Interactivity Attributes: A New Way of Thinking and Describing Interactivity

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ABSTRACT
We propose a new perspective, seeing interactivity that is the immaterial part of an interactive artifact as something concretely describable and perceivable as we do with physical materials. In order to examine the validity of this proposal, we extracted a set of interactivity attributes to be used as a design language for thinking and describing interactivity in a new way, and conducted an online survey with 14 Flash prototypes representing pairs of values of 7 interactivity attributes we extracted. The result showed that all the interactivity attributes were significant, and participants experienced distinctive and meaningful emotional effects for different interactivity attributes.

Author Keywords
Interaction design, interactivity, design language, emotion

ACM Classification Keywords
H.5.2 [User Interfaces]: Theory and methods, User-centered design.

INTRODUCTION
The evolution of human-computer interaction techniques is ever ongoing. As we see from the "command user interface (CUI)" [5], evolved to GUI, to TUI, to embodied interaction, and to ambient devices over time, the forms of interfaces are not confined by a one standardized format. And all these different forms of interfaces are mixed with each other to find the ways to have a symbiotic life together. Researchers have recognized this issue and there has actually been an attempt to integrate these different forms of interaction techniques. Reality-Based Interaction (RBI [7] is an approach for this, and searches a commonality of emerging interaction techniques.

Although the approach like RBI provides a unifying framework for describing and evaluating currently emerging interaction techniques in terms of the level of reality experienced in those techniques, the "unifying" framework still filters them through only one common value of the systems, in this case that is, "reality" based on their visual forms and usage patterns.

Our research here focuses on providing a new way of thinking and describing *interactivity regardless of its manifested forms*. In this regard, our approach can also be seen as an attempt to explore a way of unifying and integrating different styles of interaction techniques, but the focal point of ours in this paper is on examining the fundamental nature of interactivity, starting from examining it with a graphical user interface form, in order to figure out whether the nature of interactivity itself is concretely describable and such a description is meaningful or not.

The aim of our research is to *develop a set of attributes that works as a language to describe the shape of any interactivity of an interactive artifact*. We call these attributes, *interactivity attributes*. This proposal is motivated by the limitations of the existing trials of developing frameworks and taxonomies for interaction design based on physically and visually manifested patterns of existing interaction techniques. To this end, instead of focusing on the visible aspects of interaction techniques such as manifested forms of interfaces and usage patterns of those interfaces, we start to explore the importance of invisible qualities of interaction as a way to describe the shape of interactivity. [1]

The discussion of this invisible quality of interaction is not new. The terms like "kinesthetic thinking" [12] emphasizes the collective effects of behavioral and cognitive experiences through dynamic interactions between a user and a system. Löwgren and Stolterman also used a term, digital material [8] to emphasize the immateriality of digital artifacts. In the book, "Improvisational Design," [6] Ishizaki emphasizes the dynamic quality of digital media, and tries to provide a set of formal dimensions to directly connect the expressed design with computational expressions. The importance of time and space in interaction design which are the core elements to distinguish interactive artifacts from other non-interactive artifacts in terms of their expressed forms is discussed in [4] as well. Crawford in his book [2] introduces a specific definition of interaction and interactivity, which again also

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[1] The term, interactivity, particularly indicates the dynamic aspect of interaction, which is the invisible quality of interaction [3]. Therefore, we use the term, "interactivity," instead of "interaction."

emphasizes the invisible quality of interactive artifacts, where the quality is more about the communicative aspect of interaction, consisting of listening, thinking, and speaking.

Although many have emphasized the significance of these dynamic and immaterial aspects of interaction in designing interactive artifacts, there has not been an attempt to develop a design language that may help concretely describe the *shape* of such an invisible quality of interaction. In our research, we hypothesize that *such an invisible quality is concretely describable, similar to the way of describing physical materials.* In our previous publication related to this concept [8], we explored the possibility of describing the shape of interactivity through a set of interactivity attributes that were initially identified through a bottom-up approach by examining various types of existing interactive artifacts. In this research, not only we present the refined version of the set of interactivity attributes based on our previous publication, we examine the validity of such an invisible quality of interaction, namely the shape of interactivity, through our carefully designed online survey with prototypes.

A NEW MODEL OF DESCRIBING INTERACTIVITY

Our goal of this research is to enable interaction designers to "see" and "manipulate" the invisible quality of interaction, which we call the shape of interactivity, when designing interactive artifacts. We assume that this invisible quality is also fully felt and experienced while people are interacting with interactive artifacts. In [10], although this paper focuses only the design of displaying forms, Mutlu et al. showed that various forms of dynamic animations of a visual display devised by different behavioral attributes evoked socially meaningful emotions. In this research, we propose a set of attributes which can be used to describe the shape of *interactivity* as we describe physical materials with their attributes.

Knowing and being able to describe and manipulate materials has always been a central part of design practice [1]. We also recently saw an attempt to materialize the computational power through the composites like smart materials, proposed by [13]. To enable designers to be reflective on their crafting process of generating and refining design ideas, knowledge of material properties which provides a language to describe and manipulate their designs is critical. We see that our attempt here is to open up a new design space where interaction designers can build the knowledge of the material-like immaterial that may enable a new way of thinking for designing an interactive artifact.

Interactivity Attributes for Describing the Shape of Interactivity

Our idea of describing the immaterial part of an interactive artifact, namely, the shape of interactivity, is based on the idea of viewing interaction as a separable entity to be designed, detached from embodied physical materials. We introduced this model of the relationship among what matters in interaction design such as user experience, interaction, and physical artifact forms in our previous publication [8].

We refined our first set of interactivity attributes proposed in [8] and finalized them to the 7 attributes for this research as shown in Table 1. Each example prototype we developed shown in Table 1 is designed to represent one of two opposite values of each interactivity attribute.

Interactivity attributes	**Example Flash prototype pairs representing each attribute[2]**	
Concurrency (concurrent-sequential)	 (concurrent) circles move concurrently	 (sequential) circles move sequentially
Continuity (continuous-discrete)	 (continuous) continuously dragging on the slide	 (discrete) discretely pushing the buttons
Expectedness (expected-unexpected)	 (expected) each circle moves to the nearest place	 (unexpected) each circle moves to a random place
Movement range (narrow R.-wide R.)	 (narrow range) when a cursor is near to the circles, they move in a narrow range	 (wide range) when a cursor is near to the circles, they move in a wide range
Movement speed (fast-slow)	 (fast) when a cursor is near to a circle, it moves quickly	 (slow) when a cursor is near to a circle, it moves slowly
Proximity (precise-proximate)	 (precise) the number shows the exact size of the circle	 (proximate) there is no precise number showing the circle size
Response speed (delayed R.-prompt R.)	 (delayed response) several clicks of each circle makes it moved	 (prompt response) just one click makes it moved

Table 1. The list of interactivity attributes.

USER STUDY

In this research, we were interested in examining whether these invisible qualities, namely *interactivity attributes*, are meaningful in terms of people's experience with an interactive artifact or not. If these attributes are clearly perceivable while interacting with an interactive artifact, and they provoke some consistent and meaningful patterns of emotional effects, then we should consider that these attributes are important and consciously to be concerned and researched in interaction design.

In order to figure out these issues, we devised and conducted a user study based on the following two research questions in mind:

i. Are interactivity attributes perceivable as we perceive the attributes of physical materials?
ii. Do interactivity attributes have meaningful emotional effects as other physical materials have?

[2] To see how each of these Flash prototypes works, please refer to our movie file uploaded along with this paper.

Study Setup

For this user study, we devised an online questionnaire with Flash prototypes representing a value of each interactivity attribute. The 14 prototypes shown in Table 1 are the ones we designed for our online questionnaire. In this research, we start from examining interactivity expressed by 2D graphic interactions. For each interactivity attribute, we had a pair of prototypes, representing two opposite values. For example, for the *concurrency* interactivity attribute, we had a prototype representing the *concurrent* value, and another prototype representing the *sequential* value. For each prototype, we asked two types of questions for the online questionnaire: 1) one about whether people can clearly *perceive* the represented interactivity quality or not, and 2) the other about what people *feel* from the represented interactivity quality. In order to make sure if people answered to the questions earnestly, we first asked open-ended questions, and then asked a set of semantic differential questions, examining participants' recognition of the corresponding interactivity attribute value and feelings toward that interactivity quality. Each participant needed to go through total 56 questions—i.e. for each prototype among the total 14 prototypes, two open-ended questions and two sets of semantic differentials (one for an interactivity perception semantic differential pair and the other for the set of emotional feeling semantic differential pairs (Table 2)) were assigned. The semantic differential pairs for emotional qualities were extracted, based on Norman's three levels of emotion [11], namely, visceral, behavioral, and reflective.

Type	Adjective pairs for the semantic differentials
Visceral	heavy-light spicy-bland soft-hard
Behavioral	simple-complicated deep-shallow clear-ambiguous
Reflective	natural-artificial exotic-mundane sympathetic-unsympathetic digital-analog

Table 2. The list of emotional quality pairs used for the study.

We took only the data (samples) that sincerely answered on the open-ended questions as well as the ones that answered all the questions. There were total 193 people participated, but due to this reason, we took only 106 samples out of 193 for our analysis.

The average of participants' ages was 22.15 (N=106, SD=2.995). Most of them were university students except two participants—one was a writer and the other was working for a broadcasting station. The participants were asked to interact with the corresponding prototype for a few minutes before they answer any questions given to each prototype. In order to minimize the effect from the order of the prototypes, we prepared 5 different sets of questionnaires with 5 different orders, and randomly assigned one of these five to each participant.

Study Results

We analyzed the data using Wilcoxon's paired signed rank test since the data gathered cannot be assumed as parametric data and each participant needed to go through all the 14 prototypes. First, we ran this test to answer the first research question, "Are interactivity attributes perceivable?" It turns out that the 'Z' values from the Wilcoxon's paired signed rank test for the descriptive adjective pairs of **all** the interactivity attributes showed significance ($-8.812 < Z < -7.314$; $p=0.000$ for all the attributes). This means that all the interactivity attributes were meaningful—that is, people can perceptively recognize and distinguish all those interactivity attributes.

Second, we ran this test to answer the second research question, "Do interactivity attributes have meaningful emotional effects?" Almost all the emotional qualities seem to be meaningful based on the results from the Wilcoxon's test for comparing the values of emotional quality pairs, although there are some meaningless ones. Table 3 shows how many emotional quality pairs showed significance in the Wilcoxon's test for each interactivity attribute.

Attributes	No. of meaningful emotional qualities
Concurrency	6 out of 10 (60%)
Continuity	9 out of 10 (90%)
Expectedness	7 out of 10 (70%)
Movement range	6 out of 10 (60%)
Movement speed	8 out of 10 (80%)
Proximity	9 out of 10 (90%)
Response speed	9 out of 10 (90%)

Table 3. The number of meaningful emotional qualities shown significance in Wilcoxon's test for each interactivity attribute.

In Table 4, we summarize which emotional quality is caused by which interactivity attribute values. We believe that this information is very important and meaningful in interaction design since designers can consciously explore such emotional effects when manipulating the interactivity qualities for their design of an interactive artifact. This kind of exploration in design is not anymore confined by physical material attributes. The invisible qualities of interaction also take a significant part of determining such effects.

In addition, the answers for the open-ended questions, especially about their emotional feelings of using each prototype, were very interesting as well. Although they interacted with 2-dimnensional graphic-based Flash prototypes, their expressions were more like *the feelings of touching or manipulating real physical things*. For example, several participants wrote that they feel like using a magnetic bar, rotating a jog dial, pushing a domino bar, touching jelly, pushing a small ball with a large ball, using a touch screen, and etc. Although all the prototypes were manipulated with a mouse, they expressed these feelings, associating various physical objects. Another notable result was that many participants (24 people) wrote that they *feel like interacting with something alive*. They sometimes used some adjectives that are mostly associated with living animals such as cute, smiling, running away, and etc. Many

participants (18 people) wrote that they *feel like using something placed in another space* such as water, windy air, oil, inside of jelly, and etc. Although the interaction took in a conventional 2D computer display, people felt something more than that, which is not actually caused by physical manifestation but an invisible and imagined quality.

The results here also imply that the emotional feelings the participants expressed seemed not to be confined by the 2D forms of the interfaces since they expressed that they felt like using various different forms of physical objects and materials. Their experience of interactivity is rather to be independent from its manifested forms.

Emotional qualities	Relevant interactivity attribute values (only the ones showed significance in Wilcoxon's test)
Light	sequential, continuous, unexpected, wide range, fast, proximate, prompt response
Spicy	sequential, continuous, unexpected, wide range, fast, prompt response
Soft	continuous, unexpected, wide range, slow, proximate, delayed response
Complicated	sequential, unexpected, continuous, wide range, proximate, delayed response
Deep	unexpected, narrow range, proximate, slow, delayed response
Ambiguous	continuous, unexpected, slow, proximate, delayed response
Natural	sequential, continuous, wide range
Exotic	sequential, continuous, unexpected, fast, proximate, delayed response
Sympathetic	sequential, continuous, slow, proximate, delayed response
Analog	continuous, slow, proximate, delayed response
Heavy	concurrent, discrete, expected, narrow range, slow, precise, delayed response
Bland	concurrent, discrete, expected, narrow range, slow, delayed response
Hard	discrete, expected, narrow range, fast, precise, prompt response
Simple	concurrent, discrete, expected, narrow range, precise, prompt response
Shallow	expected, wide range, precise, fast, prompt response
Clear	discrete, expected, fast, precise, prompt response
Artificial	concurrent, discrete, narrow range
Mundane	concurrent, discrete, expected, slow, precise, prompt response
Unsympathetic	concurrent, discrete, fast, precise, prompt response
Digital	discrete, fast, precise, prompt response

Table 4. Meaningful interactivity attribute values for various emotional qualities. [3]

CONCLUSION AND FUTURE STUDIES

Our study confirmed that the interactivity attributes we identified are all recognizable and create some distinctive and meaningful emotional effects. The key implication of this result in interaction design is that the immaterial part of an interactive artifact has concrete effects on human emotion and designers may be able to consciously manipulate the interactivity attributes to shape various forms of *interactivity*. In other words, the set of interactivity attributes can be used as a design language to describe the shapes of interactivity. It was also very interesting that the perceived experience with this immaterial part of an interactive artifact triggered some feelings that are completely unrelated with the physical medium for actual interaction—in our case, it was a mouse and a display.

In this research, however, we did not examine the effects of different styles of interaction techniques when the shapes of interactivity are similar to each other. In order to truly see the possibility of unifying the different styles of interaction techniques, this will be the further step to be researched for.

[3] We rearranged the listed order of the emotional qualities in this table to group the ones that are more tightly related to one another, based on the similarity of the patterns of the interactivity attribute values relevant to each emotional quality.

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