, attempts to develop *design patterns* for interactive artifacts that do have a partly artifactist perspective. These attempts are in most cases built on personal experiences and can be seen as attempts to develop some form of 'best practice'. This is perfectly fine from a practice and design point of view, but it does not provide the field with any well developed and foundationally sound frameworks based on research with a claim to be general.

Overall, we have not found any serious attempts at developing analytical artifactist approaches to the study of interaction in the sense we propose here. The research we have briefly discussed above has, however, influenced our work and is relevant in many ways.

A proposed framework
In [7], the authors go through existing approaches in some detail when it comes to complex interaction studies in HCI. They specifically discuss how complexity is handled when it comes to interaction design practice. But most importantly for this work, they propose a framework

suitable for the analysis of *complexity of interactive artifacts*.

The proposed framework is based on the notion that complexity can be understood as a quality residing in different locations. These locations or *loci* can be either components or relationships (see Figure 1).
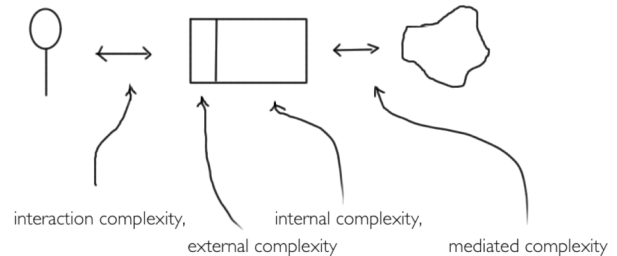

Figure 1. A visualization of the Janlert & Stolterman complex interaction framework [7]

The core elements in the figure are a *user* on the left side; an *artifact* with its interface facing the user in the middle; and on the right side, the "*material*", which is what the artifact and its functionality is examining, manipulating or drawing from. Interaction complexity is an emergent aspect that is located in the relation between the user and the interface. The framework distinguishes between and defines:

- *Internal complexity* as the complexity of the internal workings of the artifact.

- *External complexity* as the complexity of the artifact's interface with the outside world and the user.

- *Mediated complexity* as the complexity that is *not* located in the interior or on the exterior of the artifact but in the environment (material), channeled through the artifact and thereby impacting the level of interaction complexity (without changing the level of internal or external complexity).

- *Interaction complexity* as the complexity of the relation between input and output, between how the user and the outside world influence the artifact, and how the artifact influences the user and the outside world. The emerging interaction complexity is a result or consequence of an artifact's internal complexity, external complexity, and mediated complexity.

Given the framework it would be possible to 'measure' the *level* of each form of complexity and create complexity profiles for any interactive artifact. Such a profile may (with the possible measures: high, medium and low) look like this: *internal*-low; *external*-high, *mediated*-medium; *interaction*-high. In [7], the authors create some profiles by

analyzing some everyday artifacts. It is also clear from [7] that such complexity 'distributions' or 'profiles' can vary between artifacts in ways that are not easily and intuitively determined. There is thus a need for more empirical testing of the framework.

STUDIES

Since there are few examples of analytical studies of artifacts of this kind in our field, we chose to start our research in an open and exploratory way. After some initial discussions and attempts we decided to perform three types of studies. Two of these studies are in line with an artifactist analytical approach: one *compare and contrast* study and one *group artifact analysis* study. As a complement, we also conducted an *interview* study in order to explore how designers think about interaction complexity and how they define it.

The Compare and Contrast Study

In order to explore the concept of interaction complexity we decided to conduct an artifact analysis using the proposed framework. We considered this to be a logical next step given that this was to some extent done in [7], but not in any systematic or structured way.

Method and Findings

We identified and selected four classes of artifacts that had artifacts with identical purposes but differing designs within each class. The choice of the classes was based on criteria such as the 'everydayness' of the artifacts and diversity of designs, and also on our personal interests. In order to expand our analysis we decided to have one class of something less typical for our field, so we added espresso machines to the three digital artifact classes. All together we analyzed about 50 individual interactive artifacts. For each artifact we gathered images, some technical and/or functional descriptions, user manuals or instructions, and comments and reviews that related to our examination.

Each artifact was first analyzed by one individual in our group. That person later presented the artifact to the group where we discussed and analyzed each artifact again. By analyzing these artifacts, we aimed to identify the levels and differences in internal, external, interaction, and mediated complexity between the artifacts within each class. We also used these analyses to compare and contrast between the four classes of artifacts as an attempt to discover any particular patterns that would relate to class properties. All these activities were primarily attempts to support a critical reflection on the framework itself.

For every artifact we tried to determine the level of complexity for each of the different types (internal, external, interaction, and mediated). The ambition was to explore and test the statement made in [7] that it would be possible through careful examination of artifacts to establish a *complexity profile*. As a measure of each form of complexity we decided to work with the rough level descriptors of *low*, *medium*, and *high*. We found, however,

that even with such crude measures it was quite difficult to come to an agreement on what levels were correct for each artifact.

Continuing the exploration of artifacts from [7], we examined twenty television remote controls (see Figure 2). These ranged from those that were purely novel (like a light saber remote), to those with very few buttons or many buttons, and those with unique forms of input (a voice controlled robot remote and a motion controlled wand remote).
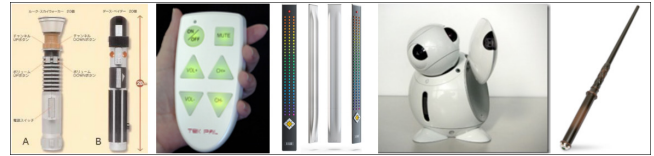

Figure 2. Examples of analyzed TV remote controls

As another class of artifacts, we chose to examine seven espresso machines (see Figure 3). The machines ranged from one machine where the process of creating an espresso was fully automated by the touch of a button, with reminders given to users to do certain functions such as refilling beans, to a traditional espresso machine with completely manual controls.

Figure 3. Examples of analyzed espresso machines

For another class of artifacts, we studied nine video game controllers (see Figure 4). The controllers present different interfaces and functionality; for instance, the controllers for the XBOX 360 have buttons, analog sticks, and a control pad. Users give inputs to the games they are playing through presses on the control pad and buttons, and movements of thumbs on the analog sticks. With the Wii remote controller analog sticks are not used, but rather buttons, motion controls, and an infrared laser. The XBOX Kinect, on the other hand, is a physical device without any buttons whatsoever that relies instead on the user's entire body itself as controller via motions and poses.

Figure 4. Examples of analyzed game controls

The final class of artifacts that we analyzed was a collection of fourteen keyboards (see Figure 5). We looked at traditional keyboards with the keys arranged in the typical layout but designed for different purposes, such as

Microsoft's Ergonomic Keyboard 4000 (for increased ergonomics) and Maxi-Aids' Keys-U-See keyboard (for accessibility). However, some keyboards' layouts were altered to serve certain purposes, like the Maxi-Aids' Maltron Left-Handed Keyboard (for quick single-handed data entry) and Wolfking's Warrior XXtreme Keyboard (for gaming).

Figure 5. Examples of analyzed keyboards

Reflection
The analysis of these four classes of artifacts led to further discussions on how to define and measure internal, external, interaction, and mediated complexities. We found that analyzing such a large number of artifacts with fairly similar purposes is both challenging and intriguing. Our analysis forced us many times to reconsider our assumptions and preconceptions about the artifacts. We had methodological problems with separating notions of "ease of use" from complexity—that is, to stay with an artifactist lens instead of taking a user's perspective. Although we had considerable difficulty in some cases in sorting out various aspects of complexity and describing them conclusively, we found that the framework at least helped us to have these conversations and to recognize aspects of artifacts we had not previously considered but that we now recognize as having a significant bearing on the nature of their interactivity.

The Interview Study
After our 'compare and contrast study' we felt the need to relate our findings to how interaction designers themselves think about interaction complexity, whether explicitly or implicitly. We thus decided to conduct an interview study, using some of the findings from the first study as input. The purpose of the interviews was to gather information about how interaction designers think about interaction complexity, how they define it, and how they approach it during their design processes.

Method and Findings
We interviewed ten interaction designers with somewhat different backgrounds and competence. The interviewees were advanced PhD or MS students in HCI, all with experience in academic settings and with substantial industry practice.

Questions in our interview study included, among others: give an example of a complex and a non-complex interactive artifact; give an example of a complex artifact you have designed; how would you define complexity when it comes to interaction and interactive artifacts; how would you deal with complexity in a design process; what is your design strategy when it comes to dealing with complexity; what do you see as good and bad consequences in relation to interaction complexity; how does interaction complexity relate to user experience?

The interviews were conducted in an open way that made it possible to focus on any aspect of the topic that the interviewee saw relevant. We used the results from the interviews in formulating more questions about the nature of interaction complexity and developing a more solid grounding for potential aspects that we could use in our own analysis.

We will here only briefly present some of the insights from the interviews. These are very condensed summaries of what appeared as topics in the interviewee's responses.

Complexity related to task. Interaction complexity may be a consequence of the complexity of the task that the artifact is designed to handle. The amount of effort required to perform a task translates into the level of sophisticated or complex control required. This would mean that interaction complexity is not possible to 'control' as a designer; instead it is a given.

Complexity related to predictability. There is a difference between perceived complexity and 'real' complexity. When it is possible to predict artifact behavior it may not be an example of complex interaction. Designers can influence the level of perceived complexity.

Complexity related to functionality. Complexity facilitates multiple interaction actions. There is a level of complexity related to number of possible states (e.g., a chair has only one state, while some interactive artifacts may have thousands). Complexity has to do with functionality and is therefore to some extent given and cannot be 'designed away'.

Complexity related to complicated/simple. Complicated interaction can be described as difficult, clunky, ugly, awkward, while complex can be thought of as the opposite of simple (e.g., tasting food or wine).

Complexity related to good/bad. Complexity is not inherently good or bad. Complexity can mean diversity, human engagement, richness, while it can also relate to things such as time, effort, anger, and frustration.

Complexity related to skilled use. Designing for skilled use might mean higher complexity, but also higher rewards for the user. What is considered to be complexity in interaction is related to the level of skill of the user.

Reflection
The insights we gained from the interview study were not clearly focused or obvious. However, the study showed that it is possible to discuss interaction complexity with interaction designers and that they are able to reflect upon the different aspects of the phenomena that we presented to them. But it was also clear that there is no existing framework or concepts available that makes it easy to find a common language for description of interaction complexity

or a common understanding. The interviews were quite arduous and involved a lot of "what do you mean?" from both the interviewer and the interviewee. Overall, however, the interviews did provide us with a lot of materials and, most of all, they helped us to develop questions that we used to examine our own presuppositions and understandings.

The Group Artifact Analysis Study

After conducting the interview study and reflecting upon the difficulties we encountered, we began to wonder how we ourselves would discuss interaction complexity if we asked ourselves similar questions or tried to talk about the complexity of specific artifacts together. So next we decided to analyze artifacts together as a group in order to get a more conclusive and consensual analysis of the artifacts used during our investigations. Additionally, we hoped to possibly discover a more refined and systematic method or technique for analyzing artifacts.

Method and Findings

We extensively scrutinized two artifacts as a group, using the framework as well as the insights gained through our individually collected and analyzed artifacts and interviews.

We decided to analyze a television remote control and an XBOX 360 game controller due to their shared functionality as television interface devices as well as the functional differences suggested by their relative usage scenarios. We had an assortment of remote controllers and a game controller physically present with us, alternately holding, interacting with, and referring to them during our discussion and analysis.

We analyzed one artifact at a time while one member of the group took notes using mind-mapping software to construct a visual hierarchy of the analysis results. We started with an analysis of the external features of the artifacts, and continued our investigation by discussing the interactive capabilities and use case scenarios to account for the mediated complexity present in each artifact analyzed.

We used mind-mapping software to account for and to categorize the complexities present in the elements of the individual artifacts under our investigation. The mind-mapping technique allowed us to quickly record and create a visual hierarchy of these elements, which resulted in an account of our analysis that at once created a quick reference as well as a way to find and annotate interesting relationships between the various elements present in an individual artifact and other artifacts.

Reflection

This study assisted our group in arriving at a more thorough representation of the artifacts in question and how best to represent those artifacts with respect to their relevant external, internal, interaction, and mediated complexities. Through this examination we were able to refine our analysis and the analysis process by bringing our individual techniques and understandings of the artifact complexity model to bear on actual artifacts from our collection of interactive artifacts.

FINDINGS AND INSIGHTS

The overall approach of this research proved to be appropriate in relation to the purpose with which we began. We did gain insights in both the nature of artifact complexity and the proposed framework. We also had valuable experiences with how to conduct analytical examinations of artifacts.

We have structured our results in three sections. The first section on *interaction complexity findings* deals with findings related to the actual examinations of interaction complexity and artifacts. The second section is about *visualizing interaction complexity*. This is something that we had not planned to work on, but we often found ourselves being engaged in questions around how to visualize the framework and our findings. The third section addresses *methodological findings*, in which we discuss the analytical artifactist approach, its pros and cons, and its usefulness.

Interaction Complexity Findings

We will here discuss some overall insights about the framework as such but also briefly comment on each of the particular types of complexity and how our study relates to the existing definitions of these concepts [7]. We will also add some insights about aspects of complexity that our studies brought out and that stood out as particularly interesting in relation to our purpose.

The Framework

Overall the framework that we set out to examine and test in our studies proved to be inspiring and did promote serious and in-depth discussions about the nature of interaction complexity and of the nature of interactive artifacts in general. Throughout the studies we engaged in endless discussions regarding the nature of the framework in which we tried to critique its definitions and elements.

However, we did find that our overall conception of interaction complexity and complexity profiles became more complicated as we discussed various artifacts. One artifact in particular that we kept coming back to was the violin, an example also discussed in [7]. This example was both challenging and compelling for our purposes: challenging in that it involves the interaction of many different kinds of complexity, and compelling in the ways that it, as an artifact, can facilitate both virtuosity and beauty. A violin is in itself a quite 'simple' thing in terms of its number of parts and their configuration, and also in its general mechanism for interactivity. However, in actual practice and in the hands of a skilled performer, interaction with it is highly complex. Further, in discussing this example in particular we found it necessary to bring other variables such as personal attributes and skill, context, purpose, history, and culture into the analysis. In other

words, a good deal of the complexity of skilled violin performance does not reside in the artifact itself, but is rather *channeled through it* in a sort of extreme case of mediated complexity. This is probably not the case with most of the digital artifacts that are the primary intended objects of this framework. But it is at least interesting to use violin 'interactivity' as a prototypical case of virtuosity and richness, and to consider how digital artifacts could potentially be designed to allow for similar qualities. It is interesting to note that this might involve making the actual artifact *less* complex—something that might be counterintuitive in terms of more traditional HCI design.

In [7] the authors present a set of tradeoffs when it comes to the framework, that is, the different forms of complexity are intertwined in a way that makes it impossible to manipulate one form of complexity independently from the others. For instance, changing internal complexity has a tradeoff when it comes to external complexity and vice versa. We found these tradeoffs to be highly interesting and challenging to discuss in relation to our findings. Although we have not yet been able to clearly formulate these insights in any detailed way, the results show that understanding these relationships and tradeoffs could be of potential value to interaction design.

Internal complexity.
We did not have any serious problems analyzing internal complexity as defined in [7]. This is probably the most straightforward type of complexity. We did, however, have a problem with the question of whether all digital artifacts should 'automatically' be treated as having high internal complexity due to the complex nature of electronic hardware. Is this a valid and useful way to approach internal complexity or should/could some electronics have low or medium complexity?

External complexity.
During the analysis we experienced some difficulties with determining and measuring external complexity. It was for instance a challenge when we approached some newer technology, such as the Kinect. With the development of new interface solutions with sensors of different kinds, it becomes quite difficult to even determine what the interface *is*, let alone whether it is complex or not. However, we do not see this as necessarily a problem with the definition of external complexity. It may be a consequence of the unfamiliarity that comes with new technology. External complexity also became a challenge when we approached artifacts that combined analog with digital controls and interfaces. Again, we do not necessarily see this as a major issue with the definition. We are, however, convinced that an analysis of external complexity when it comes to digital interactive artifacts does pose difficult challenges. Yet at the same time, we found it rewarding since it did reveal and change many of our intuitive preconceptions about what would be regarded as high or low external complexity.

Mediated complexity.
Maybe the biggest challenge in our study was to arrive at an understanding of mediated complexity. We realized that we had to expand the definition in [7] in order to bring in other factors such as personal variables and skills, experience, culture, history, etc. This was especially true in the case of the violin, as discussed earlier, but was also true of artifacts such as keyboards.

Mediated complexity is in a sense the 'interface' between the artifact and the way it interacts with the real world—and all of the social and experiential complexity that entails. So it is perhaps unsurprising that it is also one of the most challenging to analyze. However, the results indicate that analyzing mediated complexity is possible, and that it is value in an artifactist approach even as other variables outside of artifacts themselves are recognized and included.

Interaction complexity.
Interaction complexity is maybe the simplest form of complexity and at the same time the most complicated. It is the form of complexity that emerges or appears in and during the use of an artifact. In our analysis we did not have any substantial problems with determining interaction complexity but we did have many discussions about how to account for the emergent quality of many interactions given the back and forth between artifacts and people in specific contexts.

Apart from the examination and testing of the framework, our studies also led to several insights in relation to more detailed aspects of artifact complexity.

Virtuosity. In [7] the authors discuss the notion of virtuosity in relation to interaction complexity. They make the case that virtuosity by a user might not be easy or even possible to achieve with any kind of interactive artifact and that there might be a connection between the complexity profile of an artifact and the posibility for virtuosity in use. In our studies we paid a lot of attention to this question and found some aspects of complexity that seem to relate to virtuosity. There seems, for instance, to be a difference between an artifact in the form of a remote control and those in the form of a violin or an espresso machine. The latter two allow for a certain kind of virtuosity, whereas the fomer does not. Or, if it does, we have not been able to determine what that would look like. One exciting and unanswered question is: Why this is the case?

The most salient difference between the types of artifacts we analyzed is perhaps the nature of their controls. A remote control typically has a set of discrete buttons, with a button press (or combination of them) performing a certain operation. The way in which a button is pressed generally does not affect the function that is performed. It may be pressed firmly, gently, quickly, or for a long period of time: in most cases they all have the same result. On the other hand, when it comes to a violin or a (high-end) espresso machine, the controls are much different. Instead of discrete

controls, the 'controls' are continuous, and even subtle differences in pressure on a string or timing in the turn of a knob can significantly shape the effect that is produced. This is at least one aspect of why a violinist or a barista is able to achieve virtuosity with regard to their tools.

Coupling. If we look more closely at this relationship between virtuoso and artifact, we can see that there is a high degree of *coupling* between person and artifact. We might think of this as the *number of points* at which they are connected in such a way that the movements of the body have some bearing on the outcome that is produced with the artifact. For example, a musician's posture, breathing, and—of course—intricate movements all affect the sound that is produced. On the other hand, none of these things matter when using a remote control or another selection-style device. However, the coupling is clearly different when comparing the artifacts we analyzed. Some designs encourage or support close coupling while other do not.

Intrinsic versus strategic motivation. There are also various motivations for engaging with an artifact that shape the way it is used. Some of that motivation is inscribed in the actual design as a consequence of its purpose. For instance, the interaction with a remote control is *strategic*: it is a *means* used to accomplish a certain *end*, and it is the end that matters. On the other hand, in a video game there is ostensibly an end to be achieved, but it is clearly not the only motivation. The motivation is *intrinsic* to the interaction activity itself, and the end is pursued primarily for the purpose of having the experience of the interaction itself. And of course sometimes both motivations might be present, which might be the case for an espresso machine where the actvity itself is a source of pleasure even as a very definite end is pursued.

Scope and level of analysis. In addition to bodily levels of connection, there are also broader 'connection points' that contribute to the complexity of interaction with artifacts. For example, in the case of a high-end espresso machine, there is also the complexity of the coffee beans used and their various attributes (origin, blend, roast, age, grind, etc.) that affect the outcome and potentially how the barista pulls a shot. Broadening the analysis still further, there is also the rich history of espresso making that feeds into a barista's practice through her training, and the current culture and state of the art that determine what counts as excellence. In the case of the violin, there is similarly a rich history and culture that feed into performance. Additionally, there is the complexity that is specific to the performance context: the venue, acoustics, size, audience, time, other musicians, history, etc.

When analyzing complexity it is clear that the analysis could encompass an almost innumerable number of elements. Thus, part of any such analysis must be determining the appropriate *scope* and *level of analysis*. Also, it should be emphasized that an artifactist approach can be maintained even as the scope of the analysis is broadened to include aspects outside of the artifact itself.

Visualizing Interaction Complexity

In diving more deeply into various manifestations of complexity in relation to artifacts, we found that there were multiple layers of influence and connection to be untangled. Even though this in some ways pulled us away from the artifactist approach and the framework we felt a need to be able to contextualize our findings.

Beginning with a focus on the artifact itself, the next obvious piece of the picture to be considered is the *person* who interacts with the artifact. This person acts within a specific context and with a specific purpose, which is itself shaped by the broader *culture* in which it is embedded

We realized that in our attempts to describe the 'landscape' we were studying, we intuitively engaged in the creation of different forms of visualizations. In most cases our visualizations emerged on our whiteboards as a way to explain to each other what we meant. We realized that these visualizations worked as analytical tools in themselves, and we became convinced that any examination of interaction complexity needs some kind of visualization for both analysis and communication. We used several forms of visualizations, but will here show only one that we found ourselves coming back to.

In order to visualize the interaction complexity 'landscape', we used a set of concentric circles to represent different *layers*. In this particular visualization (see Figure 6) we can also recognize the location of different types of complexity. Internal complexity is obviously contained within the artifact, and external complexity is located at the interface between artifact and person. Mediated complexity is located at the interface between person and context, with interaction complexity emerging through the interplay of external and mediated complexity.

We have found that it is also possible to modify the diagram in order to reflect on and analyze particular artifacts. For example, the size of the different circles can be changed in order to reflect the importance or significance of each layer in a given situation in terms of its contribution to the overall interaction complexity.
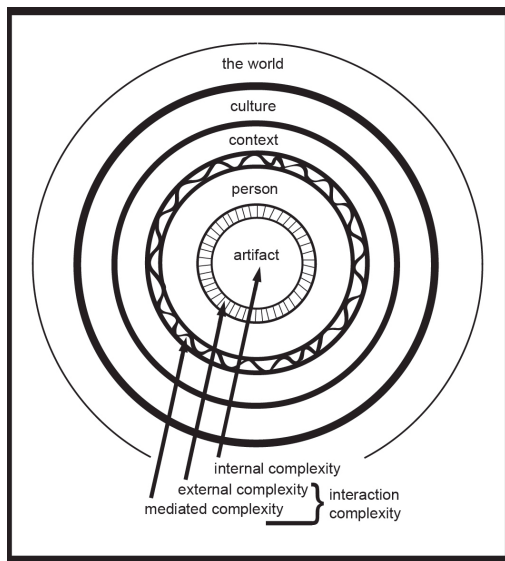
Figure 6. A basic generic depiction of the interaction complexity 'landscape'

So in the case of the remote control (Figure 7), the skills and experience of the person and the influence of culture are not that important. On the other hand, in the case of the violin (Figure 8) the skills and experience of the person are extremely important, as is the broader history and culture in which violin performance and notions of musical excellence are embedded.
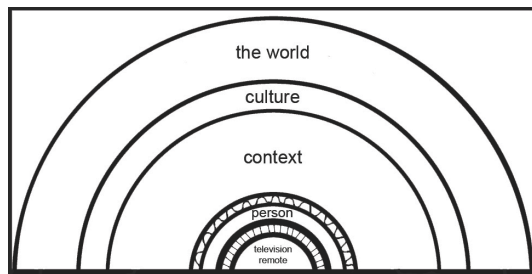
Figure 7. Visualization of the complexity profile for a TV remote

The nature and significance of the interface between the different layers can also be visualized. A thicker boundary, representing the boarder between two layers, represents greater signficance of that associated type of complexity for contributing to the overall interaction. The texture of the boundary (jagged or wavy) can also be used to speak to the degree of coupling or number of connection points at that interface. So the interface between a remote control and a person is not at all tightly coupled, whereas that between a violin and a violinist is highly coupled and significant. Finally, the overall size of the diagram can speak to the overall level of complexity: the larger the diagram, the greater the complexity (although this is not depicted in the examples here due to space constraints).
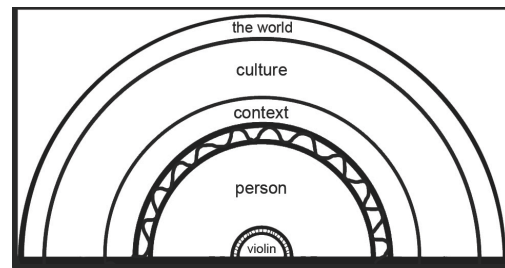
Figure 8. Visualization of the complexity profile for a violin

The purpose of this visualization is not to provide a conclusive representation of any distinct aspect of complexity and interaction, but rather to serve as an analytic descriptive tool that can be helpful in sorting out various aspects of complexity in specific cases. The circle with the artifact at the center is also significant in that it reminds us to focus on the artifact, and to see complexity not so much as a certain configuration or series of actions, but rather as an emergent and dynamic property that is always already embedded in higher-order complexity. However, this is only one of many potential analytic visualization tools that could be used.

Methodological Findings and Reflections

Our research also had methodological ambitions. We did take on this research as a way to explore a more artifact-oriented approach: that is, analytical studies of interactive artifacts that are not primarily from the perspective of use or the user.

We found the approach to be quite intriguing, but at the same time difficult. We found that we occasionally had left the analytical perspective and taken on a 'usability' or 'user' perspective. This was not necessarily a problem for us, since it helped us to become more aware of what would/could be analytical and/or formal qualities in the artifacts we studied.

The results of our analysis show that an analytical approach can support the development of a more critical sensibility towards some qualities of interactive artifacts that otherwise seem blatantly obvious or remarkably subtle. For instance, the level of external complexity seemed in many cases to be quite obvious, but we also found that with careful analysis the 'true' nature of external complexity was much more complex and difficult to grasp. We also found that very subtle and minute differences between the designs of interfaces in some cases had serious consequences when we tried to establish the level of external complexity.

The approach of using the framework and its core concepts really pushed us to explore and expand our own understanding of complex interaction and interaction as such. The research results suggest that (1) using the framework, (2) analyzing many artifacts in detail, and (3) comparing and contrasting artifacts, is an effective, though challenging, approach to developing design knowledge and competence related to interaction and complexity.

We found that through engaging with these concepts we developed both knowledge about and a sensibility towards interactive qualities. We see this to be similar to what is the process and goal of the type of analysis of buildings that is pervasive in architectural educations, or of art in art appreciation classes, or of wine through wine tasting. In these cases the analysis is done with the purpose of developing an internalized sensibility towards subtle but distinct qualities. The process relates to what Elliot Eisner calls *connoisseurship* [3]. It is a process that is not about finding the purely subjective personal qualities of an artifact, but an attempt to develop a common understanding through the creation of a language that relates to intrinsic or formal qualities of the artifact, art piece, wine, or building.

The process of doing analytical studies thus has several benefits. It is a process that can lead to the concrete development of concepts, frameworks, and theories—that is, a development of a descriptive and analytical language. But, it is also an approach that has benefits as a personal learning approach since it leads to a constant challenge of personal presuppositions, assumptions, and opinions about artifacts and designs in a way that can lead to development of personal competence and sensibility to interactive qualities.

CONCLUSION AND FUTURE RESEARCH
Our studies indicate that paying close attention to interaction and interactivity in an analytical way has potential. Our studies 'forced' us to realize that many of our own assumptions about interactivity and interaction are not well grounded. For instance, what it is that makes a particular interaction with an artifact to be experienced as complex, difficult, easy or simple is not easy or straightforward to determine. In many cases during our studies we had to reexamine our intuitive assumptions for why an artifact is experienced as 'difficult to use' or what really constituted complexity of a particular interface.

Our studies have shown that a lot of work has to be put into the exploration of how to analytically study interactive artifacts. There is a need for the development of appropriate methods and techniques, but maybe even more there is a need for good examples where interactive artifacts have been closely analyzed, described, compared, and evaluated based on a well developed conceptual framework focusing on some particular aspects of interactivity. In this paper we have only focused on the aspect of complexity. As we mentioned earlier, there are many other potential aspects of interactivity that can be studied with the same kind of analytical approach.

However, our studies have also shown that detailed and carefully conducted analytical studies in general are valuable and do provide insights and knowledge about interactive artifacts that are different from findings that come out of research focused on user experience. We see a promising future in analytical artifactist research in human computer interaction.

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