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Emotion centered design: Affect, think, and act

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Emotion centered design: Affect, think, and act

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DEDICATION

I dedicate this study to my family: my father, Mahmut Herdem, my sister, Canan, and my mother, Melek Herdem.

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ABSTRACT

User interaction (UI) designs often cannot adapt to changes in user contextual conditions. While users usually expect UI designs to change based on changes in the conditions of external contexts, most current UI designs propose only a single design rule for all user actions in their context. Users must either accept the suggested action or modify their actions to adapt themselves to a new design-based condition. Each alteration may cause changes in the structure of human activity. This study proposes an emotion-centered design method that enables designs to adapt to a user's contextual conditions. Changes in contextual conditions often cause users to experience different emotional states, and, the proposed design method chooses among most likely UI designs based on identified user emotional states. The emotion-centered design method is applicable to a wide variety of different human-computer interaction fields, including mobile and wearable computing, contextual computing, the Internet of things, affective computing, personal computing, etc.

The design method is implemented through user verbal interaction design methodology. Two user studies were run: In user study one, 19 participants viewed 14 examples of TV content, while in user study two, 27 participants interacted with 9 examples of multimedia content. Users then created text messages and reported their emotional states using mobile applications. Performances of Bayesian networking classifiers, used for detecting users' affective states, were evaluated using two methods: 10-fold cross validation and leave-one-person-out. These two test studies achieved emotion recognition results approximately 80% of the time. These results show that learning classifiers can detect user emotional states in users' present contexts. Two learning classifiers were also tested with user behavior features obtained from each other's studies. Comparison studies demonstrated

recognition rates of about 30%. Because UI designs reflect the assumption of action independence with respect to natural context, the dependency between user actions was set based on users' requirements at that present time. In other words, context, as an entity connecting actions to each other, was created to help users with their activities. Whenever the users were done with the activity, the context was broken up, and users were not able to transfer results of previous experiences into the new context.

CHAPTER 1 GENERAL INTRODUCTION

Today, many everyday tasks are transferred to online platforms, so that people often don't need to remember and follow ordered actions of the tasks because computing platforms complete them for the users. In this way, users benefit from online services, hardware, and software to save time and energy for other tasks. Although users may adopt Human Computer Interaction (HCI) designs, some users continue to experience difficulty when interacting with them.

User interaction (UI) designs use predicted human actions applied in context. Human interaction in context may include multiple actions applied in a particular order. User interaction includes selection of an action to be implemented at the present time, and design methods tend to be focused on the development of design idea for user needs at the time. The user needs to broadly cover the process of turning present goals into activities. The user-centered design (UCD)[1][2][3] method introduces cognitive biases into the design process. UI design tasks turn into user experience (UX) designs that focus on non-materialistic aspects of the UI designs. UX designs require testing multiple design ideas with real users. An activity-centered design (ACD)[1][4] method tries to focus on observing user activities to identify user need and required UI design for satisfying that need. A value-centered design (VCD)[5] method considers asking users to identify expected user action and design of UI reflecting that action. Emotional or emotionally-based design (ED)[6] considers asking users what actions are expected when they are experiencing different emotional states, and creates UI designs consistent with those states. DesignX [6] is proposed to set up communication between two UI designs that may belong to different users and/or interactive and autonomous agents; several different socio-technical problems may arise while creating interactive systems of this type.

When the public exhibited interest in the use of computing devices to complete everyday tasks, interaction designs of devices based on outputs of research on human behaviors in contexts were improved. At the beginning of human behavior research, the assumed context was assumed to be independent of the human, and it is assumed that human actions within the context have no mutual aspect [7]. In other words, human actions influence the objects in the context, but not vice versa. Human interaction is created based on multiple interactions with contextual objects. The desired actions are for completing goals, resulting in objects changing states. Because of this, the actions taken in order are dependent on one another and created after the human observes a change in the context. UI designs generally require selected actions to be implemented at particular times. The action to be designed is dependent on other actions to develop human interaction.

When users chose to implement UI designs for completing their tasks, they expected a range of different actions for each next step of performing their tasks. However, UI designs tend to generate the same set of action responses independent of changes in users' expectations. Under such conditions, users must deal with new limitations in the natural context created by the designs. Users either accept or reject the design rule. If they choose to reject, they may be able to find alternatives to challenges at different levels of their actions, but if the designs challenge their goals, they must turn all of their attention to dealing with negative influences of the UI designs. Under conditions of either accepting or rejecting the design rule, users must change their expected actions to be able to adapt and communicate within newly created contextual conditions. Changes in user expected actions mean changes in human action skills. Following a change in user action, multiple consecutive steps will usually take place: disconnection from natural context, creation of virtual context, and unexpected user behavior. As a result, since designs tend to lose the connection to the natural context, designers cannot identify the real goal of the user, and design of user interaction would probably not meet user expectations.

When transitioning from UCD[1][2][3] to ACD[1][4], the design focus shifts from UI to UX and becomes more focused on non-materialistic aspects of the interaction, the primary factor in differentiating quality of the designs. Designers assume that actions in contexts are independent from one another. UI designs have single states, meaning that independent actions occur in a present context and a next action would be determined after experiencing the UI designs. The assumption is that a designer bias may be introduced into the design process, and the designers' expectation regarding interrelationships between users and their contexts will influence users' behavior. Users change their behaviors with respect to an interaction with natural context and tend to only consider how to benefit from a context to satisfy their present tasks. The external user context is evaluated based on individual requirements of a user's current tasks.

Interaction is described as "mutual action or mutual influence". Actions in an interaction are dependent on one another. An action within an interaction influences its recipient, and the recipient of the action may turn that influence into an action. To describe the dependency between actions, a roadmap with three main steps is followed: development of an action model, followed by development of interaction model, and, finally, based on these two models, development of a new interaction design method called emotion centered design.

The action is described as combination of goal and activity components. It is simply "to do something to achieve a goal". The goal is conceptualized as a "desired change in the state of object" sharing the same context with the user. Actions of the subject change the states of objects, and the objects generate an action. The objects' actions then change the emotional states of the subjects, and the subjects generate actions called situated actions [8][9]. They are human action responses to situations that change both externally and internally. Human activity includes selection of multiple actions based on previous experiences. The selection is based on identification of a best likely action among planned actions [10][11]. This loop between subjects and objects continues. The human cognitive process is intended to turn human goals into reality, while human feelings regarding the desired state change of the object are embodied into human activity.

The assumption of action independence in an interaction causes creation of dynamic contexts based on requirements of users' present tasks. Because a user wants to perform the task, unrelated actions are connected with one another to create human interaction. User-selected actions are unrelated with respect to bringing them together in the natural context. All human interactions represent situated actions connecting multiple user everyday actions. Multiple situated actions create the context for describing and defining interrelationships between users and an interactive entity sharing the same context. Because user actions are selected based on requirements of user tasks, the context for each experiment is created based on users' internal states and task requirements. It is expected that each set of user experiences is unique and not repeatable. A set of experiences creates its own context, and identification of features in such contexts cannot be transferrable into new contexts.

The emotion-centered design method connects users' actions to their natural contexts related to the change in state of subjects and objects in the interaction. The method has two simple steps: recognize user subjective states and use this information to estimate the next likely action. Implementation of this design method can be exemplified with a user verbal interaction design problem. The dependency of user actions tends to be missing in verbal UI designs. Verbal activity design includes various design problems inherited from the background touch interaction design topic, and those created in run time while users are dealing with verbal UI designs. Emotional states of users can be recognized from user activities using devices in two different contextual settings. User body movements while creating verbal message via the device can be sampled with on-device touch and 6d motion sensors. A model of user typing activity on the device is extracted, and features of this activity are calculated. Two Bayesian networking classifiers are created with features of user activity as input, and user reported affective dimensions (arousal, and valence) as output. In user study 1, 19 participants responded to 14 event-based stimuli (TV content) on a screen, then reported their emotional states with a Twitter-based social media application, using a provided mobile smart phone. The 14 stimuli were two sets of 6 basic emotions and neutral state. Emotions were described based on basic emotion theory and core affect theory. To report their basic emotions, users chose face images reflecting 6 basic emotions (happiness, sadness, anger, fear, surprise, and disgust), and a neutral state. To report the level of their affective dimensions (event predictability, valence, arousal, dominance), they used sliders with 9 different points, later discretized into 3 levels: low, medium, and high, with respect to related affective dimensions.

In user study 2, 27 participants respond to 9 event-based (online) multimedia stories as experimental stimuli, and reported their resulting emotional states with a Twitter-based social media application, using a provided mobile smart phone. The stories were created with text-based event description called vignettes, with accompanying pictures and song to support the events within the vignettes. Emotion was described based only in terms of core affect theory. Users reported their level of affective dimensions by selecting one from among 9 images (mannequins) that indicated intensity of related affective dimensions. The 9 images corresponded to 9 different points in related affective dimension, and these 9 points were later discretized into 3 levels: low, medium, and high, with respect to related affective dimensions.

The learning models for emotion recognition were tested via two methods: the 10-fold cross-validation and the leave-one-person-out method. In user study 1, when the learning models were tested with the 10-fold cross-validation method, the recognition rate for arousal was 82.6% accurate, and the recognition rate for valence was 83.4% accurate. On the other hand, when the models were tested with the leave-one-person-out method, the recognition rate for arousal was 78.9% accurate, and the recognition rate for valence was 79.6% accurate In user study 2, when the learning models were tested with the 10-fold cross-validation method, the recognition rate for arousal was 81% accurate, and the recognition rate for valence was 86% accurate. When the models were tested with the leave-one-person-out method, the recognition rate for arousal was 79.8% accurate, and the recognition rate for valence was 82.6% accurate.

This study considers observing user behaviors in two different contexts. Results from both the 10-fold cross-validation and the leave-one-person-out method show that user emotions could be recognized from observing user mobile-device activity. Learning user emotions in their own contexts are also possible. To compare how learning models will work under each others' contextual conditions, the model in user study 1 was tested with data from user study 2 and vice versa. When the learning model from user study 1 was tested with user behavioral data from user study 2, the recognition rate for arousal was 28.1% accurate and the recognition rate for valence was 29.8 % accurate. On the other hand, when the learning model from user study 2 was tested with user behavioral data from user study 1, the recognition rate for arousal was 31.7 % accurate, and the recognition rate for valence was 34.7% accurate. Bayesian classifiers basically predict based on previous human experiences. The influence of UI designs on human activity can confuse users. UI designs may cause changes in previous action skills, and may affect design of independent future actions. Depending on the degree to which a human is affected by the designs, any learning algorithm based on human natural-learning skills would not provide better results when the context is changed.

The primary challenge ahead in the HCI field is to remove design bias related to the idea that user actions are independent of one another. Until that has been accomplished, identification of any user features, including emotions, will be valid for the present context, a new context will be dynamically created for each next user task, and a particular context will be to some extent independent from the previous context. Whenever this interaction design challenge is removed, recognized emotions will be more helpful in predicting a user's next verbal actions, e.g., predicting the next words that a user is likely to type into a device. In addition, user emotion information can be used to remove communication challenges resulting from missing subjectivity aspects of messages. All previous HCI designs, such as desktop, mobile, and wearable interaction designs, have shared the same assumption about actions in interactions. An emotion-centered design method would be helpful in dealing with challenges related to interaction design topics. The model of action might have been helpful in several machine-learning studies, pervasive and ubiquitous computing works, that require knowing how to model user activities in context. In the future, when UI design problems with input technologies are solved, the design of personalized hardware and software would make possible adaptation to users' expectations.

CHAPTER 2 RELATED WORKS

This section provides an overview of two topics: user interaction design methods and design of complex interactions among multiple users.

2.1. User Interaction Design Methods

User interaction design methods can be categorized into two groups based on the focus of the design: user behavior or activity design, and user experience (UX) design. UX design especially focuses on what users experience after interacting with objects or entities in contexts. Users typically experience feelings, sense, perceptions, or ideas, and they usually want to turn their experiences into activities.

2.1.1. Design of user behaviors or activities

Design of user behavior or activity includes identification of multiple actions executed to turn user experiences into embodied forms. User behavior[12] highlights subjective aspects of human activity and covers selection of multiple actions to achieve personal goals. On the other hand, user activity includes a combination of multiple behaviors or actions created in response to different conditions in the context. User behaviors and activities are designed using two design methods: user-centered design (UCD) [1][2][3], and activity- centered design (ACD) [1][4].

2.1.1.1. User-Centered Design

The UCD[1][2][3] method applies rules of human-centered design (HCD) [13] to the HCI design problem. The method follows the steps given by a design approach called "design as crafting or making". The approach performs analysis of how to make products [7] such as mechanical and/or industrial designs in industrial design fields. Making a product requires analysis of how humans perform action in natural contexts and turn the predicted model of action into a product. Users' timely interactions are identified via user research techniques [2][3]. Quantitative and/or qualitative data collection and analysis methods are applied to identify users' needs in their contexts, followed by designers proposing UI designs and developing design prototypes that demonstrate how the design idea performs an action corresponding to their needs. The design is repeatedly tested with potential users and refined multiple times until test users are happy with it. When designs are finalized, developers turn prototypes into software and/or hardware products. The iterative process used during testing is called "design as crafting or making" [2][3].

Designers identify users needs from field-collected user behavioral data, and then estimate the most likely design of activity to turn their goals into some tangible forms or embodiments. They may introduce cognitive biases into the design process as they use their understanding of activities while designing for users [1]. Users must identify tasks and designers' intentions if they wish to adopt the UI designs in completing their everyday tasks. At the beginning, users are aware of what they would like to do, and only need to provided methods for satisfying their goals. While users are asked to feed design process with information related to their expected activity designs, if it is later found that design directed to individual likes and dislikes make the product ideal for some groups, it still may be inappropriate for others [1]. Too much listening to users may also cause overly complex designs [1]. Cohesion within UI designs and increased design complexity may detract from support for multiple-step activities.

UCD[1][2][3] gives priority to design for present need and activity with multiple actions in an order not at all considered. Such design misses details about how to deal with sequences, interruptions, ill-defined goals, and many other aspects of real activities. This design method is also unresponsive to dynamic changes in user experiences[1]. Design for perfect cases in which all the information is available in proper format may be easy, but good design requires knowing how to design in dynamic environments and how to handle unexpected situations[4]. The design should show alternative ways for moving forward from where users left off during the interaction, instead of just providing simple error messages in the design[4].

2.1.1.2. Activity-Centered Design Method

The ACD [1][4] method focuses on activity to support sequential requirements of user activities; requirements of complex actions could be identified with this method [1]. The main principle of ACD [1][4] is design for activity, with other aspects organized around activity [4]. The method follows the steps given by a design-as-thinking approach in which designers observe users in real world, ideate, and turn the resulting ideas into prototypes to be tested with real users. User experience can be modeled as three steps [13]: inspire, ideate, and make or prototype. Designers test each possible idea with real users using mostly low-fidelity prototypes and, based on user feedback, run tests iteratively. Users are involved in the first and last steps of the design to test the design iterations with real users. In this way, the cost of production will be lower than when the product does not work with selected users.

Norman said "I use design as thinking to mean the use of human-centered design (HCD) as a method of reframing the problem" and "not focusing on the development of pretty things but rather adding value to any activity, bringing a new framework upon which to view the world"[14]. HCD[13] is described by Norman as a deep understanding of people, starting with observations, followed by using them to determine underlying issues and needs, then addressing needs and issues through an iterative evidence-based procedure of observation, ideation, prototyping, and testing [126]. It is a form of incremental innovation, optimizing a solution through a hill-climbing process. The method is based on continual design and carefully analysis of the situation, using each design as a way to test ideas in small and controlled ways, and to use resulting evidence to guide further continual refinement [14]. In this way, improvement of a design solution based on user needs would be possible and better products might be designed without excessive cost.

2.1.2. Design of user experiences

User experiences are designed using two design methods: value-centered design (VCD)[5] and emotionally-based design (ED)[6].

2.1.2.1. Value-Centered Design

Values are a part of the invisible experiential aspects of human life. Many UX definitions consider a value to be an entity that users experience or discover. VCD [5] gives importance to any user action's values, an important factor in selecting actions in other experiences. The method is based on the idea that, to provide happy endings with respect to user experiences, happy outcomes should be associated with product features [5]. This method uses a technique of asking questions and collecting user responses to understand human values associated with their actions[5]. The challenge in using this method is that user values frequently change with time and place, and reporting values via questionnaires may not adequately reflect such changes.

2.1.2.2. Emotional/ly-Based Design

Emotional or emotionally-based design (ED)[6] concentrates on user activity results in terms of user feeling of emotion indicating success or failure. Similar to VCD [5], the ED[6] method focuses on relationships between users' emotional states and their activities.

Emotional design identifies three different levels of user experience: visceral, behavioral, and reflective[6]. The designs should meet user aesthetic, behavioral, and identity values and expectations, leading to user acceptance of the designs. The first level[6] relates to human likes, dislikes, and the prewired parts of human beings; it includes design aspects that are perceived as pretty. The second part[6] is all about use, and is mostly within the purview of usability professionals. Performance, function, understandability, usability, and physical feel to help in a design's use are important elements of successful behavioral design. The third level[6] is about reflective design, how we do the tasks; it reflects who we are in terms of values. It is related to memories triggered by an object's use and is about message, culture, and the meaning of the design and its use.

2.2. DesignX: Design of Complex Interactions Among Multiple Users

DesignX[108] is a recently on-going design method development effort providing connections between designed user experiences. This method is in its early stages, so since researchers do not feel comfortable in giving it a name, they put X to highlight that it reflects unknown parameters of future design[15]. It is proposed for developing practical solutions to large and complex issues with socio-technical systems. Socio-technical problems[15] are related to the design of complex organizational works performed with many people, and to interaction between people and/or technology. The two main aspects of this issue are to provide social ability, in terms of working together, and technical aspects, in terms of interacting with computing systems.

DesignX [15], [16] would like to address system level issues that may arise when two UX/UI designs interact with one another. The method originated based on challenges in the design field. Major problems in that field include designs of complex issues with interactional systems among multiple stakeholders. Examples of such complex issues occur when large numbers of people interact with technologies, specifically in communication, computation, and transportation problems. Those challenges fall into three groups: the psychology of human behavior and cognition, the complex and interactive nature of design problems in terms of integrating knowledge from various disciplines, and the state of technology that increases the complexity of the problem[15]. Any design problem could become a designX[15], [16] problem if it has following features: if the design includes challenges with respect to understanding human behavior and cognition, if it requires a multiple-discipline view, or if it includes challenges with technical topics such as non-independence of elements, non-linear causal relations, feedback, long and unpredictable latencies, multiple scale sizes, and dynamically-changing operating characteristics[15].

CHAPTER 3 ANALYSIS OF USER INTERACTION WITH UI DESIGNS

User interaction design is the process of predicting humans' everyday actions in their personal contexts, and identification of interaction models to turn those actions into user actions completed via computing devices. All user interaction design methods described in Chapter 2 are based on the conceptualization of HCI designers and researchers regarding the nature of interaction. By description, the interaction concept tells that actions in a natural context have mutual attributes. In other words, every action triggers a reaction coming from the context to the owners of the action. UI design methods, however, assume that actions are independent of their own context, and actions influence only their external context, not vice versa.

This section provides a comprehensive analysis of testing whether or not the assumption of action independence comes from a natural context. The section begins with the interaction concept by describing how interaction is created via the presence of mutual action and/or influence. It provides a step-by-step analysis of how an initial assumption of action independence changes research and design activities in the fields of human and user interaction design. The influence of HCI in human-centered design field studies, and a user-centered design method is created. Because actions in natural contexts are considered to be independent, UI designs are able to produce single design rules for human actions, but when dependent conditions exist in the contexts, they should be dealt with in one of two ways: either they accept or reject the universality of the design rules, or they reject the design rule, breaking the rules of natural interaction elements and using them outside of their primary goals. Both user acceptance or rejection behavior causes variance in the display of user behaviors, and that variance helps designers to create new design rules to include new users and new device and/or technology usage scenarios.

The new designs only perform optimization of user experiences, and they may open the way for users to experience a new set of problems. Because users may have problems within old design scenarios, this new set of problems increases overall problem complexity. In addition, the acceptance or rejection of design rule implementation in all dependent conditions results in a change in people's action skills built through interaction in previous contexts. The analysis shows that an initial assumption regarding action independence was a cognitive bias of HCI designers and researchers at the time when that idea was introduced into the field. Later, other researchers and designers based their work on this untested assumption, resulting in an increase in the rate of complexity in UI design problems.

This section concludes with a proposition for a new study related to connecting users and their actions to their natural contexts. To accomplish this task, interaction in nature is studied with respect to dependency of human actions on natural context, resulting in a new design method connecting human actions to natural contexts. Every action influences a human's internal context. Considering recent developments in the affective science field, an interrelationship between human affect and actions are established, showing that actions cause the development of affect, and affects in turn result in development actions. In this way, as human actions become part of their contexts, development of human action skills will be improved based on the inclusion of dependent conditions into the design field. Two user studies are proposed to test the implementation of this new design method.

3.1. Natural Interaction and Development of Natural Context

3.1.1. Concept of interaction: influence, action, and their common attribute of being mutual

Interaction is defined in Webster's dictionary[17] as "mutual action or mutual influence". The word interaction may be understood in different ways: something between two actions, an action leading to development of another action, "kind of action[18] that occurs as two or more objects have an effect upon one another", and content of any action, independent of action type or complexity. Interaction includes two main components: action and influence. Both have a reciprocal attribute, meaning that, in response to action received and/or performed by a subject, the action's object in turn produces an action and, in response to action received, the object is influenced and vice versa.

1. ***Mutual action***: During an interaction between a subject and object, if the subject acts on an object, the object may act on the subject. Figure 1 gives a pictorial description of interaction as mutual action between subject and object. Every action causes generation of a new action.
2. ***Mutual influence:*** During an interaction between a subject and object, if a subject influences an object, the object then influences subject. In other words, a subject's action influences the object and an object's action may also influence the subject. Mutual influence means that every action generates influence, and every influence in turn generates action. Figure 2 is a pictorial description of interaction as mutual influence between subject and object.

This underlying dialog between subject and object creates a cause and effect relationship in two ways: a received action from an external context ends with an influence and this influence turns into an action response by the subject executed in the external context. The received action is the cause, and generated action response in the effect. When the object receives the response, it acts in the same way and turns the influence on the object into a reaction addressing the subject.

3.1.2. Everyday interaction in natural contexts

Referring to Figure 3, subjects have needs. Activity[19] is understood as a “unit of life” of a material subject existing in the objective world. Subjects should meet their own needs to be able to survive. Subjects must carry out activities to survive, and must interact with objects in the world to meet their needs. The world is structured, i.e., it is comprised of discrete objectively existing entities called objects. Subject interaction with the world is structured and organized around objects. Objects have objective meanings determined by their relationships with other entities existing in the world. To meet their needs, subjects must reveal the objective meaning of objects, either partly or totally, and act accordingly.

Interaction between subject and object shows that influence and action are connected to one another. In other words, subjects and objects are connected to one another, and one’s action creates of influence on others, leading to the development of reaction to another. Figure 3 depicts the three main aspects of activity theory: a model of interaction between subject and object, embodiment of cognitive intelligence that connects consciousness to activity, and structure of activity.

3.1.3. Development of Natural Context

3.1.3.1. Context provides visibility to dependent actions during interactions

The concept of context is closely related to the interaction concept. Context provides connection and/or dependency between actions during an interaction. With the help of context, actions and their results become sensible, i.e., visible to people's eyes It is a combination of conditions, the rule that brought together the actions within the interaction, that causes actions to be executed.

3.1.3.2. Dependency of actions with respect to space, time, space, social aspects

Context broadly covers representation of space, time, and social circles enclosing a person, corresponding to when, where, and with whom the person is acting in the world. Any context can be classified in terms of space, time and social context. Social context relates to other humans, animals, or living organisms sharing the same time and space with a person. Space context means "a boundless three-dimensional extent in which objects and events occur and have relative position and direction". Time context is related to the development of a situation of cause and effect.

3.1.3.3. Natural context

Natural context considers the design of the world outside the human domain. A human is connected to such an external context. If we consider a human to be an object, the context could be thought of as a second object or perhaps multiple objects surrounding the human. The term object simply means anything that fills a space, with physical and/or sensory appearance in time.

3.1.4. Everyday context: self-designed context with selective natural design rules

The word everyday is used as a term while describing natural interaction in a context. If one wishes to describe natural context without reference to the natural aspect of context, people may refer to everyday context. It may become an abstract control parameter of the world, created for describing commonalities about a life without mentioning its relationship to nature. Everyday context gives us rules of natural context in terms of bringing together people's actions with respect to space, time, and social aspects. It is a time-based natural context, in everyday terms.

3.2. Study of Human Action in Natural Context

This section gives an overview of the steps between interaction and action.

3.2.1. Interrelationship between human and nature

Humans have needs, and they should interact with the world to meet these needs[19]. Activity theory[19] describes the relationship between humans and nature. People's actions are dependent within a natural context, and activities are influenced by the attributes of subjects and objects that are transformed by activities. Subjects express themselves in their activities, but subjects' consciousnesses are also determined by the activities.

An activity is a purposeful, transformative, and developing interaction between actors and the world. The idea was originally developed by Russian psychologists with an interest in understanding the development of human activity who formed a special organization of social movements in the world[19]. The theory is based on an effort to overcome the challenge of divisions between the human mind and culture and society. The perspective is that culture and society cause the human mind to work, in terms of providing conditions for the functioning of the mind to dealing with an opportunity or a challenge in the external world.

Referring to Figure 3, human mental functions begin with differentiation between self and others, followed by people mastering self-related processes. The unity of consciousness experience and activity stands for human internal and external context, and they are closely interconnected to one another. There is a mutual relationship between them: human conscious experience determines activity, and activity determines the conscious experience.

Mind and activity represent internal and external contexts, and psychological studies should be focused not only on psychological aspects of an activity; how activity transforms the context should be known through the principle of the inseparability of consciousness and activity. Activity theory brings consciousness into everyday practice. "You are what you do!"[20]. All human experience is mediated by human language and designed tools.

Activity theory[19] describes the dependency of actions on natural context. Each alteration of contextual conditions with respect to the expected contextual conditions complicates user activity, and the resulting confusion may cause people to misinterpret contextual conditions and change their behavior. To predict human behavior in real life, the difference between motives, goals, and conditions are important[21] : For instance, in different frustrating situations, if human operations are prevented from achieving their goals because the related conditions are changed, then people can orient themselves to the new situation. If the goal is blocked, people can create a new goal to try to identify what to do next under the same motivation, but if people's motives are blocked, then behavior may become most unpredictable.

Everyday actions are components of human actions in any context. Everyday means happening or used every day or daily. Everyday actions are learned actions demonstrating normality or an average of people's behavior at the time. Through dependency of actions in the natural context, people learn from the world. They discover contextual norms via everyday experiences and learn rules about their environments.

3.2.2. Actions: independent or dependent to natural contexts

Referring to Figure 1, actions are part of interactions in the contexts. The concept of interaction requires making a decision regarding actions' position in natural interaction. To develop an approach to study natural interaction, an assumption describing decisions about actions' with respect to natural context should be made. There are two available options: action is either independent of or dependent on natural context. Researchers and designers commonly assume that actions are independent of natural context, i.e., actions are assumed to be entities independent from natural context. Referring to Figure 1, the action is removed from the action-reaction cycle between the subject and the object.

3.2.1.1. Action is independent from natural context

Figure 4 below shows a model of interaction as an action response. An action is considered independent of context and has only a one-way influence: from the subject to the object.

Referring to Figure 4, subject and object are independent of each other, and only the subject acts on the object to achieve her/his goal. To simplify the interaction concept, the dependency between actions[7] is considered to be that the actions of two sides in the interaction are independent of one another, and there is only a one-way dependency: from one side to another side, but not vice versa. Dependency between subject and object is only one-way, from subject to object, and the subject influences the object, but not vice versa.

The object could a mechanical, industrial, or electronic digital device that is to be designed, and the subject's action is modeled to turn it into a product. Since activity includes discrete, visible and physical features of things done in an external context, the study of action mainly focuses on the development of activity that tells us how to perform an action in a given context in terms of selection of actions to complete a task. The connections between subjects and objects and the connection between their actions are severed. The mutual aspect of influence and action will work in only one direction, from subject to object.

3.2.1.2. Analysis of results of decisions about actions in natural context

Assumptions regarding actions' positions in natural interaction are a choice of researchers and designers in the field, and they represent only one type of cognitive bias they may introduce into the study of action and interaction. Such decisions may be a reflection of their perceptions or predictions related to the studies. When the action is independent of natural context, humans' positions in that context are that humans are independent of the context. The results of the analysis will show us whether the assumption is true or should be changed.

3.2.3. Development of human interaction

If it is accepted that action is independent of natural context, the interaction concept is reduced to a human interaction concept, i.e., interaction is understood to mean human interaction. Referring to Figure 4, the study of human interaction consists of studying an action occurring in a context. Under such assumptions, human interaction corresponds to identification of development of activity to achieve a goal.

Referring to Figure 3, human activity includes multiple actions, and actions in turn include multiple operations. Human interaction stands for the development of activity in terms of people's action repository or memory that gives them the ability to know how to act when they face entities in an external context. The entity may be an event or an object in the context. Human interaction provides motor and/or automatic programming of human behavior to instantly respond to an external event.

Human interactions accumulate with the execution of multiple everyday actions that follow one another. Change in the natural context causes creation of a new situation, and people create responses to such a new situation. Referring to Figure 3, people create goals and turn their goals into actions through cognitive evaluation of contextual conditions based on their goals. Human interaction design means identification of interactional elements of human action response to situations occurring in nature. Study of human interaction means studying dependent actions happening in natural context when objects' actions influence subjects' actions. In the context of action independence from natural contexts, human interaction means the study of independent action in the natural context.

3.3. Development of Human Centered Design (HCD) View

When an action is assumed to be independent of a natural context, then humans decide the interaction design of their actions. Because HI design has multiple components, a HCD[13] design view considers starting with initial design of action, then complementing the missing points in the design via multiple iterative steps based on human feedback. The design is updated based on human needs.

Designers learn from failures and correct mistakes within next design iteration. Depending on how much a user is satisfied with the design, the design is evolved iteratively by manipulating the design based on user expectations. Designed users' actions are results of prediction. The design methods have iterative steps, and designers implement lessons learned from a previous cycle. This design process with multiple cycles provides an incremental improvement on features of the product [22]. The HCD [13] method is an implementation of the hill-climbing method in finding local optimization via mathematical operations [22]. The method is only suited to incremental innovation [22]. The hill-climbing method provides continual improvement of a solution and finds local maxima, but it does not tell whether the current hill is the highest hill or not. Norman [7] said that hill-climbing method works if the system has linear decomposable and independent elements with simple causal relations.

Also, the hill-climbing methods assumes that there is only a single hill to be climbed. In other words, if actions in the interaction are not mutual, and the only subject acts on the object, these actions are good for UI design methods that use multiple iterative steps.

3.3.1. Development of incremental design methodology

UI designs are based on a transfer of human action skills to a new interaction medium. There are two main design approaches: incremental, or radical innovation [22]. In the implementation of an incremental innovation method, professionals assume that an action to be designed is neither bi-directional nor mutual. That helps them to create an incremental design methodology that will initiate UI designs, and by experimenting with use of the design with real users, they can update mistaken design components. HCD[13] as an incremental innovation method is good for improving functionality and usability of designs[22][1] by allowing adaption to current conditions of the user context.

HCD [13] is a design view shared by UCD [1][2][3], ACD [1][4], and DesignX [15], [16]. The design view might be shared with ED [6] and even the VCD [5] method, although the methods are used on a more theoretical level. The UCD[1][2][3], ACD[1][4], ED[6], and DesignX[15], [16] methods belong to Don Norman, and they are based on improvement of the central idea of implementation of an iterative process consisting of observations, an ideation phase, and rapid prototype and testing. The incremental method has multiple cycles, including checking the design with intended users' behaviors, likes, dislikes, and preferences with respect to how to do the actions [1]. The method helps to improve the quality of information about an object in terms of information fragments and integration of information showing the design of object features.

Radical innovation[22] in a design field occurs through technology change and meeting suitable requirements or needs of people. There is a direct match between human needs and design of human interaction to meet the needs.

3.3.2. Methods used for studying human interactions in contexts

Because HI includes multiple components, researchers have chosen to study pieces of the HI and go through incremental, step-by-step analyses of discrete pieces of the topic. Such step-by-step analysis is a common research method applied in many disciplines.

3.3.2.1. Cognitive methods for study of everyday actions and behaviors

Cognitive methods consider everyday actions and details of everyday actions in terms of human behavior under different conditions. They can be interpreted as an approach examining cognitive aspects of activity. Cognitive methods concentrate on selection of actions based on how a human evaluates an external event. The event is called a stimulus, and how people behave in the context can be explored to identify its principles. Cognitive functions and their effects on human behavior are the primary focus of the cognitive psychology research field.

Initial studies dealt with the identification of behavior, or the way one acts in a given context. A behaviorist approach is a primary paradigm used in psychology during the 1920-1950's. Assumptions underlying behaviorism are that people's behaviors are determined by their environment. Because of this, new behavior is learned through experiencing different conditions in the environment. Theories should be supported by empirical data obtained through careful and controlled observation and measurement of behavior. Behaviorism is primarily concerned with observable behavior, as opposed to internal events like thinking and emotion. Thinking should be explained through behavioral terms. All response behaviors are results of stimulus, and the purpose of research in that area is to predict what reaction will take place in response to a stimulus.

Cognitive psychology updates the behaviorist view by adding subjective evaluation of contextual conditions. It is a discipline focused on the psychological aspects of an activity that concentrates on the relationship between activity and subjective experiences over human cognitive evaluation functions. A human experiences an event in external context and this influences the human's internal context by producing an action response. The relationship between event and action response is a basic study topic of the cognitive psychology.

Cognition provides a medium between input signals and output expressions via the human body. It has some aspects of dualism: cognitive intelligence/functions, and human behaviors in terms of showing how to act in an external context. Connections between them are not clearly given by the cognitive model. Humans could be considered as functional entitys processing information provided as input from an external context and producing outputs to external contexts. There are various information processing development models at different specificity levels[23]. The cognitive method is a way for making behavioral prediction of a person based on the relationship between inputs and outputs.

Cognitive methods consider the human and the world as two different objects, and events in the world cause changes in human behavior. In other words, contextual conditions that may be results of human actions are not included in the analysis of human behavior. The path from external context to human action response is the primary focus of such studies. Feedback from an external context is considered to be a learning outcome, but how the action affects others in the same context and is returned to the person are not considered. In other words, situation analysis seeking to understand why people change their actions is not included.

3.3.2.2. Post cognitive methods to study development of HI

Post-cognitive methods consider the connections between everyday actions that are building blocks of human actions. The dependencies among everyday actions reflect subjective differences in the composition of an action. Post-cognitive methods consider the analysis of the situation in the context and selection of action based on the situation, and then implementation of a situation-based action response via some selection and execution of action, called behavior, that are known rules of "how to do."

a) Embodied Cognition

Embodied cognition deals with how a human selects an action-based evaluation of results of action on person's experiences and actions. Outputs of cognitive functions are turned into activity in terms of planning and/or ordering actions in time. Pure intelligence means it is disembodied from the world and observed through cognitive products, e.g., decision, memorization, etc. However, humans use the physical world as a source of information, reminders, and extension of human knowledge and reasoning systems.

Cognitive science is a discipline that focuses on the relationship between cognitive functions and activity as outputs of those functions. Artificial intelligence and physiology-related topics are in the realm of cognitive science. They deal with prediction of activity development in response to external events, for example, artificial neural networks. Cognition is embodied in actions, not isolated from the world. Thinking is a distributed and interactive process. Body movements are taken as a way to think by turning intelligence into activity. Embodied cognition[24] connects human consciousness to actions and activities in external contexts. People operate through a type of distributed intelligence in which human intelligence results from interaction with objects in the world, constraints of the world, and behaviors developed with others through a cooperative process.

b) Distributed Cognition

Distributed cognition deals with how humans select an action based on an evaluation of external condition in terms of influence on human need, value, and goals. The distributed cognition concept is taken as an alternative in solving human context interaction challenges. The environment is taken as a source of information, and some portion of human information is spread to their environment and represented in different forms. Distributed cognition [25] provides an explanation of social interaction and exchange of information. Through such exchange, humans develop new understanding about their environment. Cognition is distributed to the human environment, and external context for a person stands for information represented in different forms [26]. Distributed cognition proposes that if there is no clue in the environment, people may use their mind-based skills to deal with interaction challenges[27].

3.3.3. If actions are dependent on natural context

Designers might ignore dependent actions in a human interaction, and an optimization method could be applied to reduce the effects of such ignorance into the design. Each design is compensated by checking it with intended users, and some aspects of any ignored aspects of interaction will be included in the design if users provide feedback about their needs with respect to such aspects. A total HI design would deviate from natural interaction design that would be applied in natural context, and would reflect tendencies and behavioral biases of certain groups of people included in the design process[1].

In the context of climbing a hill, the hill represents an average of people's behaviors, and identification of a common behavioral pattern via iterative checking with intended users of the designs. Current contextual conditions typically play a central role in identifying the hill to be climbed.

3.4. Human Interaction (HI) Studies

Many dimensions of human interaction are studied in the literature: types of actions in natural context, structure of human activity as action response to the situations in the context, developmental steps of human interaction in natural contexts, and creating complex actions to deal with new situations in the context.

3.4.1. Types of actions

Human actions are part of human activity. An activity represents a componential view of an action that includes multiple sub-actions identified via evaluation of contextual conditions.

Two types of actions are used in the development of an activity: planned actions and situated actions. Planned action is a concept of cognitive science brought to computer science by Norman. Norman would like to come up with a plan of a user interacting with computing devices. His view considers the cognitive aspect of human actions [10], and concentrates on the use of everyday tools to complete daily tasks [11]. Based on the action cycle model given below, before acting in the real world, users have an explicit plan of how to act, called intention, that organizes the execution of human actions. After execution, results of actions are evaluated and evaluation results are used for selection of a next action [10]. A plan of action could be considered as a motor program controlling steps of human behavior[28].

A human selects an appropriate set of the schema and activates them in memory when external conditions match those required for their operations [28][10]. The simulation model of a skilled typist briefly reveals two schemas in the mind: parent schema and child schema. Parent one corresponds to words, and child one is for letters. Words represent an action necessary to complete the task and letters represent operations within the model. Schema implies a motor program, such as software programs on devices. Typing data analysis shows that typing *th takes a shorter time to type than separated t and h, indicating that there is organization in the mind that helps reach "th" rather than separately accessing t and h[28].

Situated actions are human action responses resulting from interaction with context. Suchman [9] studied human machine interaction problems and explored human plans and situated actions via anthropological and ethno-methodological techniques. She has argued that artifacts built on a planning model of human action confuse human plans and situated actions. That type of designed artifact affects human everyday interactive actions.

The study states that plans are something located in actors' heads that direct their behaviors. Suchman[9] said plans are just formulations of antecedent conditions and consequences of action, and believed to represent a reliable way to act in the real world. Based on these ideas, the researcher gives significance to contextual conditions and plans are vaguely created to recover from unknown challenges from the present context, called "situations of actions". Plans of action do not consider the actual course of actions occurring in a situational context, the plans relate to how to recover from contextual challenges. However, the plan can be seen as a method for recovery from current challenge. The plan might be formulated in one of two ways: plans in the mind, and new plans to update previous plans based on contextual conditions.

"The term [situated action] underscores the view that every course of action depends in an essential way upon its material and social circumstances"[8]. Based on situated action theory, actions mostly emerge "spontaneously" in strong relationship to a situation to create everyday behaviors. These actions are called situated actions and they constitute everyday behavior. The theory is based on both sociology and anthropology. She has identified 5 factors in the situated actions generation based on her ethno-methodological study[9] : "Plans are representations of situated actions. In the course of situated action, representation occurs when otherwise transparent activity becomes in some way problematic. The objectivity of the situations of our action is achieved rather than given. A central resource for achieving the objectivity of situations is language, which stands in a generally indexical relationship to the circumstances that it presupposes, produces, and describes. As a consequence of the indexicality of language, mutual intelligibility is achieved on each occasion of interaction with reference to situation particulars, rather than discharged once and for all by a stable body of shared meanings". A basic observation in situated actions theory[29] is that people create their actions based on observations from the context, so human actions are connected to context and can be changed at any time during interaction with the world.

Errors in human activities exhibit differences between planned versus situated actions. Errors in actions show that if context is new, users would have less information about how to act in the context, and they would learn how to act after experimenting in the context. The learning period would include errors in human behavior, and Norman analyzed human errors of behavior because they have consequences in the world and provide us information about what is happening during action development in the mind. Human errors may take place in the formation of intention, in the activation of schema, and during triggering of schemas[30]. The role of attention in control of action becomes important when modifications in an action plan are made, at which point the human takes control of behavior. Most attention problems occur in the initiation step rather than during execution of the actions [31].

3.4.2. Analysis of planned actions

Activity theory [19] provides an explanation derived from analysis of executed actions in natural context, specifically in social contexts, and helps in understanding the structure of an activity.

3.4.2.1. Structure of human activity

The concept of activity broadly means an interaction of an actor with the world, where interaction means a process relating subject to the object. Subjects of activities have needs that should be met through interactions with the world. Activities and their subjects mutually determine one another. Activities are generative forces that transform both subjects and others.

The hierarchical model contains three levels: less conscious behavior, conscious behavior, and semantic and/or conceptual level of behavior. The differentiation among these levels is based on the consciousness that persons have about their behavior. Figure 5 shows a hierarchical structure of activity given in the activity research field.

Activity has a hierarchical structure: activity, action, and operation. The top layer is the activity itself, oriented toward a motive that corresponds to a certain need. The motive is the change in the object that the subject ultimately seeks to attain. Actions are conscious processes directed at a goal that must be undertaken to fulfill the object. Goals can have sub-goals. Actions are implemented through operations, routine processes providing adjustments of actions to the ongoing situation. They are oriented toward conditions under which the subject is trying to attain a goal. Humans use tools to mediate their activities. Activity theory requires analyzing activities in the context of its development. This may determine research strategy as well.

3.4.2.2. Activity, task, action, operation

Activity[32] is given in the dictionary as " behavior or actions of a particular kind". Activity means "actions taken to achieve the goal". A subject has a task[33], "a piece of work to do". Action[34] means "to do something to complete a goal". Task means "have something to do". It in some way describes intentions of people that they have in mind but may not perform.

Based on activity theory, Norman improved activity structure by adding a task into the hierarchy. He said that activity is comprised of multiple tasks, each task is comprised of multiple actions, and each action is comprised of multiple operations [1]. The task is a combination of multiple actions, a kind of action planned in the mind but not performed in the real world. Similarly, activity is a kind of complex action that requires a combination of tasks and actions related to one another. Activity occurs through implementation of tasks.

3.4.2.3. Expression as expressing out and display of action through body medium

As actions are executed via the use of the body, with operations indicating commands given to the body, and expressions reflecting control of the body in terms of use of body actions. Expression generally means expressing out via the body. Expressions, in the simplest case, represent body actions to make the human message visible to the external world. An operation is comprised of multiple expressions, and an action is comprised of multiple operations. From that aspect, expressions are a type of actions, and operations are more complex actions compared to expressions.

3.4.3. Development of human interactions in everyday contexts

Human interaction in natural context is analyzed with respect to use of product designs to complete everyday tasks. It is about analysis of how to use learned functions and operations to complete actions. In other words, it is about the analysis of planned actions' implementations in an everyday context.

Information regarding the development of human interaction in natural context is based on learning from analysis of constructed and/or planned human actions in different situations. Norman observed the use of everyday, mostly mechanical, tools within external context, and studied behavioral interaction within the real world in terms of use of everyday tools [11]. He created an action cycle model based on activity theory studies given above, an implementation of the cognitive science method in terms of turning cognitive functions into output actions.

3.4.3.1. Multiple operations during task completion creates user interactional response

Figure 6 and Figure 7 show multiple steps in an action cycle used to execute actions to complete a task.

Referring to Figures 6 and 7, an action cycle[10] is initiated by forming a goal and intention, with the goal given as a person's internal state information. An action is then specified and executed. Finally, the state of the world is perceived, interpreted, and the experience outcome is evaluated, with the evaluation step including comparison with the goal. Perception to evaluation steps is also described as evaluation. An action cycle may be run multiple times until a goal is completed.

The evaluation process includes three main cognitive functions: perceive, interpret, and evaluate in terms of comparison with a goal. Action is selected based on evaluation output values. Figure 8 below shows the inner steps of the action model whose details should be clarified. The following sections provide an explanation about how those steps are run to create an action response.

An action cycle includes the steps of forming a goal, forming an intention, specifying an action, executing the action, evaluating action results, comparing the output with the goal and making a decision to select a next action if the goal is not met.

3.4.3.2. Actions are planned with operations

Referring to Figure 3 and Figure 5, the action cycle model gives us a broad activity model in which a person develops an activity via selection of actions to be performed. The activity model shows how consciousness is connected to activity. Cognitive functions (perceive, interpret, and evaluate with respect to a goal) are connected to the action selected by the person based on evaluation of contextual conditions.

The action cycle connects goal and influence to consciousness and activity. A human receives an action and a change in internal state and creates an overall goal to create an action response. This shows that people choose actions from previously developed ones to perform current tasks, leading to planned actions whose goal is abstract and turned into activity. An action cycle shows how people choose actions based on an evaluation of results of actions with respect to how they influence people internally. Multiple action selection based on the evaluation of results of actions creates a task.

The action cycle explanation gives the steps of action selection and evaluation of results from the action used to select the next until the human completes a task. Selected actions are planned actions, previously designed actions selected to complete the current goal. The evaluation process produces a value indicating the significance of action results, and based on that value a new action is selected to complete the task through comparison of the value with the goal.

3.4.4. Creating complex actions to deal with new situations in everyday contexts

Complex actions are situational actions in the context of the development of future actions, and this means learned action in the context of creation with relatively simple learned or planned actions. An action cycle is based on analysis of planned actions while completing an everyday task. It provides cognitive analysis of the results of the actions in terms of how much they are helpful in achieving personal goals. Each action causes a change in the condition of the environment, and people are able to understand how much their actions are effective in achieving their tasks and, if not, how to change their actions to achieve their tasks.

The design of human interaction corresponds to the development of action response to a change in conditions of the external context. The action cycle shows us that this is an integration of planned and situated actions, evaluation of contextual conditions, and selection of action. A task represents something planned in the mind, in terms of intention, and people turn their tasks into activity via action selection. Each action is selected as a piece of the work within the task definition.

Situational actions [9] indicate that people create actions within an interaction dependent on contextual condition and influence of that condition on the person. In other words, situated actions show that actions in an interaction are dependent on one another. Complex human actions include body, physical, behavior, mind, and mental activities in the vertical (top-down) level of analysis of human activity. Activity and tasks are related to design of future actions via action, operation, and expressions.

In the context of analysis of planned actions, operations are planned actions in terms of functions demonstrating how to do something. Operations show the actual conditions of an action. Actions are complex action responses created based on conscious goals. A conscious goal is one for which people are aware of what the action is to do. Actions are directed at specific conscious goals, so a clear goal should be intentionally established. Activity is developed for motive[21] purposes, and motive is an object, material, or ideal in a context, used to satisfy a need.

In the context of analysis of action responses to new situations, action means situational action created based on active evaluation of a contextual condition. The terms task and activity are normally used in the analysis of planned actions and they are used to analyze human planned actions in the external context. Because any future action in response to a situation in external context will have a developmental component view, task and activity could be used to describe what and how multiple planned actions, everyday actions, are brought together to create situational actions, and how these situational actions create activities of any future actions.

3.5. User-Centered Design View in HCI

UCD [1][2][3] view is an implementation of HCD [13] into the HCI design problem. UI designs address prediction of everyday actions, planned action components of the HIs. Related to relationships between human action in natural context, HI and UI designs are given to show the interrelationship between hierarchies of actions while designing for any human action in natural context.

3.5.1. Relationship between human action, HI and UI designs

Figure 9 shows the relationship between interaction, human interaction, and user interaction when actions in an interaction are independent of one another,

When subjects perform actions to achieve their goals, these actions are considered independent from the actions of objects. A human is independent of context, and human action influences context, but not vice versa. When the actions of subjects are independent of the objects, or generally from their contexts, their interactions would have actions independent from one another. One such action would turn into a topic of user interaction design, so when human actions are considered to be independent, their interactions would create independent actions in terms of happening in different times, and user interaction design would be related to the design of one action belonging to human interaction at the present time. The action to be designed is a user need.

Interaction is a general concept used for describing a relationship between two objects, or between one object and its connection to the outside world. The interaction is a concept defining an entity that is part of the natural world. Interaction includes actions and influences of two sides in a communication. There are two main topics related to the concept: human interaction, and user interaction. Human interaction corresponds to design of human action in response to an action received from a natural context, objects and/or entities that are not a production of man-made or artificial techniques. User interaction corresponds to the prediction of how a human performs the action in the natural context. It is a designer's predicted human action. Human Interaction describes a combination of multiple everyday actions, and user interaction means a component-based view of any everyday actions executed by the subject within a context.

3.5.2. Design of UI is a problem of everyday action prediction in an external context

Design is about decoding the meaning of parts of nature normally connected to the natural system. Design causes us to think that a human is connected to other things, and people should focus on designing, meaning that it should provide decoding to understand why it is there.

The research problem of how to design user interactions is basically a problem of prediction of human action in natural context and development of human interaction to perform the action in that context. HI studies acquire the view of action independence from natural context, and since UI designs are based on research outputs from HI studies, UI designs have already inherited the same view in developing computing devices placed in human natural context. The independent design view causes UI designs to concentrate on everyday action components of HIs.

3.5.3. Methods for studying user interactions in contexts

UI is the design of everyday actions, the components of HI. UI includes multiple components, and it requires a method for studying them components and how they are brought together. UIs are based on research results of human interaction, where researchers have chosen to study pieces of the HI and go through incremental step-by-step analysis of discrete pieces of the topic, a commonly applied research approach in many disciplines.

3.5.3.1. Cognitive methods for designing UIs for everyday actions and analysis of serial behavior

Everyday actions are learned and executed in daily settings. While design methods based on cognitive methods consider identification of planned actions and design of user interactions when a design involves human goals, user behavior may become unpredictable. Challenges in a natural human context may cause humans to search for use of new techniques to achieve their goals, and they would like to benefit from using computing devices to complete some of their daily tasks. Based on action cycle reasoning, people may have intent to act and may select an action to implement, but they need to know how to perform the action.

The design of user interaction begins with the use of cognitive methods in HCI to identify human behaviors directed toward completion of their intentions. In other words, they intend to do something, but they need to know how to turn this intention into activity. Cognitive methods are based on analysis of human behavior within a context, and integration of the behavior information into UI designs. Based on the cognitive view, analysis of human behavior is implemented with product designs. The design approach used for product design is called design as crafting or making, and is based on analysis of how people make products. It assumes one-way influence of human actions.

UI designs share common principles with other industrial product design principles. Based on a cognitive view, analysis of user behavior is implemented within a user-centered design method in which designers ask users to evaluate UI designs. Users then evaluate behavioral details of how an action is executed in a context.

3.5.3.2. Post-cognitive methods for designing interrelationships between user interaction elements

Post-cognitive methods consider a connection between UI design elements, operations brought together to execute an everyday action. The dependency between the operations reflects subjective differences in the composition of an action. Subjectivity in user interaction is a topic of UX, in terms of non-materialistic aspects that cause users to select actions based on subjective evaluations of contextual conditions.

The term UX was first used by Don Norman to cover all aspects of human interaction with computing devices commonly called user experience [35] that meets all aspects of the person's experience with a designed system. The term includes the human interface, usability, industrial design graphics, interface, physical interaction, and the user manual. The term has often been used without regard to its origin or history, and it has started to lose its original meaning.

The design of interaction is focused on non-materialistic aspects of the interaction designated as user experience. UX is identified as an extension of interaction design, because it was discovered while designing for user interaction. UX design is basically directed toward values, emotions, and feelings that are not materialistic elements that can be touched. Most HCI researchers describe UX as post or non-materialistic aspects of HCI. This new field is called user experience, and researchers call it "transcending materials"[36]. User experience research helps researchers to discover individual aspects of the HCI. In contrast to usability, user experience highlights non-utilitarian aspects of interactions, and the focus areas of its researchers are affect, sensation, and the meaning and value of the interactions in everyday life[37].

With the discovery of UX from UI design practices, the significance of subjective aspects of the interaction was discovered, including the development of goals and evaluations of contextual conditions. UX design is different from UI design, because identification of situated actions corresponding to turning a goal into activity are required, so how a user evaluates contextual conditions is the primary focus of the design. What a user experiences or discovers from a received action in terms of influence is turned into action and the study of human contextual conditions in terms of behavior context relationships is a primary direction in improving UI designs.

Experience design is an identification of user's internal perception from an event, and turning that cognitive product into an activity design. Cognitive methods help improve usability aspects of designs, while post-cognitive methods focus on additional reasons of human interaction, such as goal-directed behavior development. There are three main post-cognitive methods described in the literature: activity theory, embodied cognition, and distributed cognition. Activity theory is accepted as a principle to be applied rather than producing a complete model of how human performs an activity in external contexts[19]. Post-cognitive methods still consider user needs, because user needs become reflective with respect to the values of their behaviors. What a user experienced is a cognitive product such as feeling, idea, perception, sense or emotion, and such internally-discovered entities are turned into activity design, a user needs evolve from the design of UI with intention toward design for abstract things or entities.

3.6. Design of User Interaction in Contexts

3.6.1. Development of HCI design methods

Figure 10 shows the development of HCI design methods to turn any human activity into a user interaction (UI) design and design of interactions between human and computer.

Referring to Figure 10, the subject has needs that cause it to act in the world. The dictionary definition of need [181] is lack of something requisite, desirable or useful, a condition requiring supply or relief. The object is a computing device such as a mobile phone, and the subject would like to perform an everyday task with the device.

The UI design field aims to provide better everyday experiences by using computing devices to complete various everyday tasks rather than letting humans perform the actions on their own. The primary goal of UI design is to transfer all previous human action skills to a new platform, a computing device, and the user should be able to develop new skills by interacting with the device.

While UI designs are all about planned actions, the problem of missing dependent actions in designs increases design complexity and causes users to pick important problems from a collected problem set. Dependent actions are typically arranged on a stack (FIFO: first in first out) or a queue (LIFO: last in first out) or most often in a bag (with no order), and users dynamically create goals dependent on the urgency of the problem. An order would normally be followed but, depending on complexity, such an order may not be applicable, in terms of conveying solutions to old problems towards new problems, so UX operates in terms of new situation, new solution.

The expectation of independent action-based design causes generation of various new UI design challenges and increases the complexity of UI designs. Usability and user satisfaction become the central focus of HCI studies[37], and HCI researchers turn their attention to non-materialistic aspects of user experiences to identify what is missing in the design of UIs and place the missing aspect into the UI design process [39].

3.6.2. Design for independent and dependent human actions to Natural Context

Figure 11 depicts a design for independent and dependent human actions. Referring to Figure 11, an initial assumption about actions in an interaction is that actions are independent, and all design methods are able to identify the single action of a group. For example, UCD [1][2][3] considers that a designer will decide on user activity within present contextual conditions. On the other hand, ACD [1][4] focuses on step-by-step identification of components of user activity by considering designers' biases introduced into the design process in UCD [1][2][3]. VCD [5] and ED [6] ask users to report their subjective values and emotions to determine an action to be designed. All methods consider that human actions are not mutual, and users can be considered as independent from their context. All user interaction designs are for identification of human actions to be designed via different methods, and design for human activity is reduced into single action components of the activity. Experience design means to design for the present situation.

Complex human actions are simplified by interactive design methods. Human actions, tasks, and activities are simplified in a way that the (usable) part of them is only transferred into user space, and rest of human activity is deformed in a way based on an evaluation of user's current contextual conditions, so the user experiences happiness at the time they use designed devices.

3.6.2.1. UI design methods: Design methods for learned everyday actions

UI designs based on identification of human behavior in a given contextual condition help to improve the usability of computing devices. Behavior analysis includes details of how a person acts in the world. Usability is an initial concern of human-computer interaction design, and usability is a functional aspect of the HCI, a quality attribute of user Interface designs. A traditional usability framework focuses on user cognition and user performance in human-technology interactions[37]. It is defined by five quality components: learnability, efficiency, memorability, errors, and satisfaction [40], indicating whether the system is easy to learn, efficient to use, pleasant to use, and so forth. “Usability, when interpreted from the perspective of the users' personal goals, can include the kind of perceptual and emotional aspects typically associated with the user experience. Usability criteria can be used to assess aspects of user experience.”[41]. Usability corresponds to design of user interaction. On the other hand, user experience corresponds to the identification of user goals, and to design of UI for that specific user experience. When designing for user experience, individual interests become very important in the design [19].

UCD [1][2][3] and ACD [1][4] are two UI design methods developed for designing human everyday actions. UCD [1][2][3] methods deal with the design of a single everyday action on different levels of a human activity map, such as a single operation of an action, a single task of an activity, a single expression of an operation, or a single action of a task. UCD [1][2][3] provides design of independent actions from natural context. When UCD [1][2][3] is applied, new conditions become visible, i.e., when designed for planned actions, the results of action cause designers to realize that there are dependent conditions and actions.

On the other hand, the ACD [1][4] method provides an incremental design process to include dependent actions into UI designs. Due to the incremental approach, ACD [1][4] only helps to identify complex actions on the vertical hierarchy of the human activity map and requires observation of how users deal with dependent actions by the designers to identify dependent actions of the users. For this reason, ACD [1][4] also provides optimization rather than the addition of real dependent actions into UI designs.

3.6.2.2. UX design methods: Design methods for situational future actions

When UI designs challenge human goals, a non-materialistic aspect of user interaction called user experience is discovered. As goals are challenged, user behavior becomes unpredictable and interaction designs require more complex solutions. Early designs are for improving features of the UI design, but the design task then becomes more complex, involving search for what is the right user action, and how to turn such an action into usable UI designs.

UI designs are for identification of interaction designs of everyday human actions in external contexts. Because actions are considered to be independent from natural context, users are faced with challenges of making decisions about dependent actions in that context. While users may either accept or reject the application of a UI design rule in all dependent conditions as action design, differences in user behavior help designers see the significance of non-materialistic aspects of user interaction, such as creating new goals to deal with dependent action conditions. Designers may benefit from user realization that subjective evaluation plays a central role in action formulation (UI designs), and change the direction of UI designs to propose new design methods based on subjective aspects of user interactions. In this way, new design methods, such as VCD [5] and ED [6], based on results of how users deal with designs based on UCD [1][2][3] and ACD [1][4] design methods, have been developed.

VCD [5] and ED [6] are two UX design methods developed for identifying user next actions based on subjective evaluation outputs of external contextual conditions. VCD [5] provides a prediction of everyday next user action based on subjective evaluations such as likes and dislikes. VCD[5] helps in design of everyday actions at different levels of the human activity map, such as a single operation of an action, a single task of an activity, a single expression of an operation, or a single action of a task.

VCD [5] provides a design of independent actions from natural context. On the other hand, the ED [6] method provides a human action response to situations based on a change in user emotional states. As with ACD [1][4], ED[6] is also based on an incremental design process to include dependent actions into UI designs. Because of this, ED [6] can only provide an optimization rather than an addition of real dependent actions into the UI designs.

3.6.3. UCD, ACD: design of independent and dependent actions of planned actions

3.6.3.1. UCD method for identifying design of independent actions

The UCD[1][2][3] method has been proposed to find independent human actions in natural context and produce a UI design for users to use in performing an action with a computing device. This method assumes that actions are not mutual in a natural context, but actions will cause some changes in the contexts, and humans need to modify their actions based on such changes change. In user-centered design (UCD)[1][2][3], the focus is on how humans develop actions in response to received action from an external context. Designers may develop a user interaction design based on collected contextual user behavioral data, but designers also can use their understanding and skills to predict the best possibilities with respect to the design of user activity, so many individuals and social factors related to designers ca affect user interaction design.

The role of users in the development cycle is to provide an approval authority of the product features. Designs reflect likes, dislikes, skills, and needs of a particular population, and since designs may increase frustration and anger of others[42][43], designs are complex structures in which many features are not used by most users [44]. The main disadvantage of the UCD [1][2][3] method is that designs may have high potential to meet individual static requirements of user actions, but may fail still fail to support sequential actions of a particular human task or activity [1].

3.6.3.2. ACD method for identifying dependent actions

UCD [1][2][3] has been developed as a limited view of design. Instead of looking at a person's entire activity, it is primarily focused on details of a current task. The ACD[4] method was developed after UI designs challenged user goals. Designers must find situated actions of the users, and the ACD design method considers the problem of finding components of complex action to be completed. Rather than identifying the actions to be designed, user behavior in the related context will be observed, and ideas related to how the user behaves in that context are developed and tested via some initial prototypes. This process will continue until discovery and identification of user behavior. This approach is "design as thinking", and it proceeds step by step to identify components of user activity. Each idea about how the user behaves in the context is tested with real users until the best approach has been found.

3.6.4. VCD, ED: design of independent and dependent actions of new situational actions

The VCD [5] method considers asking users to evaluate actions to be implemented and, based on user evaluation outputs, a UI design idea is selected. VCD [5] is used for selection of action and execution of the action. The method considers the use of evaluation outputs as values to identify human actions to be designed for. It is similar to the UCD [1][2][3] method, but users report their subjective evaluations in place of their needs or intentions to perform an action. VCD [5] provides a design for single everyday actions most likely to be selected for the next user experience. On the other hand, ED [6] provides an HI prediction of multiple everyday actions that users are likely to implement.

Emotional design (ED)[35] deals with understanding of user emotional states based on a change in contextual conditions; for each such state, designers identify a user interaction method. Users are asked how they feel and what are the desired actions to be implemented. Based on those user inputs, emotional design becomes possible. The method is slightly less applicable in the context of user experience design, because UX design looks for UI design after a user goal is challenged. One concern is that there is no developmental connection between user actions and/or user experiences, and the components of a task are actions independent from one another. The only implementation is based on an individual request from a person in terms of change in emotional states. The ED [6] method has been developed to identify human situational actions; is based on the idea that UI designs for each emotion should be produced, but it gives no clear way of how to do that.

3.6.5. DesignX: connecting independent action designs to contexts

Because actions in an interaction are considered independent from one another, dependency should be provided through providing feedback to users. After user interactions based on the experienced subjective entity of the users are designed, any possible challenge based on people or technology designs should be covered by a new design method focusing on socio-technical issues during interactions. Figure 12 shows how to connect independent and dependent actions of HI belonging to two different users.

The DesignX[15], [16] method has been developed to concentrate on the design of interrelationships between designed user actions, and it creates a connection between new UI designs and helps to deal with social and/or technical issues in terms of order of designed actions in communication between two users. DesignX[15], [16] is a system design method that complements missing parts of user experience designs, such as social and technical problems during peer-to-peer interactions. In other words, designX[15], [16] is proposed to identify interaction patterns between users and/or computing devices, and design for interaction outside of user interaction designs.

Referring to Figure 12, planned actions of two users are designed based on the UCD [1][2][3] method, and dependent actions may be identified via implementation of the ACD[1][4] method. The mutual aspect of actions is set up by the DesignX [15], [16] method, in terms of what action of HCI would produce what action of another end user. The challenge is that, if a design misses the contextual conditions, then a new interaction design would become different from the old human action design. DesignX [15], [16] may cause integration of two or more unrelated actions into one based on human activity and natural context, and that would cause disconnection from that context and development of new context based on users' frequently changing needs.

By the setting up dependency between actions, a virtual context is created to make an external interaction possible. The existence of a new context is due to the time of satisfaction of user needs, where the user may be looking for something new. If context at the beginning is not included, a new context will be created.

3.7. After Users Interact with UI Designs: New Situations in the Contexts

This study assumes the UI designs for present action meet user expected action design and considers the possibility that the UI designs produce the same UI designs for different natural context conditions.

3.7.1. Users realize dependent actions and situations in their Contexts

After users interact with UI designs, they will be faced with new situations in their contexts. First, they will realize the dependent actions and situations in the context. Then, they must deal with new situations with dependent actions. Because UI designs do not consider actions' dependencies on natural context, users should make a decision as to whether they will accept and apply the UI design rule under all related new conditions, or instead reject and break the rules of natural interaction, and whether they will use dependent actions outside of their goals in the natural context. They then set new goals for their dependent actions. This represents a human skill that lets users survive in the hard contextual conditions of the world, and people may create alternatives to reach their goals if they are challenged in the world.

UI designs are suggested human actions in contexts, and situations of either accepting or rejecting a design rule in dependent conditions take place around the UI design rule. The users cannot change the design rule because they do not produce the device. Whether they accept or reject the design rule will cause them to be divided into multiple groups, and such groups will have created their own communities. People gathered based on natural interaction rules are broken into subgroups based on shared aspects.

3.7.2. Accept or reject UI design rules when dealing with the dependent actions

The UI designs challenge human actions in natural contexts, and humans are implicitly forced to adapt[1] to the design rule and change the implementation of their actions to match the predicted human actions.

3.7.2.1. Users accept suggested action design rule by the UI designs

When a user interacts with an HCI design based on a current design view, design changes conditions in external contexts, and users may experience difficulties in adapting to new contextual conditions. Users must either accept new design rules in external context and re-organize their activities so that context will be changed based on new user activity, or orient their behaviors to complement missing design states. If people agree with the design decision, they begin to change composition of their previous dependent actions, originally usable under the condition of natural context. Figure 13 exemplifies change in user behavior if the user accepts a UI design that can be implemented under all contextual conditions.

Based on those two new conditions, users may correct their natural behavior by applying the UI design rule into implementation of all dependent actions in the context. If a user were adapted to the technology, the user would try to estimate the designer's intention, increasing design complexity. If the user accepts the design rules, the user applies it to next behavior. In other words, users adapt to errors in the design. The user learns of errors in the design of user experience with a device and, to avoid erroneous actions, they adapt their behavior based on the errors in the design [45]. Users learn misrecognition errors depending on how frequently they occur in their experience, and they change their behaviors with alternatives to correct errors in the device[46]. When users adapt to designed contextual conditions, their behaviors are affected by that change, and it is very unlikely that people exhibit identical behavior. This can cause deviation from real tasks depending on how much attention is required to correct for errors in the design via user effort. Developers often provide an alternative solution to users for dealing with design feature errors [46], so rather than solving the base problems, the solution space is extended with an alternative set of solutions inspired by user behavior to correct design errors, i.e., a user adapts to design errors [45], [46].

3.7.2.2. Users reject suggested action by UI designs

If a user does not accept the current design rule, the user completes the missing states of UI designs in two steps: breaking down the previous hierarchy of human activity, and synthesis of new user activity. Users may break rules of natural interaction and start using natural interaction components outside their goals. Since the goals of natural interaction elements are changed, the elements are positioned in users' context as tools to deal with new dependent conditions. Examples can be given from verbal behavior with designed devices, such as using emoticons, and language rules may be changed to survive in the new digital world. Although UI verbal design rules are not changed, users differentiate their behaviors to achieve their goals, although the UI designs may challenge the users in their own contexts.

Humans often must compensate for design limitations. They must either discover how designers think about how a user might have been challenged and how the designer solved the challenge[1], or they can try to correct device response and complete missing parts in their expressions. They often must spend the time to deal with design challenges, decay in skill usage, tiredness, giving up, etc., and accept the erroneous design[46] because of no alternative or sufficient time to change it.

Design limitations can negatively affect users, and user tasks will be complicated by unresponsive design. How can users deal with the challenges created by unresponsive design? On one hand, the user needs to deal with real world events and create action responses to them. On the other hand, users must keep their responses in the mind, and look for ways to communicate meaning in the presence of design-related contextual challenges. In this way, user attention can be automatically divided into two components.

3.7.3. Newly emerging situations and multiple design challenges

UI designs based on the initial assumption of actions' independence from natural context creates a roadmap for UI designs to follow vertical hierarchy in a human activity map, where dependent actions on the horizontal line of the map are put aside and considered as an optimization topic when needed.

Actions on the vertical hierarchy represent simple actions on the bottom level and complex actions at the top levels, e.g., body actions on the bottom and cognitive or mind actions on the top. Because of this structure, UI designs for actions on every level of the vertical hierarchy will add a set of dependent actions into the list of UI design complexity and, after certain numbers of user interactions, the UI design requirement for dependent actions will emerge without providing solutions to individual dependent actions. In other words, because dependent actions are the topic of UI designs, people tend to need quicker design solutions, such as design solutions obtained by picking some attributes of dependent actions. Depending on mental workload, people will be looking for shortcuts, depending on the urgency of their problems and their need for design solutions.

Since UI designs for dependent actions are not provided, this second set of user needs increases design complexity. This forms a dynamic closed loop of need and solution, each feeding the other. In the context of natural interaction, the dependent actions or attributes of different dependent actions are brought together in terms of having emerging situations; this will present opportunities for new user experiences, because the UI design will provide rapid, instant, and timely solution to user challenges without following the ordered list of dependent actions. This design logic is built upon the assumption that actions are independent of natural context, and supports the perception of any context based on individual needs of people in the world.

3.7.4. Users feel confusion and complexity when faced with dependent conditions in their contexts

Users can experience confusion when the design produces only a single response to them; the difference between the user's expected action and the UI design response may cause a user to feel confusion when evaluating interaction results. An external reaction causing a change in a user's subjective state may change the user's need and the user will then need a new interaction design, but the design may not be able to identify the change in user need and will respond to the change in user need with the same interaction design. For example, a mobile device may consider unintended movements to be meaningful gestures[47], or device may not recognize other users' movements as gestures and users are therefore not able to accomplish their tasks via the device.

Confusion increases with the complexity of the problem, because each interaction causes creation of a new set of problems before solving the previous set. Complexity, associated with the structured nature of user experience and activity, is a property of human activity[48], but confusion problem should be solved, otherwise simple solutions can complicate life[49]. After confusion, they need to make a decision between either accepting or rejecting the design rule with UI designs. A change in user context may cause reorganization of user actions and users need to think in terms of overall interaction design, not just the design of everyday actions but also interrelationships between multiple everyday actions following one another. Simplicity is thus not the best answer for user experience with a design [50].

3.8. Applying Optimization Methods to Minimize Effects of New Situations

When users attempt to change the disadvantageous positions of UI designs for themselves, new design opportunities may be created. Users' dealing behavior may show designers how to improve their designs. The following gives an overview of some topics in the implementation of applying optimization methods to UI designs while users deal with dependent actions in their context.

3.8.1. Missed dependent actions, and generation of dependent UI Design Problems

When users experience challenges when dealing with dependent actions, causing people to have new experiences in the form of new problems and forcing them to create new goals for each new situation. People in this situation may feel confused and become lost in problems. Every new experience is considered to be an opportunity to avoid the pressure of such challenges, but that may increase the rate of problem occurrence. Norman described "relieving the symptoms of problems" [16], i.e., visible cues in the natural context, but people may not face real problems due to either problem complexity or urgency of a present solution. In exchange for short-term solutions, people may gain strongly bad problems.

An incremental problem-solving method applied to design methods [22] may create a new set of problems while solving the current problem. This problem-solving method is based on an assumption of actions' independence from natural context, and is basically an indication of cognitive bias of designers and researchers, leading them to choose actions' independence rather than dependence of the action on the context [7].

The result of a design method implementation is that people may be faced with a great challenge to continue to use UI designs to complete their everyday tasks with the devices if they choose to perform the quite tedious and extensive work of deciding what to do under dependent conditions. UI design limitations may cause rules of natural interaction to be sabotaged and create a new set of problems, referred to as dependent problems, that some of them may not have seen before.

3.8.2. Some of identified UI design challenges

User interaction designs are designed as static human actions applicable in every condition within a natural context, and computing devices store those designed user interactions to be executed by the device. However, the design rules influence dependent human actions in the context, and that influence is uncontrolled. Therefore, it is difficult to tell how much the new design changes with respect to human previous action skills, and the reason for such change may be unknown.

3.8.2.1. Inheritance from lower level UI design

HCI designs are influenced by inheritance of lower level design challenges (along the vertical dimension) and missing context adaption of design. The design is a medium, and it should not be of primary focus in the interaction; it should probably be invisible. Many research problems in Computer Science (CS), HCI, and related fields are inherited from low-level design problems, and a solution of those problems is beyond the scope of the research problem under study. The only implication of this research study with respect to new topics or objects would be their future roles as future research problem to be studied. For example, user verbal experience design adopts methods from spoken word, touch, body expression, and interaction, action, and affect understanding in the field, so rather than using a forward-looking research approach, looking backward to understand complexity created at each step is required.

3.8.2.2. Missing design states, incomplete designs, and unresponsive designs

In addition to having inheritance-related design challenges, UI designs may be incomplete. A design may be based on user data collected under certain contextual conditions, and when the context changes, the design will continue to create the same response without regard to the condition change. Unresponsive design causes users to find their own methods of dealing with contextual conditions created by the design. While a user-based solution is one way to deal with such a challenge, designers can sample user behavior under various contextual conditions and turn it into a newly designed product or product feature.

Because the influence of a designed object on the human and human action is not considered during the design, only a design solution in which users can deal with current contextual conditions is considered. Designs include identification of how to do an action, i.e., activity design. Humans normally deal with everyday contextual events, and they need to divide their attention to design related challenges and look for ways to deal with them. The user has to fill in missing components in the activity structure and hierarchy. Each design will open a new cycle, and the user may thus not be able to complete the cycle and overall goal when mutual influence and/or mutual action are considered.

User verbal experience design studies shows implementation of this scenario, with many incomplete design features on software keyboards, leaving both users [51][52][53][54], and designers [55][56][57][58] still looking for new ways to deal with texting problems. Designers look for alternative ways to meet user interaction challenges rather than fashioning a direct solution to such problems[46].

3.8.2.3. Unconnected and unused features of UI designs

Design accomplishes generation of new features discovered through study of user behavior, but unconnected features may cause a burden on user experience and impede flow in user experience. In addition, design for general user behavior rather than individual behavior features design solutions with some general rather than specific features for advance usages and improvement of user skills. This may cause another challenge, that people with better skills become only average skilled users, and vice versa. Fewer people may use advanced features of a design depending on the underlying design approach. In a design with many product features, users may not experiment with many of them. Any designed HCI solution would help users to relieve symptoms of the real challenges that people are experiencing [15]. The design may provide compensation with the addition of new features. Even though a design may have many features, most of them may not be used by average users, and may even not be understandable at all for average users [59].

3.8.2.4. Complex UI design problems due to one or more of the above design challenges

By inclusion of design challenges like those described, complex UI problems such as those described below may be created. They are not simple problems, but rather represent combinations of multiple dependent action challenges at different levels of UI design. For example, mobile devices create many problems by generating owner distraction [43], frustration [42][43], and anger [43]. People may experience difficulties in interacting through the small screen of a device to read or text, or waiting for slow downloading [42].

Mobile smartphones have some inherent design constraints that create challenges for users, including small screen, short sessions, single-window visibility, and unreliable connectivity[60]. Because mobile devices are portable, when people use them in different contexts and situations, they can be interrupted when performing a task resulting in mobile device usage with short usage sessions [60]. The most challenging feature of mobile devices is the requirement for typing on a soft touch keyboard, requiring users to divide their attention between the screen content they are typing and the keypad area to check the results of their actions[60]. Devices are problematic. Mobile device users in the USA may feel that their communication problems are solved by such devices, but they may encounter a new set of problems, such as interaction with fingers on small screens [42].

If a design does not give a clear connection between user actions and results, a user loses sense of control over the designed system[61]. Many interaction design principles that are independent of technology are often not considered, including visibility, feedback, consistency or standards or norms, non-destructive operations, discoverability, scalability, and reliability[61]. Signifiers showing how to perform tasks either may not exist or may mislead users, e.g., an interface button may indicate that an operation is possible even though it is not working[61].

There is confusion between application interfaces and website design. Websites are accessed for communication, information seeking, data handling (such as picture upload, install an app), entertainment, and transactions [62]. Many of these tasks require typing in some information, and typing on mobile devices can be a really hard and error-prone task [62]. If a user accidentally touches something on an iPad app, the user often cannot find the way back to the starting point. Also, many users do not like typing on an iPad touchscreen. iPads are used mostly for media consumption [63], and this may cause people to change to other devices to get real work done [47].

3.8.2.5. Natural interaction and user interface designs challenges

Natural user interfaces are not really natural [64], and people may need to learn and/or remember specific gestures to effectively use them in their interactions. A gesture leaves no track after completed, so users may have limited information about the gesture results if needed. Also, if a system is designed for gesture control only, it may be quite a hard challenge for users to overcome the learning curve for operating a device[64]. Timing and dynamics of gestural motions represent another dimensions of gestural interfaces. For example, pinching and spreading can become natural replacements for zoom effects, if the dynamics are consistently based on human factors and pinching movements are easy to control [64].

Either a gesture may not be recognized due to limited human action understanding, or researchers' selected features for action recognition do not include that specific behavior. Random movements on/with the devices may be misunderstood as device gestures[47]. Not only at the physical interaction level but also at other levels the interaction challenge continues to survive. For example, event notification [65] on devices can interrupt everyday life in a undesired way, and gestures for giving commands and controlling a device may differ from device to device[66]. Also, devices often may either interpret a random movement as a gesture [47] or do not understand the gesture performed by the user due to its noncompliance with action features set by designers for creating the user gesture. In addition, user interface design objects, while aesthetically pleasing for Apple users, may have less usable characteristics, such as low-contrast fonts with small or thin features, making it hard to read screen-based text [67].

3.8.3. Cumulative problem solving behavior

Design methods are based on the concept that users should first have needs, and then the design will work for satisfying them. When a current need is satisfied, the design will be based on another need, possibly related to other things. Whenever the user needs something in addition to a designed solution, designers will look for ways for improving previous solutions, perhaps by changing some parts of the design based on new user contextual conditions. That means that, depending on how much a user changes, the design would change. However, the design should offer multiple solutions, and should switch between those solutions depending on user state rather than forcing users into a permanent change in their states.

Interaction design problems become visible when users realize that actions are dependent on external context, and when users begin dealing with that situation, designers should be able to identify user challenges. To that purpose, a cumulative problem-solving behavior is often observed in terms of waiting until a problem occurs for individuals and solving it whenever it is a problem for individuals, and/or for people with certain skills. The problem solution may also create problems for other users or people who share the same context with the original users.

3.8.3.1. Unpredictability, and selection of important problems to survive

Another problem-solving behavior is picking the important problems at critical times. The only way for users to survive is to choose an important problem requiring a solution and deal with that problem. Users do not always know the next problem that they may be dealing with; designers' cannot predict what to design for. Each design adds one block onto the complexity of interaction design, because users must deal with missing components of a design under different contextual conditions.

Users usually feel that something is missing at any time, and they are often not satisfied with UI designs. Designers try to improve the quality of their designs, but if they don't notice that an underlying assumption is not true, user satisfaction would be impossible for all users. Consequently, designs usually reflect only certain groups' likes, dislikes, etc.[1]. Humans take the role of users, but they are often not doing the same tasks done in natural context, but are rather controlling and commanding a device so that it performs tasks in place of the users. Therefore, user skills are different from human skills.

3.8.4. Future direction of UI designs

The future of UI designs is generally determined based on a simple principle: How much do users accept or reject universality of UI design for independent actions. The following discussion is intended to give some overview about selected topics when looking at the future of UI designs.

3.8.4.1. Internal design problems with design methods

While UI designs are created to meet expected human actions, not all designers are able to meet human expectation in terms of interaction design. There might be several problems in the processes of design, such as in user selection, contextual behavior data collection, designers' cognitive biases, design and developer tool challenges, etc. Although these various effects may change the quality of the UI designs, that topic will be excluded from analysis; it is rather about details of individual UI designs for present-time experiences. This study considers what happens after a user implements designed actions, initially thinking that the UI designs can meet human present time expectations.

3.8.4.2. Cues of the natural interaction design problem, and optimization

Design becomes an optimization for relieving symptoms related to user confusion. Norman describes that effect as relieving symptoms of today's challenge, but the real challenge will continue to survive[16]. If a symptom is removed by some instant solution, bigger problems might occur in the future. The design solution may help relieve symptoms of a real interaction problem and provide only the optimization of design to present contextual conditions. Current design methods may provide an optimization of the state of design, but the use of design in context may influence other related user skills. Each optimization effort makes it more difficult to solve the interaction challenge except for providing some relieving effect. Instantly meeting user needs may cost loss of many other connected or related skills affected by that decision.

3.8.4.3. Initial assumption about actions in contexts causes creation of an adaptation problem

Subjects acting on objects describe the independent action assumption of research and design fields. Objects acting on a subject in response to the subject's action shows dependency between actions and owners of the actions. If actions are independent, then a context based on people's wishes of desires will be developed. Nature should adapt to the human, and people set the rules of their space, time, and social contexts. If actions are dependent on nature, humans should adapt to nature. People are responsible for identifying rules of space, time and social contexts. Under both conditions, nature corresponds to the rules of life free from any man-made of artificial objects and system designs.

An adaptation problem will take place between human and user or technology. A human will either adapt to the technology or technology will adapt to the human [1]. If people agree with a design rule, they will be part of a design-based community; if they disagree, they will create their own community based their common preferences, in which case their agreements about how to perform an action become the basis for future design of user actions. Norman discussed this when proposing ACD [1][4] to replace UCD[1][2][3], because UCD [1][2][3] is based on an assumption that "technology should adapt to human". He proposed that "humans should adapt to technology" in terms of changing their activities to learn how to use designer-described user interaction designs with computing devices [1].

3.8.4.4. Evolution of UI designs based on change in user behavior

Under unpredictable user behavior conditions in terms of identifying dependent actions in the context, UI designs would be based on a statistical average of behavioral change. User behavior is kind of normalized, and similarity between users will increase. In other words, behavioral patterns of people in large numbers would be the only alternative for all users, because product designs would choose to design for behavioral expectations of those large numbers. Also, initial UI designs may turn into a new form, but still unable to retain the initial design in updated form. Also, each design should cover all contextual conditions; it is part of a closed loop that leads to creation of a new problem. The degree of complexity is increasing with each design, and each design adds to the interaction design problem.

3.8.5. Optimization Based Solutions: continuous loop between problem solving and creating new problems

Either designer or user rules for completing or correcting an interaction design initiate the start of a new action cycle that may be missed by the design. Every uncompleted action design increases the load on both user and designer, and designs become more complex as time progresses. In addition to these aspects, each new action design by a user or designer requires thinking about other actions in relation to the initial action. This leads to the creation of context, such as presence of other social beings, which reacts to the execution of the designed action. Optimization is an action applied to a problem in the world, but if dependent actions are not considered, it only works to create problems. The following discussion deals with some steps in the continuous loop between creating problems and solving problems.

3.8.5.1. Finding design opportunity in created chaos for users

Users often either manually correct or complete missing parts of a user interaction design. To change user behaviors while correcting or completing UI design defects, designers may consider the changes expressed through user behavior as an indication of user need, and they may consider this an opportunity to create values to improve user experiences. Sampling contextual user behavior, while the user is dealing with another problem, is a form of analysis of user behavior within a specific contextual condition. Without information about previous and/or next contextual condition based on a change in user subjective states, the design will only increase the degree of complexity of the UI design problem.

Based on the current model of interaction, when a user interacts with a designed device, user needs, values, and goals are affected by the interaction, and users change their states. However, the design would be unchanged and unresponsive to changes in user need. Therefore, users will experience HCI challenges and create their own methods of dealing with such challenges. Depending on how much users are involved with challenges in their external context, designers will sample users' behavior during that time, and any needs demonstrated as part of the main challenge that the user is dealing with would be identified by designers and an activity design for users to experience would be turned into a product or features of a product. Then when a user used the new feature, a new cycle as described above will start for running that cycle, so the user will have multiple unfinished works, reducing the human mind performance.

When a user deals with a solution, and designers obtain samples of contextual user behavioral data at any time during that process, designers may turn the research findings into a solution such as a product or a product feature. Depending on how much user experience overload there is in managing daily tasks, they may use that new feature, and a new cycle will be started for the new feature's use, the feature would be working under determined contextual conditions, and it will be unresponsive under other contextual conditions. Norman mentioned the same problem with respect to gestural input in mobile devices; he said that he would not use them until there is a consensus related to each gesture and its meaning[47].

3.8.5.2. Complexity and confusion created for users by the UI designs

As assumptions about human action in the natural context are made, human interaction becomes a topic of user interaction design. User interaction design methods apply the same assumptions about human interaction, and they consider that actions belonging to human interaction are not mutual. All UI design methods assume that a subject's action is independent of its context. However, context connects a subject to the other objects and entities surrounding the subject. The action of the subject causes generation of reaction from the object towards the subject, but most design methods do not consider this.

User actions are not connected to one another. To design for each action of human interaction, actions are selected based on user needs of the present time. UI designs are based on user needs within present contextual conditions constrained by time and space or place. The design of user interaction is about the prediction of user need based on contextual user behavioral data. If any UI design influences human interaction, and influenced human interaction influences human action in unknown contexts, design based just on users' present need causes confusion for humans, and the confusion is reflected in their behavior. In this way, the design of user interaction becomes very complex.

3.8.5.3. Creation of new UI design problems

There are two issues with behavioral challenges: current design may create new challenges, and challenges with components of the current design are inherited. The degree of complexity to deal with while designing would be increased in this way. Some user challenges inherited from previous designs are given by examples of HCD[13] based interaction challenges at different levels of user experience such as device, experience, interaction, expression, and product design.

Each new UX design based on a current method causes the creation of a new set of problems, although old problems may not be solved at all. This requires selection of the most important ones and leaving others for the future. New UI designs mean new challenges for users. UI designs are based on actions independent of one another in an interaction. When a context is excluded from a design, any design idea would create a new challenge for users. In other words, design as thinking is valid for new conditions after the human goal is challenged, and a designer can look for ways to recover from it and create new challenges. However, if the context were excluded, no other solution would help solve the UI design problem, but would only increase the complexity of interaction design.

3.9. User in Natural Context: Recipient of Actions in Natural Context

3.9.1. Development of virtual contexts for human actions

When humans are considered to be independent from natural context, and their actions are independent of the context, the following things happen. In the context of HCI, users realize the dependency of their actions on their context, and they start dealing with the challenge of UI design. UI designs propose to apply the same design rules for all other dependent conditions, but the actions suggested by the UI designs does not meet the needs of users.

Users begin to make decisions about dealing with effects of the situation that UI designs create. They either accept the design rules and internally change the designs of their dependent actions, or they reject the universality of the UI design rules under dependent conditions, but they begin using their dependent action skills, developed in natural context, outside of their original purpose. Depending on variance in use of the dependent action skills necessary to deal with new situations created by UI designs, people with similar tendencies come together, and have their own set of rules for their dependent actions. Based on the similarity in their preferences, they create their own communities, and people are divided into different social groups.

Humans' decisions about dependent actions cause the creation of new contextual conditions and the creation of the user in a natural context. Context means rules organizing actions in an interaction. Based on the dependence of actions to the natural context, natural interaction external to the human will be learned by the human. A human interacts with natural objects and gains action skills based on evaluation of the external context. When humans start making decisions about dependent actions, humans will create their own contexts, different from natural context, because they change designs of their dependent actions. The dependent actions are created based on natural context rules, so the new set of dependent actions, creating user interaction, is different from the previous set of dependent actions, based on natural context. The challenge to the creation of this virtual context is that because UI designs do not change, users produce only temporary solutions with which to tackle the current state of their interaction problems.

In other words, users make a decision about various dependent actions on different levels of their activity or action map, and they are forced to choose one over the other for a certain period of the time. For example, if people are using texting features of mobile devices, they will have dependent action problems on two levels: touch interaction design and verbal interaction design. They will either have better touch interaction based on their attention to the dependent action conditions related to the touch interaction design level, or they will have better verbal interaction if they direct their attention to the verbal interaction level. However, neither of them provides the quality of their original experience when they were able to touch and speak in natural context.

Context helps us to think about dependency between actions in an interaction. Context establishes a border of a setting in which objects are connected to one another based on rules. This border is abstract and broadly reflects the space, time, and social circles around a person. If any object appears within the condition, this will trigger repositioning of other objects that share the same context with the initial object. The steps of change in human actions towards change in human context are as follows. User activity becomes different from human activity; users are not familiar with the old context in that they don't know details of actions, such as what to do or how to do. Finally, they are part of a new context, in which members share the same and/or similar methods to accomplish actions.

UI designs become barriers or blocks between natural context and users, and this causes the creation of a new context for users, with elements of the context continuously changing. User and designer become two ends of a closed loop in the design. The user becomes the context of design activity. Reposition of any object within the context causes it to be missed from its previous place, and also causes the creation of new contextual conditions such as virtual or online context by users,. As designers learn from user behavior, human contextual interaction becomes some kind of competition between user and designer, but users may change their behavior to recover from design challenges. Finally, a new context is created via user behaviors within new contextual conditions created by the designs.

The new context is a virtual context, created dynamically to help users meet their instant and urgent needs at the time. When users are finished with their tasks, the context will no longer be meaningful, and it will gradually disappear to help users create new virtual contexts for their future actions. Because of this, learning from context and applying in next experiences could become a hard task for users depending on how they designed their futures based on their decisions about dependent actions and conditions.

The future of human actions will possibly lie in dynamically created virtual contexts, in terms of a combination of independent and dependent actions. This will cause users to be strongly connected to the created virtual context, because that context helps them to retain what they have in the past. If context at the beginning is not included in the design, a new context will be created. At the end, a context would exist, but it should be one created without deleting old context and human skills. The change in human actions at lower levels causes changes at higher levels, so while independent of the type of problem, a problem may be seen as one of low-level user interaction designs whose effect will be visible in other interaction design methods.

3.9.2. Connecting multiple users in contexts external to one another

Finally, when users are created in an external context, interaction between two user actions in the external context should be designed, i.e., two different virtual contexts for two different users should be synchronized to one another so that actions of one user should trigger actions of the other users. In parallel with the internal virtual context that helps users make decisions about their actions in external context, actions in external context may also cause creation of new external virtual contexts. An interrelationship between two UI designs belonging to two different users is created by them, and a mutual dialog is set by linking action components of two UI designs.

DesignX[15], [16] aims to design a relationship between designs, such as the design of tasks between designed actions. This is for interaction design, not for real context action, and influences dialogue rather than influencing between designed actions. DesignX[15], [16] is expected to connect the correct actions in a human activity hierarchy with other correct ones, but in the current implementation of DesignX[15], [16] as an extension of HCD[13], design methods support the underlying action independence assumption and, rather than providing a smooth transition between two contexts, DesignX[15], [16] will work for design of user activity based on new contextual conditions. It will be used to apply rules of new contextual condition over a wide scale.

To sum up, through implementation of current design methods, humans' positions in natural contexts are imitated to create a virtual world by picking attributes of natural context based on people's wishes and likes/dislikes. The virtual contexts are created inside the natural context, and those virtual contexts are virtually connected to one another to create virtual social communities. The challenge with all these design outputs is that the design UX's and system designs are temporary and require repair each time they face incompatibility with situations in natural context. Because the context is virtual, decisions about dependent actions are for solving the current state of their problems, not the real problems in natural context, and the design task becomes tedious due to the requirement of continuous repair of the designed UI/UX and systems.

3.9.3. Creating mutual aspects of actions in the external contexts

Through users' decisions regarding dependent conditions, what happens in external contexts can be explained in this way: The initial assumption was that action is independent of the natural context, so designs are based on missing mutual aspects of actions in an interaction. When people make decisions about dependent actions, they begin creating the mutual elements of their actions, i.e., interaction can be described as "mutual action or influence". From the perspective of activity theory, if subjects act on objects, objects act on subjects. Through actions of subjects, objects are created in the natural context. In the context of HCI, humans create users as objects whom they would like to interact with in their external contexts, and people create their mutual aspects by their actions. Humans' decisions about dependent actions create the mutual aspects of their actions, and owners of these mutual actions are users. Based on this concept, humans and users are two different titles given to people. Humans are people living in a natural context, a world created for them based on rules of natural interaction, and users are people living in a virtual context, a world created for them based on their decisions about the conditions of their dependent actions.

Mutual actions are created through subjects' and objects' actions in a natural context. Based on activity theory, if subjects act on objects, objects act on the subjects. From one perspective, "mutual" refers to the second object in natural context. The mutual component of subjects' actions passes from the objects towards the subjects. In other words, a human creates technology and a user of that technology at the same time. In the context of activity theory, technology is an object and the user is a second subject created in the same context, and humans would like to see that second object that shares the same virtual context with them.

The mutual aspect of interaction is directed from exploring the mutual toward creating the mutual based on users' requests. People set the mutual part based on their wills, desires, etc., and create an internal virtual context for their actions to give meaning to their activities, and their activities create the mutual part as an object in the external context. From one perspective, creating the mutual part of human actions in natural context means creating the technology. Think of mutual is an attribute of interaction, and interaction is an object.

Mutual aspects of actions in an interaction are created based on human wishes. Being mutual means being reciprocal, and this indicates something between two actions. It is an interrelationship, the influence of people's actions and response of the world to human actions.

Current design methods output design of independent actions and mutual relationships between independent actions set up by bringing them together with temporary contexts created for this purpose. When mutual aspects of humans' action are excluded from their contexts, a human creates mutual components by picking some from natural context.

3.9.4. Users: owners of mutual actions in the external contexts

Humans create users in their natural contexts to help them deal with the challenges of dependent conditions in the contexts. The user is a role that humans play while interacting with designed technologies. Due to the underlying assumptions of UI design methods, the user turns to be a real person rather than simply a role played during user interaction.

The user is created as a person with selected characteristic features that are meaningful and special when challenges in previous contextual conditions are considered. Design methods put humans into a position where they must give up some previous action skills and, while doing so, the future is unpredictable, frequently changing, and temporary. The solutions that users develop are not permanent solutions for their problems, and they can only consider the current time and problems of that time.

The decision regarding dependent actions in user interaction leads to the creation of the user in natural context. Device or UI designs represent users through a representation of user interactional skills, and users are created through such skills. In the context of activity theory, subjects' actions create the object in their context. By excluding some of the human skills, a new object with action skills is created in natural context. In reality, this happens by either deactivating previously-gained skills of current people or by transfer of the new action set to new generations. This is somewhat visible in examination of skill differences between populations representing generation X, generation Y, and generation Z[68]–[70].

3.9.5. Development of virtual context in the future: design of users' spaces, times, social surroundings

Based on human challenges in dealing with dependent actions, the future of human context can be designed. The following discussion provides an overview of the current direction of future human context if underlying assumptions of design methods have not been updated. UI designs based on a current design view requires a change in user behavior to identify user needs and design for them, but they don't reflect the meaning of changes in user behavior, so at any one time users are dealing one of their problems, that behavioral data taken from a user context that may show something irrelevant and/or temporary is still important for the user and turned into a product feature.

Users live in present time with no past or future, and can only deal with present challenges. When disconnected from a natural context, further UI designs cause individualized pieces to come together single user-centered designs. The conditional connections among the actions would turn into user instant selection in the new action design. There would be a single action response to each change in human internal context, and those actions are ordered in time to create tasks and/or more complex actions. No two experiences would be identical; each would be single individual singular experience, used for the single time, and people would experience a feeling of being unconnected. Their sense of unity could be lost and they may feel that something is missing, affect their satisfaction.

Designs are independent of the past and completely based on their influence on user needs, values, or goals. No phase-based logic exists between actions, and selected actions are unconnected to one another. There is no continuous experience, and all experiences become only for the time being, so people may lose sight their goals due to the challenge of the design, and are not moving toward the goal but taking steps based on dynamics of mutual influence between user actions and UI designs.

When a design causes users' planned actions to be influenced in such a way that users are not able to achieve their goals, users don't know what they will face during the next steps, because they are influenced by their previous actions, and the future is built on current steps. Because designs are independent of external context, the user may not be able to see the results of action, and reasoning between actions is lost. Related history or memory may be lost in terms of accessing the actions, and there would be no way to backtrack because past memory has already been manipulated.

Past, present, and future should have cause and effect relationships and be connected. Emotions help to discover such relationships. Otherwise, there is no rationale between actions in the order, and connections are hard to predict because the user does not know anything about that. If actions are dependent to the context, then actions are planned, so they are predictable, and demonstrate steps of completing a task. A future is created when individually designed experiences are brought together. Details of human experience are stored in the affective side, but details of experience located on the cognitive side are open to change. As an example of the design of future user interaction, we can look at developmental steps of the desktop computer, moving toward mobile and wearable interaction designs.

Based on users' decisions about dependent actions in their contexts, current desktop, mobile, and wearable interaction designs are created.

By the UCD[1][2][3] implementation method, when a user goal is challenged, the human is disconnected from natural context. This is the first step toward full disconnection from the context. While the human is disconnected, the user can complete many everyday tasks working in front of a single computer, focusing on tasks involving only local information[25]. In this process the user operates with the influence of previous human action skills. The time-based connection between human actions is lost, because the user concentrates on switching between different tasks. User mobility becomes an important topic. The focus is no longer on the desktop, but reaches into a complex networked world of information and computer-mediated interactions, the complex task requiring access to information and other people through a network. To deal with this, people must obtain information from different resources. What a user needs to deal with these influences is turned into product features that provide users with mobility. The transition from desktop to mobile devices corresponds to this second step.

The final step in this transition is design of an interrelationship between users and/or computing devices. The communication is idealized to become automatic via IoT and wearable computing methods, with humans disconnected from their natural social contexts and belonging to new social contexts, including not only multiple people but also multiple artificial or robotic entities, reflecting a desire to connect with other social beings, not only people, but also other artificial products, such as robots, artificial bots giving online answers to user questions, etc. This era leads users to use wearable devices, to connect with other devices and services in place of users, or to work as an agent, all goals of the Internet of

Things (IoT) research field. Another related field focuses on social computing, attempting to quantify social interrelationships and make them controllable.

3.10. Implications of Decisions About Dependent Actions on Human Skills

When people make decisions about whether to accept a design rule or not, they are making decisions about dependent human actions in natural context. In other words, they decide whether they are willing to give up their everyday learned actions to compensate for the dependent-action-based interactional challenges of UI designs.

3.10.1. Terminology used for analysis of HI, and UI

Human interaction skills can be updated to create user roles in natural context and turn humans into users. Different users will have different interactional skills with respect to their decisions of accepting or rejecting design rules. The following descriptions of related terminology are provided to help differentiate human interaction from user interaction, showing two different types of people: humans as people in natural context, and users as people in virtual context.

3.10.1.1. Terms used in the analysis of human interaction in natural context

Because a study of interaction requires a person to deal with abstract concepts, it would be helpful to provide a definition of some terms used throughout the study, aiming to show the author’s meaning when using them.

a) **Human**: Human means a person in natural context.

b) **Object**: A person, an animal, any artificial product, a living organism, etc. The object has functions that, when applied, produces outputs. For instance, people act in the world, and their actions cause a change in the states of objects as the objects receive actions from the people. Further actions on the same objects by the same people help the people develop skills leading to knowledge of how to use these objects for their goals.

c) **Context:** Context is a general word for addressing anything in a person's surroundings. Within HCI, it is described as "any information that can be used to characterize the situation of an entity. The entity is a person, place, or object considered relevant to the interaction between a user and an application"[71].

Context broadly covers the relationships between entities developed based on results of human actions. Context provides invisible and non-materialistic connections between objects in a setting. It is produced by the effect of human actions. Context is described as "the environment or situation", indicating "where you are, who you are with, and what resources are nearby", "subset of physical and conceptual states of interest to a particular entity", "any information that can be used to characterize the situation of an entity (place, person, object is an entity), relevant to the interaction between a user and an application" [71].

Context is understood as a place or a space [72], [73]. Context includes sets of descriptive features of a setting, or practice as forms of engagement with those settings. Context and activity are taken as mutually constitutive components that form embodied interaction [74].

d) **Natural Context**: Natural context means any setting or environment with no artificial or man-made products or objects. In other words, the setting includes natural objects, entities, and things, if there is no name given to them.

e) **Design of Human Interaction or Human Interaction Design:** Human interaction design is about the design of individual human action in response to a received action from the external world.

f) **Interaction Design or Design of Interaction (Natural Interaction):** Interaction design is different from user interaction or human interaction design. Interaction design means the development of cause and effect dialog between two entities in the world.

3.10.1.2. Terms used in the analysis of user interaction in any context

To analyze the current situation, we give some states tags. There is a division between the use of words with respect to humans versus users in the description of interaction and/or action, activity. Because user interaction considers human present need, we will use a tag of "human" for the overall model of action and/or interaction, and a tag of "user" with respect to present state of human action.

To highlight the differences in people's experience before and after technology use, the following terms are used: The "human" is used to describe people before they use any technology, and the word "user" is used to describe them after they use technology.

a) **User**: User means a person in virtual context. The user is a term used to describe a temporary human state that is frequently changing, specifically when a design meets a human goal. Situational actions are for unpredictable action completion, and there is no coherence among the actions selected in an order. For that reason, a user is a temporary entity.

b) **Artificial or Virtual Context:** Artificial context means any setting or environment containing man-made artificial products or objects. Such objects may reflect the personal view of its developers, so some aspects of objects' action may be intentionally or unintentionally ignored in their design.

c) **Design of User Interaction or User Interaction Design:** User interaction design is about the design of individual user actions in response to a received action from the external world. User interaction design means identification of human interaction with computing devices.

3.10.2. Human interaction Skills: dependent actions and activities

Human interaction skills are previously gained human actions. Interaction or activity skills that are helpful within a natural context will be affected by defects of UI and UX designs. UI designs could be considered as suggested everyday actions that humans may use in place of their original actions. There are two main steps in the analysis of human activity suggested through UI designs: design for a single, independent action, and manipulating structure of human actions dependent on initial human actions designed via UI designs.

The result of this design view on human activity is as follows: An action from human interaction to complete an everyday task is designed via UI Design methods and, as a result, other components of human activity are open to change based on future contextual needs of users. UI designs cause decomposition of human activity, giving priority to the design of actions related to their importance for the completion of present user activity, so the significance of actions was determined by the conditions in previous context, but now, it turns to how useful the actions are for a user to complete the present task. Users determine the action design.

The primary goal of UI design is to keep previous human action skills and provide an undamaged transition from natural context to virtual context. Such skills are planned actions that would be usable as next experiences based on user evaluation of contextual conditions. However, UI designs do not include all actions for different conditions, so users may start changing the planned actions. The changes may be temporary, but likely to become more complex in the future, user actions representing only present contextual conditions are designed, causing the rest of actions created following the first action and its effect on context to be forgotten. Rather than design action for all conditions, only present conditions are considered in the analysis, and design of other actions is postponed until they are needed. Based on the logic that actions are not mutual, such further steps in the design would be possible.

People may either accept or reject a design rule for how to implement the actions, but under both these conditions, their actions are influenced by their interaction with the design. In short, people must pay a cost for gradually losing the action skills gained in their natural context, and afterwards may disconnect from a previous natural context and join a new, virtual context. In the second step, the forgotten actions are changed based on current contextual conditions created via user interaction with the designs. This mainly results in decay in human action skills usable in natural context, and disconnection from natural context and creation of new virtual context in which a user integrates himself of herself to the new community. Simply speaking, the designs will cause reductions in human interaction skills, i.e., body, behavior, mind, and social skills. The difference will become visible when comparing action skills of a human with technological and virtual skills, and human skills with natural skills.

In both ways, although the degree is different, users may change their behavior in response to challenges by the designs. Every change in related action skills results in skill degradation and people will be disconnected from their contexts, meaning that that users don't know or remember how or what to do with objects in their contexts; the objects may seem strange or unknown to the user. Disconnection from natural context causes users to fail to develop more complex action skills. It also causes user behavior to become unpredictable, and interaction design problems of today may turn out to be more complex than ever before.

3.10.3. Change in design of dependent actions and reduction in human interaction skills and abilities

Because of the underlying assumption of actions' independence from natural context, when users realize the presence of dependent actions in the context, they modify the design of dependent actions based on their present needs. Depending on how much users adapt the actions suggested by the UI designs, many human action and interaction skills turn out to be not useful, and dependent actions will be used independently and outside the initial goals in the natural context. People will be connected to computing machines depending on how much they lose the interactional skills previously gained in the natural context. The result may be reduction in a rich set of human interaction skills when people start using misaligned and/or incorrectly designed UIs.

3.10.3.1. Influence on human memory skills

The influence on human memory skills is related to forgetting previous memories and making up new memories. Design influences on human needs, values, and goals changes planned actions stored in memory to different degrees, and design methods can create an influence in two ways: change in past action skills and creation new future skills. People decompose previously gained skills, serialize the process to select what is needed in current experience, and use others for synthesis in random next experiences. Changes in human memory records based on an evaluation of contextual conditions create a difference between human activity and user activity. In other words, depending on how much people interact with misaligned designed products, they may differ from the states existing before the device use.

Long-term memory retains a record of previous actions to represent the evaluation of results of human actions in memory. Details of human everyday actions alternated with current conditions of human context. People may not remember details of a task but still may have information about it. Depending on the degree of design effect on their behaviors, users may completely forget tasks and task details but may remember feelings that they have trouble give meaning to [75]. A change in details of everyday actions means a displacement of old action components with new ones. Actions tell about events in an external context in terms of something that happened outside people. The displacement behavior is described as development of stories in the human mind. With respect to actions dependency to the natural context, people create new memories and new stories by using originally unconnected pieces of actions.

Story development is one of the negative effects of the one-way influence of interaction. Human behavior is to create something new from a collection of components. A person develops a story by bringing together different action components to design a new experience by modifying old experience records. People create stories by synthesizing information fragments in a manner that best exemplifies what they experience. This ability is useful in human memory formation, because episodic memory organization is similar, but if there are several fragments of human memory, people may bring them together and start believing that they are true and act in accordance with the associated stories. The new experience is not completely different from old experience, and the new one may include something that makes people believe that the experience is essentially unchanged with respect to one aspect, but with respect to other aspects, people may believe that they have something new that works to survive under new contextual conditions.

3.10.3.2. Influence on human decision making and learning skills

The influence on human cognitive skills is related to decision making and learning skills. Correction or completion of incomplete states of UI designs by users causes an increase in user tasks in completing everyday tasks with the devices. Every ill-designed product or feature of the product may result in a cost when users choose to use it. Users may divide their attention into multiple tasks and be good at switching between tasks, but at a later time, it is possible that people might feel tired or fatigued and may experience a memory-loss problem. If users prefer to choose to create their own method, they would change natural rules, applicable in the natural context, and assign their own meaning to previous actions. For example, in social media, users may change rules of natural language use different symbols, and meanings associated with words may change.

Users' decisions about dependent actions in their contexts cause design of virtual context that is meaningful for users in implementing what they would like to do at a particular time. However, context causes random decisions about the design of dependent actions by the UI designs, and the decisions provide only optimization-based support to relieve the symptoms of real challenges in dealing with dependent actions. People cannot learn in the presence of frequently-changing decisions about dependent actions. Users cannot change the UI designs, and can only change the design of their user interaction methods. No rules can be extracted from the context in terms of how to respond to actions received from external context. Users make a decision at the time when it is needed, and the decision may be based on pressure and urgency of the problem requiring solution, so user experiences are not mostly replicable in an everyday context and learned rules are less effective in the decision-making process. However, natural context is built up based on the dependency of actions to the context, and the rules are clear for people to learn. People can identify what to do under the conditions present in the context, and they can benefit from their previous experiences.

3.10.3.3. Influence on human interaction skills

The influence on human interactional skills is related to behavioral social skills. Design affects human skills in terms of changes in human context from the natural world to the virtual world. Skill decay will become an expected issue for people in terms of lost connection to records indicating what and how to do things. The human becomes tightly connected with automatic tool usage, and situational awareness may be so low that people don't know what to do if the designed tool is not accessible. Use of design in context affects human experience, and user experience is developed in exchange for losing human experiential skills.

By the time human interact with ill-designed solutions, the human's previously built skills may become inaccessible, and users may change in terms of their contextual relationship. If we consider human skills to be represented as a fully connected neural network, the influence of any challenge experienced in the context will be spread through many dimensions in the network. People often experience difficulty in adapting to new technology; they are confused between two different worlds, and skills usable in the natural world may not be usable in the virtual world. People able to use their natural skills may not use them because new device designs require different interaction techniques.

Development of HCI as a way to deal with real-world challenges makes it hard to see that previous human skills may be deformed, as users are reoriented into a new digital world. However, it can be seen that design affects human skills in terms of change in human context from the natural world to the virtual world. Device usage often causes problems within human social skills in face-to-face environments. For example, mobile phone use may meet the social connection needs of users while decreasing their pro-social behavior [76]; they exchange their natural interaction methods for completing their virtual interaction. Contextual conditions may begin to challenge user goals and a user might exhibit unpredictable behavior. Interaction with designed devices sometimes causes people to create new strategies and skills while dealing with challenges [77]. Both approaches can cause a change in a person's social aspects and people may find face-to-face communication an extremely challenging task [70].

While people may become proficient in using devices, each new generation may become less human in terms of social skills and may need to learn to communicate with other people [70]. For example, users of a device may lack social face-to-face communication skills[70], and there are generation-based differences between people [69]. Skill deformation, creation of new communication language and/or encoding standards [51][52][53][52][54], and being self-centered are some of these differences [77][78].

People seem more prone to social skill challenges in face-to-face contexts, and device usage may cause problems related to human social skills in face-to-face environments. For example, mobile phone use may satisfy social connection needs of users and decrease prosocial behavior[76]. They may change their natural interaction methods for completing their virtual interactions. As contextual conditions begin to challenge user goals. Users may exhibit unpredictable behavior. People using social platforms may become networked individuals [77], alone but together [78].

The topic of alienation can be studied in two contexts, familiar stranger [79], and alone together[78], to understand why people expect more from technologies. Through design [15], [16], a methodology that aims to design relationships between designs, a selected group of users can be brought together to create new classes and a new and elite community able to use currently-designed devices, new social groups in which users can talk using their new typing conventions. This results in the creation of phenomena like the digital divide and Generation X, Y, and Z [69]. New social groups may cause a change in social trust, like in the tele-cocooning hypothesis, indicating that frequent texters understand different meanings from various words, e.g., the phrase “all people” [77] refers to the people they communicate with. They are indifferent to other people’s difficulties except for those of their close friends. Networked individualism causes people to create new strategies and skills while dealing with challenges [77]. Both approaches cause a change in social aspects of the person and people may find face-to-face communication an extremely challenging task [70]. People on social platforms become networked individuals [77], alone but together [78].

3.10.3.4. Human survival skill: Forgetting and making up new memories

Finally, the emphasis is on surviving skills that provide people with capability for proceed by forgetting some memories and making up new ones. When users change their context, the interaction design may be unable to identify the change and generate same interaction design for them. Users should compensate for design difficulties and spend their energy and power on those challenges. If a challenge is apparent through user behavior, designers may see the challenge through sampled contextual behavioral data and design for new user needs.

Each alteration of contextual condition with expected contextual conditions complicates user activity, and confusion may cause people to misinterpret contextual conditions and change their behavior. Change in user behavior means a simultaneous change in human needs, values, and goals. User action may cause a change in state of contextual objects and, based on that change, user requirement in action response would change.

Due to static design conditions and picking independent actions from human interaction skills during UI designs, many human interaction skills at different levels would be affected. The connection between natural context and people will be lost in future steps, and the effect will spread to humans' internal context and network of their actions. This causes backward spreading of the error in human activity modeling, resulting in human skills not remaining applicable. After users change their dependent actions' implementation, the effect is spread across the network of internal activity. An error in behavior indicates incompatibility of context and user expectations. Error definition would change based on the context in which there are other objects with which the user is interacting. If we take errors to be deviations from expected behavior, it could be said that the design influences a user's previously gained skills and users are forced to change their expression and perhaps their goals, and the result is that a user makes errors.

For example, in a different situation of frustration, if human operations are blocked so that conditions are changed, people may orient to the new situation [21]. If the goal is blocked, people may create a new goal to identify what to do next if the motive remains the same. If the motive is blocked, people's behavior may become most unpredictable[21].

Breaking down the structure of human activity flows from the visible aspects of the activity to the content or meaning aspect of the activity. In other words, users begin changing their activities from components providing interaction with external context (body expressions), to internal context, (meaning and/or goal of the activity). The change process begins with changing expression (body actions) methods to communicate the message. (The term "message" broadly corresponds to task, intention, or goal (in new experiences), (thing you would like to do), and should be separated from expression and/or display methods). If you cannot express it, you change the expression method. Expression leads to operation change, and operation leads to action change. When action change leads to goal change, then disconnection from natural context occurs.

3.10.4. Users interactional skills

UI designs determine user interaction skills in the external context.

3.10.4.1. User interaction as dynamic action development

User activity following user interaction with the design would slowly turn into something completely different from human activity present before the design. Change in user action, task, or activity in the hierarchy of activity would occur depending on a challenge that users experience when dealing with a new contextual condition. Figure 14 shows that if users interact with device interaction designs with a single state while they would like to adapt themselves to design decision of the device interaction method, they need to change components of the second action on operation and expression level.

Following a change in dependent actions, humans are disconnected from their context and create a new context for themselves. Each selection related to action design creates a reaction and dialog between them creates a story. If the story were not based on natural context, then it would be imaginary to justify current contextual conditions.

3.10.4.2. Individualized and/or personalized user skills

The design is a physical entity and is part of a human context. UI designs are predicted human actions in natural contexts, and they influence real and expected human actions in the context. Personalization of user skills occurs when a user is dealing with a dependent action design problem of UI design. If the UI design changes human context multiple times, users cannot find their way toward the development of action skills. This forces users to choose one or a couple of actions over multiple action skills to be potentially developed. A human may choose to deform previously built up action skills to be able to adapt to current contextual conditions created via the device design. Those selected action skills would be helpful for development of new contextual settings.

From a broader perspective, single-state designs without adaptation to contextual change can force people to make a decision to agree with the design rule or not. There may be pressure on users to deal with current conditions of the context created via UI designs by taking steps back and forth to change the implementation of their previous actions, or to create alternatives to relieve the pressure of UI designs on the users. When users change their actions, they become disconnected from their old context, meaning that they don't know what to do in that context.

3.10.4.3. New user skills

Design methods may cause users to make decisions about dependent actions, and the solutions that a user finds to survive in current settings of the world may be a quick way to deal with work pressure. No learning is provided to users through UI designs based on current design methods in terms of settled rules of UI design. Because the design methods are based on optimization, temporary solutions are created for present user state. The solution is most likely not usable in the second or subsequent stages.

Users spend their time dealing with interaction challenges constrained by their everyday life current settings, and each solution the interaction challenges creates new design problems. From a wider perspective, users lose time, gain less from their efforts, and solutions are in their final state when dealing with interaction design challenges. In addition, real user skill development is not possible without solving dependent design problems, in terms of adding more to previous human interaction skills developed in natural context.

Although there are several disadvantages of current UI design methods, novel experiences can be created by providing links between independent actions. People learn new skills in exchange for destroying previous human action skills. Interaction with design in a case where design is not responsive to a change in context causes the creation of permanent change in user states; user needs are evolved only from interaction designs to UI designs for new value and emotion-based subjective experiences. Such new experiences are post-materialistic, and people need computing tools to attain such abstract types of experience. Users need new designs to satisfy their values and emotions. These need-based design and permanent user changes cause creation of complex design integrated with multiple features of the design, and while they provide novel experiences to users, those features are not mentally connected to one another, increasing user satisfaction in newly designed experiences.

3.11. Actions Are Not Independent of Natural Context

3.11.1. 3 levels of IA design

There are 3 levels of IA Design: action, human interaction, and user interaction. When the action in an interaction is considered independent from context, the ensuing actions of human interaction to create action in the context are independent of one another, and actions of user interaction to create one action of human interaction are also independent of one another. The design of user interaction is directed toward the design of one action in human interaction, i.e., the concept of interaction is degraded to human interaction and user interaction. Interaction is a complex phenomenon related to the design of a complex system, requiring study of what is happening on both sides of an interaction between two people or general entities, in which actions by people follow one another. The main challenge of all steps of the design process is that design solutions have a weak connection to user context and user activity in the context. For this reason, in later phases of the design process there is a risk that the design will be completely unconnected to user context if the design causes changes in user behavior. As a connection to context is provided through user action skills kept in the hierarchy of activity, each ill-designed solution could cause a change in that hierarchy.

3.11.2. Unpredictable actions: actions dependent on initial independent actions

The basic problem of UI designs is unpredictable user behavior due to the creation of design methods based on an assumption about the mutual attribute of action. The methods don't consider that the actions are mutual, and they create a design approach to start with little and improve via a learn-and-failure method.

3.11.3. Human takes decisions about dependent actions in natural context

Independent actions from natural context cause reorder of actions in natural context. The connection of human action to the past, and future actions in natural context are affected by human decisions based on workloads at the time. When the connection of human action to natural context is separated, the actions are turned into a serialized list of actions based on human wishes is created. Serialization implies independent and/or free from natural context requirements, and it is up to the human to pick and bring them together.

The assumptions of independent actions cause the horizontal view of a human activity map to be excluded from UI designs. Horizontal hierarchy deals with what comes next after something, and when it is excluded, people being picking helpful action designs to deal with dependent actions. When actions are independent of one another, situations become clearer and are considered as an opportunity for people to satisfy their needs. A human-centered design view emerges from the assumption of independent actions, because it provides concentration on situations and present time.

Human-centered design means the design of human interactions based on human wishes at a chosen time. Figure 15 describes how Bill Buxton, a leading researcher in the interaction design field, stated that human-centered design is created by picking human attributes based on undefined principles.

Because UI designs are based on human decisions, a human-centered design view mostly involves turning toward a self-centered design view. The concept of self has the following connotations: egocentric, egotistic, narcissistic, inconsiderate, thoughtless, egomaniacal, and self-obsessed. Personal pleasure plays a central motivation in user behaviors and related UI designs.

3.11.4. Development of incremental design method is lacking due to underlying assumption

HCD[13] is a form of hill-climbing used for incremental innovation[22]. Hill climbing is a mathematical method applied for achieving local optimization. Figure 16 shows an implementation of a hill-climbing method applied to a UI design problem.

Iterative steps of the HCD [13] design method help to fit design features to users' expectation in multiple steps. The hill-climbing method works best if only a single hill exists to be climbed. UI designs are predictions of everyday actions in external contexts, and there might be many dependent actions executed following an initial everyday action. Norman mentioned that the assumption of actions' independence from their contexts is made only to simplify the design processes, and there might be multiple hills around the initial hill[7]. In other words, if a subject's action causes creation of an object's action, the object's action will cause creation of the subject's next action. That causes the creation of multiple actions to be designed for, and for each action there would be a new hill, even though current assumptions about an action may cause the connection between hills to be invisible. For example, the ACD [1][4] method has been developed for identification of other hills around an initial hill identified through the UCD [1][2][3] method. Other hills correspond to connected user actions in a context. ACD [1][4] is based on the implementation of a "design as thinking"[13][14] approach, providing iterative steps to test every UI design idea within the relational context of action designs.

To address dependency between actions in an interaction and to connect users' actions to their context, Norman looks for a new design method to move between hills. In other words, when users' experiences are designed, there should be a way to move from one experience belonging to a single user to another experience of the same user. It is only possible to set connections from object to subject, providing feedback into the formulation of a subject's next action. The designX [15], [16] method considers providing dependency between actions in an interaction, in this way keeping the structure of human activity by providing feedback to humans for them to use in creating a next action dependent on first actions. In this way, humans will be able to fill in the missing parts in the design of human activity, a dependency between actions.

However, execution of current UI designs may cause the creation of pseudo-hills that may not exist if human action design is done with respect to the dependency of actions on their natural context. However, due to the negative influence of UI designs on human activity, there may be multiple hills ahead in a design. Missing elements with initial human actions are somewhat changed into a new form, and designX [15], [16] brings together only two independent designs in terms of setting relationships. The biggest influence of applying current design methods is that a newly designed action, called a user action, is different from the original human action. Because users and designers will be influenced by the interaction, none of these people will understand what is missing in the design.

3.11.5. The underlying assumption increases design complexity level

Interaction complexity may become more important than interaction design for users. Many contextual conditions are removed so that designs are working as forcing functions for users to change their behaviors. Complexity results from two main challenges: inheritance of previous design problems, and removal of various contextual conditions from UI designs. Independent action design results in turning human complex actions into simplified action forms by picking some aspects of complex human actions. A task in the human context is simplified via single action design, although the task may be comprised of many actions. This may be beneficial as a usability issue, because future alternatives are reduced to one option via user-centered design.

The assumption of independent actions in an everyday context causes generation of unconnected and independent design features for UIs. The unconnected features cause the creation of complexity and tend to confuse people. Not all people would remember all features[47] and this will affect both understandability and discoverability of usability criteria. Unconnected features may cause users to experience Interruptions by new features of the design. This effect can be observed through interruptions with event notifications in mobile devices, since people may be overwhelmed by a large number of event notifications in app and device designs [65][80].

3.12. Second Option in Defining the Relationship Between Actions and Natural Context

3.12.1. Initial assumption is a cognitive bias of designers introduced into the design field

An initial assumption in interaction research is that actions are independent of natural context. The analysis given in Section 3 shows that such assumptions can create some positive outputs for certain user groups, but from a wider perspective the assumption may cause uncontrollable design challenges in external contexts. Based on a mutual action description of the concept of interaction, actions are dependent on natural context, and actions in contexts have the mutual characteristic. Action independence of natural context is a reflected cognitive bias of designers. A list of known cognitive designer biases is given by

[81]. Figure 17 shows that one of well-known UI design researchers in HCI, Bill Buxton at Microsoft Research, approves the tendency for people in HCI to reflect their holistic views in their HCI designs.

Limited information about a natural model of interaction and/or action causes professionals to make certain assumptions about the design of user interaction. The previous approach for activity research is based on cognitive psychology principles, and cognitive psychology is considered to be a subset of the activity theory given below. It is said that "U.S. standard cognitive psychology is a reduced subset of a cultural- historical activity approach—without realizing it"[21].

3.12.1.1. Singularity in user experience and the interaction design view in the design field

If we use the terms of incremental design methodology given in Section 3.3, the UI design problem has multiple hills to be climbed in order, one following the other, but current implementations of design methods consider picking the hill most important for present conditions and creating hills dependent on that first hill. In other words, design problems are evolved during the design process and only optimization methods would be applicable to the designs, because the root cause of the problems may be lost due to the initial assumptions of the designs.

The assumption of independence is reflected when selecting the study methods, first cognitive (selected actions), then post-cognitive, (bringing randomly selected ones together). To study an action, it should be separated from its connection to other pieces. This is the abstraction step in the cognitive analysis of the topic. Incremental design methodology causes the development of singularity in the design field. Singularity means that, rather than having multiple designs for every condition, one single design, produced for considering a single group's likes, dislikes, behavioral tendencies, etc., is evolved to meet current contextual conditions. Development of a single design is achieved by adding and removing features rather than by having a design that will respond to different contextual conditions of its users.

Many people with different titles in a design group might share the assumption of actions' independence from natural context. Examples of singular design approaches can be found in the group of current design professionals involved in the design process: researcher, analyzer, designer, engineer, and developer ((industrial) designer and developer). A developer cycle is focused on industrial and mechanical design and development processes, different from ideation and research steps of previous cycles. The analyzer is derived from computer science in terms of cognitive and affective analysis.

The research design is affected by researchers' views. Every research study has started with a hypothesis[82] and designed to show a case study in which the idea is tested in a given contextual conditions. The research method is started with an assumption that this object has these features or has a relationship with another object. The idea is created based on integration/evaluation of knowledge at different topics. Then the research is designed to collect evidence from the real world to determine whether the assumption is true or not.

Research studies can be applied either to individual topics or relationships between two or more topics, and integration of information related to single topics is performed by researchers and evaluation is reflected in research design. The topic of this study has connections to the environment, where people use contextual objects during decision-making and action. If the connection to context is missed, meanings assigned to studied objects increase the complexity of the problem through disembodied intellect, isolated from the world; intelligent behavior requires a large amount of knowledge, deep planning, decision-making, memory storage, and retrieval. This is difficult to achieve for each interaction in everyday context.

Experimental psychologists, linguists, and workers create a research environment in which thought and understanding should be free from error, doubt, etc. [83]. Error-free signals imply that the real interaction challenge of a person is excluded from analysis. Scientists make certain assumptions to simplify their tasks because they believe a topic is quite complex and complicating factors should be placed aside until after central topics are studied, after which they can be considered. This means that many everyday experience dimensions may be excluded from a research field through a process of simplification, but this may make the task more difficult[83].

There are other examples of challenges experienced by professionals in the process of product design. Computer science researchers focus on development of deep machine learning models to improve recognition of user attributes (activity, emotion, action, gesture etc.) from user behavioral features, but work in developing a machine-learning model that will learn and identify real world objects without supervised learning is in its early stages. Engineers are involved in design processes where they, in collaboration with business people, decide what users need to do, and designers turn what is to be done into a plan for doing it [14]. Development steps of the design process include experience design and product design. Product design includes the design of modules and determination of physical appearances of interfaces while creating a real product. Developer tools have many features, most of which are unused by average users, and perhaps not understandable at all for average users [59].

Also, during the user testing process, design based on a certain group of users' likes, dislikes, and tendencies may not be beneficial for other users [1].

3.12.2. Requirement of design field: providing the dependency of human actions to the natural context

There are two options in interaction studies, i.e., actions are either dependent or independent of the natural context. The independence view reflects the fact that many current interaction designs have high levels of complexity, and the required depth of understanding may bring together the based on a user's temporary. User decisions related to dependent actions provide unique experiences, but those experiences may not be predictable or replicable.

Interaction in context includes mutual action. In other words, actions following one another have some inner relationship that requires an ordering. From a broad perspective, people develop skills to modify their actions based on differences in the context, i.e., a person may learn how to implement a particular action under different contextual conditions. While part of such an action may be called by other action names, all parts together create the complex action. For example, human touch action is considered independent from context, and touch actions implemented under different contextual conditions should differ.

Natural interaction has its own inner reasoning mechanisms. UI designs based on natural interaction design principles will provide both unique and replicable experiences. Advantages of natural interaction are as follows: Multiple interactions with the same object in the same context helps people develop their action skills, because each interaction with the object provides human information related to what to do, how to do, and why to do. Norman has described the difficulty of learning to play a musical instrument[1] in terms of requiring several interactions with the instrument. "Why to do" indicates your goal in dealing with an object, in terms of what you would like to learn from the interaction with the object. It is more related influence by object actions and action responses and requires response to an object action based on one's influence on the object.

Humans require natural context for their activities, because human experience is built on contextual conditions, and user interaction design is built on human experiences. Because humans are part of their context, if the design for context is achieved, design for humans will automatically result.

Humans learn from the design of external context, and while every interaction helps them to realize something new, if they are disconnected from the natural context, they would create a new virtual context. Problems with interaction will occur at the rate determined by how the new context differs from the natural context. In terms of organization of natural context, the natural context has a design that should be protected. It is assumed that mutual action or influence leads humans to develop their skills.

Without taking into account dependency between actions in a human interaction, any interaction design based on a change in user behavioral data may lead designers to change a present design to satisfy a change in user needs. Ultimately, designs may be forced to change user interaction design, but a UI design change would be a permanent change, and serving as a single interaction design solution adapting to a change in user needs.

Current UI design views influence the design of interaction and change interaction dynamics in the external context. Interaction becomes independent from design of human activities in terms of identifying actions necessary to complete an everyday task. UI designs underestimate the significance of context in the development of action response to given contextual conditions, and a user would like to respond to each influence. Each such influence may open one of two doors: new methods or experiences not previously explored, in terms of merging different actions together to have something new, while on the other hand the user should go back and repair damage or influence on users' needs, values, and/or goals. Some people choose one path and others choose the other, creating two communities: old versus new.

3.13. New Study on Dependency of Actions on Natural Context

3.13.1. Studying dependency of users' actions to their contexts

Previous design methods consider identification of all user needs, either real or created, and HCI design to satisfy the needs in the use of computing devices. This approach discretizes human interaction elements into their action components, because designers consider actions to be independent of natural context. Action is a hierarchical structure created by combining relatively simple actions to yield complex actions. The underlying assumption of actions' independence from context causes UI designs to have optimization-based solutions for dealing with requirements of human dependent actions in the context. If an underlying interaction design problem is not discovered and solved, further research on proposing a solution would only increase complexity of the interaction design problem.

This study focuses on steps provided by UCD[1][2][3] to use in natural user interaction design. The study has two main goals: Identify rules of natural interaction, and develop a UI and UX design method based on rules of natural interaction. To identify natural interaction rules, the first sub-goal is to study human action and extract rules of human interaction in natural context, to gain insight as to how humans develop their interactional skills after they interact with the objects in nature. The second sub-goal is to identify dependency of action to the natural context and provide continuous development of user action skills in natural context. To develop a new UI/UX design method based on natural interaction principles, the first goal is to provide a way to turn human actions into a human interaction form. HI provides development of human action in natural context by following the dependency of human actions on the natural context. Then, based on the HI form of human action in the context, user interaction designs reflecting design of human-planned everyday actions, and interrelationships between them could be produced by following the rules of HI and action development in natural context. Any UI design based on natural interaction rules provides HI models of all human actions in the natural context, and also provides better opportunities to design stationary and mobile human actions in the context. UI designs for the fields of desktop, mobile, and wearable computing could benefit from a model of human actions in the natural context. In addition, other research fields studying aspects of human relationships to the natural context can benefit from generation of UI designs based on identified rules of HI development in the context. Examples of such research fields include contextual computing, social computing, and pervasive and ubiquitous computing.

The final sub-goal of the study is to connect user interaction to natural context with respect to designing interactions taking place between two individual UX/UI designs. The development of user interaction will be connected to actions of second users in the same context and user interaction skills will be developed based on observation of changes in natural context. This goal is similar to that of the DesignX [15], [16] method that includes suggestions for improving research methods and practices in the design field, including HCI designs. DesignX [15], [16] focuses on interrelationship design between UX/UI designs, in terms of setting up dependency between actions of two users who share the same contextual settings. Research fields with focus on connecting individuals and/or automatic, interactional tool designs could benefit from the knowledge of providing dependency between actions in natural context. For example, the Internet of Things (IoT) field has the goal of providing invisible and natural connection between people and artificial digital products.

3.13.2. Exploring interaction in nature: identify dependency of human actions to natural context

If a person acts on an object, the object acts on the person. This is part of the definition of interaction. Any received action may influence a person, and such influence may result in reaction that causes the same effect on the object and its action. This is called mutual influence, also called two-way influence. Depending on a particular change in condition, the design should respond to the change. In other words, design methods should include both condition and context information. However, design produces a single action for each context and design may limit a set of contextual conditions into a single condition. Every situation requires situational actions, and situational actions are selected from previously planned actions based on a user's evaluation of contextual condition.

a) Identification of Model of Human Action

Development of user action is based on users' evaluation of contextual conditions with respect to their personal needs, values, and goals reflected in user interaction design. The missing components in an action model are the influence of the action, the development of goals used in cognitive evaluation, and selection of actions to create human activity. Based on research on human affects, the influence component in the action model can be explained, and the action model described in the literature can be revised.

b) Identification of Model of Human Interaction

Dictionaries provide the definition of interaction in terms of mutual action and/or mutual influence between objects and their actions. Every received action from an external context may cause a change in a user's internal context; this is called influence and change in user subjective states, and user-developed action based on influence. An interaction model can be represented as a closed loop or cycle running between two objects. An object might be a person, a thing, or an artificial entity. Actions in a sequence are connected not only to past actions, but also to subsequent actions depending on what action influences the external contextual conditions.

In addition to human interaction, interaction with context, how an interaction between two objects take place in a way that both ends create an action response when they receive an action directed to them, should be decomposed. That means that an interaction model tells us how to connect two actions to one another. The model reflects not only design of user interaction, but also the design of interaction between two users. Actions and reactions are strongly connected to each other, and execution of an action may create development of reaction, and if a reaction happens, it is due to the action implemented. Every user action can create a reaction, and every reaction can create a next user action.

Mutual action components of the interaction definition can be observed within the interaction design of a single user, because every action received from external context may cause users to produce a reaction. User interaction design methods provide identification of the serial order of actions correctly selected to meet users need at a particular time.

3.13.3. Development of new design method connecting human actions to natural contexts

If we initially understand the negative influence of assumptions, it would be easier to replace them with new knowledge, and all problems based on context design challenge will be removed. The interaction definition includes “mutual action and/or influence”. Emotion is a change in a person’s subjective state based on how much he or she is affected or influenced by their environments.

The common feature of influence between interaction and emotion motivates this study to develop a new design method connecting users and their activities and/or actions to their natural contexts. In this way, users will be able to develop their activities considering organizational rules of natural context. The dependency of actions in natural context will be transferred into UI designs, and most interaction challenges will be resolved in this way. UI designs are predicted human actions in situations in natural context. Design of any human actions, and/or providing connections between action components of any user interaction and human interaction, are difficult topics if humans’ actions are considered as independent from their natural contexts.

To create the design method, emotion from user activity should first be identified. Recognition of emotion, human interaction with computing devices, and demonstrating user activity on computing devices should be modeled. Then cognitive evaluation of results of human actions in external context should be modeled to produce a step-by-step process describing sensory data.

3.13.3.1. User studies showing implementation of emotion-centered design method for UX and UI designs

Two user studies, in which people apply texting activity to create verbal responses to pre-designed stories, are executed within two different contexts. This activity seeks to model user texting activity and recognize user emotions from the activity model. Then predicted subjective state values showing user cognitive evaluation of external context will be used to estimate the next likely user action and user interaction design for performing the selected actions. The subjective state values are affective values (event predictability, valence, arousal, and dominance) and emotions (basic emotions, core/reflective and social emotions).

CHAPTER 4 MODEL OF INTERACTION

In this chapter human interaction with everyday objects is reviewed to identify rules of a model of human interaction based on learning from previous experiences, followed by exploration of how people evaluate situations in natural context. Development of human interaction and comparison of HI outcomes with goals are reviewed to identify situated action generation. Execution of an action based on its action plan is identified and, finally, the dependency of actions on natural context and dependency between action components of human interaction is described.

4.1. Human Interaction With Everyday Objects

4.1.1. Action cycle while completing everyday tasks

An action cycle[10] is considered to be an evaluation of results of an action on human internal context with respect to goal achievement. Based on suggestions of the evaluation component of an action cycle run twice, it can be seen that there are two evaluation functions running internally. First, the evaluation controls the relationship between human states and context in terms of connecting human to context, and second, evaluation considers how selected actions change human needs, values, and goals that are human expressions, operations, and actions in which multiple expressions are brought together to create operations, and multiple operations are then combined to create action.

A detailed view of the 7 steps of an action cycle while completing a task via selection of planned actions based on cognitive evaluation starts with evaluation (steps 5-6-7), forming a goal and intention (steps 1, 2), specification (step 3), and execution (step 4).

4.1.2. Task completion: learning from results of previous experiences via everyday action analysis

The cycle model is extracted from observation of results of previous experiences. Norman studied planned actions in the context of human interaction with everyday objects, and developed a general model explaining the action cycle's operation while completing tasks with everyday objects [11]. The action cycle is for analysis of already completed and learned actions, so the task as a piece of work to do is known by the person. Norman preferred to give examples from his observation related to human everyday behaviors, including specified actions developed as a response to certain contextual conditions.

4.1.3. Human interaction responses to situations in external contexts

In a natural context, subjects act on objects, and objects act on the subjects. Actions in the interaction between subjects and objects have mutual attributes in which one's action causes development of actions by the other. In this way, people develop action skills with respect to the natural context. Any action skill includes developmental actions ordered in time, so while completing an everyday task, people would perform multiple actions based on the goal that the person would like to achieve with task completion.

Humans select actions based on evaluation of contextual conditions and may interact with a particular external object multiple times until their goals are satisfied. Completion of a task with multiple actions corresponds to development of human interaction. A task is "a piece of work to do". In the hierarchy of human activity, the task is placed between action and activity. Something in the mind turns into an action via some cognitive evaluation processes. Task completion describes the connection between action and external context. Human interaction while completing any task causes the human to produce an action response to the situation in external context. With respect to a situation in the context, the action developed by the person is called a situated action, where situation refers to conditions or events in the external context. Events in the context are created by the actions of another object that shares the context with the object.

4.2. Evaluation of Situations in Natural Contexts

Situations in external context are evaluated while completing everyday tasks. Norman gives an overview of steps of evaluation process[10], [84]. The missing parts of the evaluation process must be completed to have a full view of the steps of action development.

4.2.1. 4 cognitive functions

Before further analysis, we will add sense as an initial function for registration of sensory signals [23] in terms of turning signals into affective qualities within the mind. Figure 18 shows cognitive functions used in the evaluation process. Adding a sense function, means there are four functions in the evaluation of action results: sense, perceive, interpret and evaluate (comparison with the goal)].

4.2.2. 2 times evaluation of events in the contexts

When a person interacts with an object in a context, two consecutive evaluations occur while developing an action response to an event created by an object in the context. Evaluation is performed twice in the development of action as given by the action cycle[10] model to provide an explanation of human action response while completing a task involving selection of multiple actions.

According to the action cycle concept [10], after forming a goal, an intention, and a specification of action in terms of finding operations of the action, the action is executed and its results evaluated. An action cycle includes two evaluations: evaluation of action results both as meta-process as functional aspects of perception, interpretation, and evaluation in terms of comparing the output with the goal.

In addition to the action cycle, two evaluation processes occur when a person experiences an emotional event. Psychological construction theory[85] of emotion connects three theories of human emotion: appraisal theory of emotion [86] [87], basic emotion theory[88] and core affect theory[85]. Figure 19 shows two consecutive evaluation processes executed by a human to process information from an external context and generate an action response to the event received from the external object.

The first phase includes steps in which:

(1) An antecedent event is perceived in terms of its affective quality,

(2) The antecedent alters the core affect. A person enters into an episode with a certain core affect, and the core affect level may change during an emotional episode before an antecedent is consciously perceived, and the core affect continues to change as the episode unfolds. The core affect influences other components in the emotional episode.

(3) Attribution of core affect to the object of experience. A core affect is attributed to the antecedent that becomes an object of experience. During the attribution phase, a change in the core affect is connected to its perceived cause (person/place/event etc.) and that cause becomes the object that potentially includes full meaning and future consequences of the event and has a perceived affective quality. Ultimately the person states that the object is creating a feeling of anger, fear, etc.

The second phase includes steps as follows:

(1) When you create an object of experience, you appraise it and then take an action. Appraisal means perceptual –cognitive processing of the object, and assessing qualities of the event, such as relevance to the goal, causal antecedents, and results of the action.

(2) The instrumental action is directed at the object, representing a problem that requires a behavioral response. Pleasure and displeasure quantify the problem and may include general preparation for approach and withdrawal. Activation is a general mobilization in preparation for real-world action execution. The action is taken after assessment of current circumstances and resources (indicating task selection, action cycle) and the creation of a goal and formation of a plan to reach that goal. The instrumental action may be a fight or flight response to the external event.

(3) Finally, facial, vocal, body, brain, neural, and autonomic changes occur in relationship to core affect changes. Physiological changes indicate aspects of preparation for and recovery from the instrumental action.

To sum up, the first phase produces the object of experience, and the second phase includes an appraisal of the event based on the object of experience, a human goal. Appraisal steps [86] [87] include evaluation of event and output novelty, implication, coping potential, and normative significance after the evaluation process.

Examples of repeated evaluation can be taken from a simulation of skilled typist behavior and human natural verbal activity. Simulation of skilled typist behavior shows that there are two levels of control during typing activity: parent and child motor program [28]. The parent motor program may correspond to the task, developed via evaluation of action results and selection of actions based on evaluation values. The task is comprised of multiple actions. Actions are child motor programs and actions are control operations in this example.

Human verbal activity includes serial order in behavior [89][90][91][92]. A parent program manages every serial action group. From that aspect, word controls letters, and letters control and operate the body to vocalize the sound.

4.3. Development of Situated Actions

Figure 20 below shows the two levels of evaluation that take place during the development of a situated action and embodiment of a human message into multiple actions while creating a situated action.

Referring to Figure 20, action planning includes two evaluation processes that follow one another: emotions and conditions change, and emotion is felt and activity developed based on the goal, corresponding to influence and action components of an interaction.

4.3.1. General overview of 2 levels of evaluation

Figure 21 shows an overall view two evaluations that take place to extract information from an external event and generate an action response to that event.

The second evaluation includes evaluation of results of human actions toward achieving the goal. Such results have implications with respect to previously gained action skills, and humans produce action results with respect to a goal. The goal is made clear in the second evaluation, because human selects actions with respect to achieving the goal and, when the goal is achieved and becomes clear for the human, it turns into a combination of multiple actions selected to achieve the goal. When evaluations during an action cycle and psychological construction theory are combined, the following results occur: There are two consecutive evaluations, with the first producing a goal and the second involving comparison with the goal.

4.3.1.1. Cognitive appraisal process

Referring to Figure 21, the first evaluation creates outputs as changes in human internal state for each external condition; this is called affective evaluation. Emotion is a user subjective state, and the first evaluation includes evaluation of external contextual conditions that produces a change in human emotional state and human goal. The operations in affective evaluation cause creation of human response to the basic question of "why to do an action" related to the human goal for a situated action.

Consciousness means to be aware of something or, in the simplest case, to feel something that happens in external context. Damasio studied consciousness and connected it with the feeling of what happens in an external context [93]. He described three different types of consciousness, the proto-self, self-consciousness (core consciousness), and extended consciousness. The first layer, the proto-self, is a pre-conscious state that provides a reference for the core self and the autobiographical self to build on. Core consciousness is a second-order state of mind or brain and is capable of representing the relationship between the representation of objects and representation of feelings in the mind. Core consciousness is interested in what is happening her and now. Extended consciousness is the autobiographical self and related to autobiographical memory and perception of time (reflected identity). This third layer of consciousness corresponds to identity [94] and autobiographical self.

To feel something is to be aware/conscious of something at three different levels: sense, perceive, and interpret. Learning activity is based on the human evaluation process. It has three basic functions: sense, perception, and interpretation. Depending on cognitive functions, evaluation includes three basic levels: a sense for detection of basic features of action, perception for recognition of implications of action, and interpretation for identification of action. These three layers of consciousness roughly correspond to cognitive functions of sense, perception, and interpretation. Appraisal, evaluation, and cognition are terms describing the three levels of reasoning, and each function included internal appraisal steps.

Referring to Figure 21, the second evaluation converts the state of a user into activity via multiple selected actions. Embodiment corresponds to selection of an action for developing situated actions. Within the embodiment process, humans choose actions to achieve their goals. Meaning as an output of the first evaluation as represented through both goal and emotion during the action development process encoded into the selected actions responsible for carrying content from one end to another end without causing any external effects to the contents that are normally meanings. Actions are used to convey meaning between people, like a vehicle, or like a medium filled by water. One example of communication of meaning through actions would be the use of gestures whose main purpose is not the gestures themselves, but rather the meaning conveyed with body, hand or finger movements.

4.3.1.2. Affective appraisal process

Referring to Figure 21, the first evaluation ends with an output of an internal condition change, described as having an emotion, and the second evaluation ends with feeling either achievement or failure and also feeling one of the basic emotional states. Damasio separates the step of having an emotion from the step of the feeling an emotion, stating that "emotions provide immediate response to certain challenges and opportunities faced by organism", and "feeling of those emotions provides it with mental alert" [95].

Emotion is a neural object and triggers physical reaction in the body during which mental images emerge; the second-level self is created in the mind.

A person exhibits emotion and manages a second evaluation based on emotion-based information. Emotion links the first evaluation to the second evaluation given in psychological construction theory, as the core affect in the first evaluation and appraisal in the second evaluation, and works as a neural object to assist transfer of a message between mental components. Based on the given relationship between goal and emotion in the first evaluation step, depending on a goal indicating describing how to deal with consequences of an event, the human may have either a positive or a negative emotion.

At the end of the first evaluation, a human has a goal given as " the desired result in the context" in terms of change in the state of any contextual object that human action is directed toward. Goals indicate how to deal with implications of an event and produce emotions. A goal is described in dictionaries as an "object of person's effort or activity". A psychological construction model also includes an object of experience. From the description about consciousness given above, it is known that a human first has emotion and then feels emotion.

Based on the four steps of appraisal and the options of having a plan to deal or not deal with consequences, people have 8 basic emotions, i.e., surprise, anticipation, happy mood, sad mood, trust, disgust, anger, and fear. Based on completing an overall goal, they may exhibit 2 basic emotions: people feel either happy or sad emotion. Emotions are bipolar in nature [96][97], and highly connected to evaluation of human action results in external context [98].

Referring to Figure 20, because actions in an interaction are dependent on one another, actions from external context influences subjects and cause changes in the subjects' emotional states. Based on the evaluation's four basic steps, there can be four different situated actions developed by a human. Affective evaluation produces four goals for four different conditions of the external context while a human is interacting with the context. Depending on whether the goals are achieved in situations, there could be eight different possible emotions experienced by a person.

When we synthesize all the information into an object of experience, emotion and goal are both the outputs of the first evaluation and the inputs to the second evaluation. In interaction with an event, human needs, values, and/or goals are influenced by the event. If the human has potential for coping with consequences of an event (in other words a plan or goal), then s/he feels a positive emotion; if not, s/he feels a negative emotion.

The coping potential step includes having a plan for dealing with event consequences and goals to to be reached. Based on such goals, humans exhibit emotions. During the first evaluation step, humans have goals and emotions. During the second evaluation step, humans organize their actions to attempt to satisfy the goal. If the goal is met, the human feels positive emotions and if not, the human feels negative emotions.

Before discussing the cognitive evaluation process, goals and intentions should be formed by a user. A goal is described in the dictionary as " the desired result" by the action and the intention is given as a "clear goal". When the goal is transformed into activity, people will be aware of what they would like to do and will indicate their intentions. The action model describes goal and intentions, the difference between them, and their method of formulation should be specified.

The difference between goals and intentions is that human awareness of what to do is the intention, and if even without this awareness they have sense, feeling, or emotion that directs their actions, they have goals. The goal is generally about desired change in the state of an object in the context. In an action cycle, forming the goal comes first, followed by forming intention. The goal is the output produced by the first evaluation, and the intention is the output of the second evaluation; intention implies a clear goal in terms of being consciously aware of what to do.

Referring to Figure 20, distributed cognition corresponds to having an action response to situations or conditions in external context. Distributed behavior and cognition relate to spreading intelligence into human context and creating situated actions through human-based conditions in the external context.

4.3.2. Steps towards creating an action

Figure 22 shows the developmental steps of creating an action response, based on studies on activity theory [19] and action cycles [10].

Referring to Figure 22, cognitive appraisal means evaluating a situation based on a person's goal. There are four steps of evaluating any external condition based on the goal: sensing, perception, interpretation of perceptions, and evaluation by comparing the outcome with the goal. The series of sensing to interpretation steps produce an evaluation output in terms of values or significance of an event in terms of humans achieving goals.

The comparison step includes identification of what happened in the world, and checking to see how much this change in the world matches with the change humans would like to see [10]. What humans wanted to happen is the desired change in the state of the objects in the shared context between the humans and the objects, so humans first need to identify what happened in the world by comparing outputs of the current situation to outputs of previous or past states stored in human memory. By comparison contrasting between current and previous states, humans are able to extract information about what presently happened. As a final step, humans check how much the event matches with their goals, representing the desired change in the world. If such a desired change is not achieved in an external context a human will select another action.

From sensing through interpretation steps, the process of output evaluation produces an evaluation value in terms of intelligence reflecting the significance of human actions, and that value is used for action selection. This step corresponds to the creation of human interaction, and human interaction reflects the content of the situated action and includes action and influence components for every action creating a human interaction; they are static components of the situated actions. Comparison of the outcome with the goal is a dynamic part of the overall evaluation, and the outcome is determined based on the difference between previous state and current state.

4.3.2.1. Static aspects of the action: Describe and define human interaction

The action created in response to change in situation of the context is called a situated action, created based on an influence. Any human interaction development has two aspects: description in terms of having planned actions, and definition in terms of having evaluation values representing cognitive intelligence and used for selecting planned actions to create situated actions. Selected actions and evaluation values produced as a result of cognitive evaluation are two aspects of an embodiment.

Description means identifying discrete features of any concept, and definition means to identify the connection between discrete features of the concept. Any situated action has multiple planned actions selected based on cognitive evaluation of external context conditions based on human goals and serial behavior. Definition means connecting the individual pieces in an evaluation process in terms of its value in solving current user challenges. To define means to bring something to an end, and in conformance with the meaning of the word define, the definition of an action tells us where an action ends and where the next action starts.

Evaluation values are content features of human interaction, and selected actions form features of human interaction. The appraisal process includes four steps that result in the selection of four different actions as outputs at each step of the appraisal. Referring to Figure 22, a task is created with a combination of four different actions, an activity is created with a combination of four tasks, and an action is comprised of four operations, with each operation comprised of four expressions.

In accordance with steps of appraisal, and the number of actions in the interaction, content and form attributes of any human situated action would have four dimensions. Selected actions are visible aspects of user activity, and evaluation outputs are cognitive outputs that are invisible, somewhat abstract parts of human activity; they can become visible through relative movement of selected collective actions. Selected actions within an action cycle represent a descriptive part of human activities, and evaluation of action results and evaluation outputs as values represent definitive or interpretive parts of human activity.

4.3.2.2. Dynamic aspects of the action: Interrelationship between selected actions

Referring to Figure 22, the dynamic aspect of an action corresponds to creation of situated actions, and each situated action is discriminated from others by the difference in how the planned actions are ordered in the time domain. Situated actions are created via selection of planned actions. They are visible through relative positions of planned actions with respect to one another. In other words, the actions' order in time causes a person to extract the ideas or goals associated with the situated actions. The goal of the situated actions is embodied into activity via development of interaction and comparison of the interaction outcome with the goal, showing the desired change in the world. The outcome refers to the identification of what happened in the world, by subtracting current state information from previous state information.

The comparison step includes the realization of differences between results and actions belonging to the previous state and current state or situation. The dependency between actions become visible and people discover what happened. Discovering what happened corresponds to identifying the meaning of the actions that took place in the world. The dependency set between selected planned actions creates a virtual context internally in the human mind, and only through these human interaction models inside the human mind do the situated actions become sensible. People feel it, and realize it, and cognitively identify it.

Comparison and contrast mechanisms occur inside the mind, and every action selected helps people to feel, realize and identify differences between each pair of actions selected in an order of human interaction. The realization of the differences between each action pairs allows us to clarify definitive borders between events given with each action in the order.

4.3.3. Dimensions of actions in natural context

4.3.3.1. Static dimensions of any situated action: Describe and define human interaction

Any situated action includes both goal and activity. Activity means multiple actions selected by the human based on an evaluation of external context conditions. Static dimensions of any human activity include four content and four form dimensions. Form dimensions describe the action, and content dimensions define the action. During action development, the human works for transforming a goal into activity. Representation of the goal is same as for the activity model, the only difference being that a goal occurs in the frequency domain and an activity occurs in the time domain.

Body action is the simplest human action applied in external context, and actions can be combined to create complex actions. If the dimensions of body action can be identified, the same dimensions would be associated with actions at different degree levels. Based on literature on affect recognition from body movements [99][100], [101], [102], [103][104][105][106] [107][108] [109], content and form dimensions of an action can be identified as follows. Content dimensions are entropy, fluidity, energy and power. Form dimensions of action are fast/slow, smooth/jerky, even/uneven, and large/small.

4.3.3.2. Dynamic dimensions of any situated action: interrelationship between selected actions

The dynamic aspect of human action corresponds to the fourth step of cognitive evaluation: comparison of the outcome with the goal. It relates to the identification of relative positions of two actions with action results showing the previous and current situations, so the dynamic aspect of human action created with these two actions shows previous and next situation. Bodily affect recognition literature includes reports regarding the impact of dynamic aspects [110][100][101][102][109][111] of human body activities in terms of differentiating emotions expressed in similar patterns. Information about the dynamic dimensions of the action is calculated for every individual action, creating a dynamic view. In other words, features showing dynamic characteristics of a situated action are extracted individually through every action, and the difference between these features will produce the final output.

4.4. Execution of An Action Based on the Action Plan

4.4.1. Everyday experience: people learn from situations in natural context

Experiencing an object means development of any situated action created via selection of multiple planned actions. There are two ways to analyze human action: learning and executing. Learning reflects the development of an action from a low level to high level, while executing is the opposite.

An action model answers to 5 w and 1 h questions, which are basic questions starting with w and h (who, what, why, when, where, how) and used in information gathering, related to human activity: what to do to find a goal, what to do to find a selected action, how to find serial order in operations to complete action, and when, where, and to whom to identify space, time, and social context of human activity. Humans must identify what to do within each condition, and then identify how to do what they would like to do within each condition. The question of what to do corresponds to cognitive realization of what a person does in a given condition. The question of how to do corresponds to cognitive realization of how a human performs the action in the condition.

When an action is selected, how the action is executed describes the topic of behavior analysis. Behavior means the way one acts, and it covers the selection of actions to perform a task. Behavior can also mean operations that people apply under certain conditions.

4.4.2. Planning human actions

An action is developed in two steps. Planned actions are first brought together to create multiple situated actions, followed by multiple situated actions brought together to create an activity, the content of future action. Figure 23 shows elements of human action, and how different sections are assigned names.

Changes in emotional states indicate changes in natural context. For every change in context, a human creates action responses. Development of multiple actions for multiple situations in a context is referred to as distributed cognition. Cognition is the output of interaction with natural context, and people must explore context to bring together the elements required to accomplish their goals.

4.4.2.1. Goal achievement versus goal accomplishment

Situated action has two basic evaluation steps: The first creates emotion, and the second selects actions to turn emotion into feeling and/or a message. During the 2nd evaluation people select planned actions to achieve their goals. The dictionary definition of action is “to do something to accomplish a goal”, so it has two main components: goal and activity.

Situated actions have goals and activity as human interaction. Selected planned actions exhibit intention and activity and/or behavior. Whenever the situated action is specified, a goal turns into an intention, and the intention is itself an action. The intention, in other words, is a clear goal turned into an activity, something one knows how to do. When a goal is turned into an activity, the goal is designated as an intention, because intention means a clear goal, and a human knows what to do via planned activity steps. A goal is defined as a desired change in state of any object in natural context. Goals of situated actions show that humans have achieved conditional changes in state of an object. If a human causes permanent change in the state of an object, s/he will accomplish her/his overall goal.

4.4.2.2. Task, and activity: Creating situated actions and action plans

An action is developed in two steps. Planned actions are brought together to create multiple situated actions, followed by multiple situated actions brought together to create an activity, a content of future action. Research studies show that actions are independent of natural context and provide individual components of any planned actions. For example, the action cycle [10] functioning during everyday task completion shows us that tasks are comprised of multiple actions, and activities are comprised of multiple tasks [1]. Activity theory [19] tells us that actions are comprised of operations. In terms of the embodiment of intelligence in human behavior, operations are comprised of expressions that can be expressed by using the body to press out messages on a display medium.

Referring to Figure 23, activity, task, action, operation, and expression are descriptive, individual components of all human actions. Action, operation, and expression depict any selected action based on cognitive evaluation of external contextual conditions. If the subject has multiple situated actions, s/he could create an activity, a future human action in development. The hierarchy shown in Figure 23 shows that a subject can use previous actions to develop complex actions. Activity reflects the content definition of a future action in development.

Activities and tasks may show components of planned complex action or newly situated actions, depending on usage context. Task means "a piece of work to do". And humans should know what to do. In the context of explaining learned actions, a task depicts human interaction with multiple action components, and it shows a human complex action response to a situation in external context. Norman used the term "task" in the context of explaining human interaction with everyday tools [11] and objects. Use of tools is learned through multiple interactions with them.

For analysis of future actions, complex actions built up with simple actions, tasks correspond to situated actions selected based on contextual conditions, and activity corresponds to multiple tasks, situated human action responses to challenges with contextual conditions. An activity represents components of a human future action plan in development.

4.4.2.3. Expression, operation, and action: Descriptive elements of an action

Development of an action is as follows: expressions are brought together to create an operation, and operations are brought together to create actions. An expression is a single planned action showing how to use a body medium to press out subjective messages onto a medium. An operation uses multiple expressions to operate the body for message purposes. Operations are planned action responses, corresponding to learned actions for different contextual conditions. An action includes planned action response to all related contextual conditions. The terms action, operation, and expression can be used to depict components of any planned actions. Within any planned action, an expression is simply matched with the human need to communicate within the context, and the operation is matched with human value and the action is matched with human goals.

4.4.2.4. Behavior: Definitive elements of an action

Behavior means the way in which the selected actions are implemented. Behavior means dependency between actions in natural context. Cognitive appraisal includes the development of serial behavior that describes the order of actions in human interaction. Human interaction is the content of any human-situated action created in response to any contextual conditions. The selected actions are pre-planned, so they are serial rather than parallel behaviors having an order among them.

The affective appraisal includes the development of parallel behavior that shows the order of situated actions in human – nature interaction. Interaction elements are components of the plan of human future actions, and parallel behavior means ordering multiple-situated actions in time sequence. Parallel means that there is no interconnection in terms of accessing a record., and parallel behavior corresponds to accessing an action in memory based on evaluation of the output of current contextual conditions. Evaluation means the influence of an action received from external context. Access to the action is direct and no search is required like when accessing data in ordered form, so access to information requires parallel elements.

An activity is a combination of multiple individual tasks, and it includes no information about ordering tasks in time. Bringing together situated actions in time means ordering actions in time, and this is called parallel behavior in terms of giving “the way one acts” and information about how to do the action, and relative positions of action in time rather than what to do as action. Referring to Figures 20 and 23, any human action includes serial and parallel behaviors in its action plan. For example, a human verbal expression has serial components ordered in sequence, and it exhibits a parallel nature in terms of accessing related actions to generate a verbal expression. Cognitive research on verbal memory recall includes research on modeling both serial [89][90][91] and parallel behavior in accessing required records in human memory [92]. Serial order in behavior shows that human cognition is embodied [24] in an order as activity. Also, verbal activity has a parallel [112] nature, and both serial and parallel verbal behavior constitute distributed [25] cognitive verbal behavior.

4.4.3. Development of complex actions with simple actions

Activities have multiple situated actions. Figure 24 below is a pictorial description of human interaction with a digital device. Each action a subject develops is a human response to the situation in the external context, so an activity includes multiple situated actions.

Referring to Figure 24, a user can apply either a simple or a complex action to operate the device. A complex action refers to a combination of multiple actions, and a task can be described as a complex action in terms of having multiple actions. Each action in the structure of a complex action has both a description and a definition. Definition components are not shown in the drawings of complex actions. Referring to Figure 24, each circle belonging to a complex action represents a single action, and each action has a goal (not shown in the figure) to be represented while performing the user action.

A human develops complex actions by connecting previous actions based on an evaluation of contextual conditions. Human activity has a hierarchy consisting of activity, task, action and operation, and expression. The task is a complex action representing a combination of actions, and multiple tasks are brought together to create an activity [1]. An expression is an action in relatively simple form (due to being at low level) and that action includes an activity definition.

4.4.4. Identify computational model of human actions

Execution of action is about running planned actions in terms of following serial sequential order. It is related to how to do an action, or a behavior. The selected action has serially ordered action components that will run when they receive orders.

4.4.4.1. Components of the action

When determining the execution order of an action, the order would be as shown in Figure 25. Execution of an action follows the order in developing actions. A received action is appraised internally, resulting in an influence on human internal context. The influence is represented with a goal and emotional state change. The human goal is then turned into an activity via cognitive appraisal of natural context based on human goals., i.e., a human produces an action response to a specific situation in the context. Different situations cause a human to develop different situational actions based on interaction within the natural context.

When an action is accessed, it is specified by following a serial order in its operation of actions. A selected action has a planned activity in which many actions are performed in order. Referring to Figure 25, every planned action has intention and activity components. The intention is a clear goal stating selected actions to be executed. In addition, the goal is used for managing situated actions to complete a task that, while initially unknown, would be clear after the goal is achieved.

Every action on one level is tightly connected to the others and they are all connected to upper-level action. This repetitive structure continues until a body expression is reached in the activity hierarchy. In moving from simple actions to complex actions, the hierarchy sequence in human activity development is as follows: body action, physical action, behavior, mind action, and mental action. Execution of an action in terms of how people behave in a context is the topic of cognitive psychology and behavioral psychology because it includes subjective and mechanical aspects of performing an action with use of the body.

4.4.4.2. Total dimensions of the action

There are four appraisal steps multiplied by two (corresponding to content and form) and again multiplied by two (corresponding to static and dynamic), so an activity has 16 dimensions (4x2x2) or attributes to be represented in a computational model. Because action includes a goal in addition to the activity, and the human transfers the goal into the activity, the goal will have 16 dimensions as well. The transfer may involve transforming a goal in the frequency domain into one in the time domain.

4.5. Natural Interaction: Setting up Dependencies Between Situated Actions

When a subject interacts with an object in a context, the subject acts on an object, and then the object acts on the subject. Every action causes the creation of a new action, called a reaction. Actions and interactions are dependent on one another. Figure 26 below shows development of dependent actions and influences during an interaction.

4.5.1. Dependency between subjects and objects in natural context

Referring to Figure 26, interaction in nature involves a dialog with action and influence pairs: action, influence, action, and influence. System level interactions lie between subjects' actions and objects' actions in natural contexts, and emotion can be a cue for addressing each condition in the context by connecting activity to context during the development of human action., User emotional states change based on changes in contextual conditions. Emotion is useful in observing changes in human states in any context where people turn emotions into actions.

4.5.2. Dependency between actions in human interactions

An action is generated based on human influence. Influence may be a form of affect, such as a feeling, mood, sentiment, or emotion and a human turns the influence into activity via cognitive evaluation. The influence causes the creation of why and how to do an action in response to the change in external context.

Referring to Figure 26, from the perspectives of subjects and objects, both include serial influences and action and interaction designs. When a subject executes an action, this will influence the object in the same context with the actor, and the object will generate an action back toward the actor. Such mutual action will continue in an action – reaction type of dialog until an agreement between ends is accomplished. Actions in an interaction have two-way influences, from human to object and from object to human, reflecting the real design of human activity that is comprised of multiple tasks, with tasks comprised of multiple actions. Activity design requires thinking of mutual influence in interaction modeling so that actions follow each other depending on the influence they cause and human selection of next actions in the activity.

CHAPTER 5 EMOTION CENTERED DESIGN METHOD

This section provides an overview of how to benefit from the model of interaction in natural context to design for user interactions and systems. People use changes in their emotional states to give meaning to situation changes in their natural contexts, and they develop action responses based on their goals. The way actions respond to conditions in natural contexts is used to identify rules of the emotion-centered design method.

5.1. Use of Interaction Model for Designing UIs and Systems

5.1.1. Action responses to the situations in natural context

Emotion helps people survive under different contextual conditions. Emotion exhibits a change in state of a person planning to take action based on a state change. Emotions represent reasons for people to create action responses to different situations in the world. Information about human subjectivity is helpful in the design of human interaction and system design dealing with natural interaction between multiple entities, such as two different human subjects. Changes in any context mean actions developed by objects that share the same context with others. The actions of any object in the context are dependent on other objects' actions in the same context. Actions in the natural contexts are developed due to change in humans' subjective states, such as the state of human emotions.

People develop goals after experiencing influence that received actions create, and turn these goals into activity. A goal corresponds to a desired change in the state of objects, i.e., people. People evaluate conditions in the external natural context and decide on actions to turn their goals into actions. The action is a human response to situations in the natural context and discrete components of an action are simply called activities, multiple actions selected by people. These multiple actions support development of human interaction.

Selection of action based on cognitive evaluation output can be thought of as an embodiment of intelligence, because people are aware of and feel opportunities and or challenges in natural context. They turn their awareness into action by developing a human interaction approach.

5.1.2. Rule of interaction showing dependency between actions in natural context

The interaction model is based on the model of action, and the model of action is based on a change in humans' subjective states. The influence of any action received from external context causes people to experience emotions and goals related to the objects. The interaction model, containing an action model gives us information about how to connect two actions to one another. On the level of human behavior, action received from external context may change the basic emotions of a person who will then create an action response. Her/his action may cause changes in basic emotions of another person in the context, and that other person will create an action response. Action and reaction dialog will pass back and forth between them and create an interaction.

5.1.3. Different situations cause change in humans' emotional states and their activities

Development of human action response to a situation may be repeated for other situations in the natural context, because people may face various different situations in the context. People can be affected by events in their own contexts, and respond directly to them in the contexts. Every condition in a context causes a change in user emotional states, and users have goals. A change in state of one user is followed by a change in the state of another object in the context. Each action reflects a change in the condition of context, and the context may include an object or multiple objects.

If people have achieved goals, they may feel positive emotions; if not, they may feel negative emotions, so at the behavioral level of the human activity hierarchy, people will feel different basic emotions that are changed through actions received from the external context. They create goals for their actions and they evaluate the results of these actions. If their goals are achieved, they feel positive basic emotions, such as happiness, but if not, they feel negative basic emotions such as sadness. At the higher level of human activity hierarchy, people may feel different emotions such as social emotions when they deal with social issues in their own contexts.

5.2. Emotion-Centered Design of Human Actions

Emotional state information includes affective values as evaluation of results of action in external context, and discrete emotional state information (such as basic or complex emotions given with an emotion name). Emotion is information about the states of users, and it causes the development of human action, i.e., an action influences object's state in the context and the object produces a reaction response.

Emotion-centered design has two main steps: recognize emotion, and predict the next action based on affective values. For everyday actions, the first step is to identify the model of how the action is implemented by the person. Then, because the action is an embodiment of feeling and emotion into activity, the emotional states of the person can be identified. Emotion is one aspect of human affect, and all other affect dimensions can be recognized from human activity. With the information of emotion and action, different attributes of people can be extracted and, in the context of HI design, humans' next likely actions could be identified. It should be remembered that identification of next action is based on normal conditions. In other words, if any norms of the external context are changed, then the HI design will be different from expected human action designs. On the other hand, human experience (HX) designs are about state human internal context, and any influence directed from outside might change norms of humans' internal context, and prediction of human next experience will be affected by such norm changes.

5.3. Development of the Emotion-Centered Design Method

The new emotion-centered design method described in the previous section includes steps that designers can manually implement while designing user experiences. Figure 27 depicts the steps of development of the emotion-recognition method.

To implement the design method, designers must identify emotional states of users of computing devices, and a model of user activity should be identified, as well. Then, based on emotional state and affective values, designers can predict the most likely action a user would choose in the next experiences. To simplify the design task, a computational method to automatically implement the emotion-centered design method is provided.

5.3.1. Modeling human interaction with computing devices

Human interaction with computing devices corresponds to identification of user interaction. By using the action model of Section 4, user activity completed with computing devices could be identified by knowing the type of user activity. Many human activities are complex, so this requires identification of various levels of the human activities in the human action hierarchy.

5.3.2. Modeling human learning activity

Learning, a cognitive recognition task that includes realization of external context conditions has three levels: detect, recognize, and identify. People must feel differences in external context and turn them into meaningful information by setting up a relationship with something previously known. The feeling may therefore be represented in three levels, sense, perception, and interpretation in terms of levels of cognition. Modeling the learning function of cognitive sense includes 7 steps:

1. Feature calculation based on action dimensions,
2. Feature normalization,
3. Feature summarization,
4. Feature discretization,
5. Feature selection based on correlation with output,
6. Classification based on Bayesian theory, and
7. Information-gaining filter to improve recognition performance.

Depending on content and form dimensions of action, the literature related to recognition of emotion, activities, etc., can be explored to identify related features to be calculated to represent related action dimensions. Feature normalization is related to sampling human experience, so that analysis should be started at a particular time in a human life, so normalization reflects that cut point in time. Although we may start sampling human experience from a random part of human experience, normalization between [1,0] helps us to start the analysis by considering it is a full experience with all conditions met. Normalization functions via taking some values and turning them into the output of a function. Feature summarization helps to provide a sense of the parallel nature of behavior formulation and feature discretization is applied to the serial order of behavior.

Feature selection via a correlation-based subset selection method [113], showing features having high correlation with output classes, can be applied to select novel features with more discriminative power, and an information-gaining filter can be applied to learning results to remove learned features from the task and improve the discrimination capability of the classifier. Human activity is developed as a result of previous experience, and Bayesian theory provides a functional representation of an evaluation process based on decisions related to previous experience. Its performance with how to model human motor skills is described shown in the literature [114]–[116]. A Bayesian-based classifier helps in evaluation of action results based on previous action results and predicts what action will be selected based on an evaluation output value. The theory has been effective in modeling human motor abilities [116], [117]. A Bayesian networking classifier works by matching features of user activity to affective dimensions.

5.3.3. Emotion recognition

Although the method can be manually applied by the designers, since user subjective states are frequently changing, manual approaches may not be fast enough to meet the required change rates in user interaction design related to subjective state changes, so the final step is to identify emotions of the users via machine learning algorithms. Generally, collected data based on a user activity model is fed into a sense function and recognition results are evaluated via test methods.

5.3.4. Design of user interactions

Through information regarding user emotional states and actions, UI and UX designs could be identified, and dependency of user interaction to natural context could be set up. UI designs are human-planned actions chosen for achieving goals related to situations in natural context. The situated actions could be at any level of the human activity hierarchy. For example, body expressions are placed on the bottom level of activity hierarchy. At the second level from ground are physical or sensory actions following body expressions, followed by behaviors, mind actions, and mental activity, respectively.

Predicted affective values correspond to user evaluation outputs, and emotional state information indicates whether or not the goal is accomplished. Previous emotion and affective values would be stored in a database, and designers would record changes in user subjective states, including different UI designs for their design projects to support response to each change in users' subjective states.

CHAPTER 6 IMPLEMENTATION OF EMOTION-CENTERED DESIGN

The verbal interaction design field reflects all of the effects of an underlying assumption of actions' independence from users' contexts. The level of complexity in the verbal UI design problem is high, because the design problem is a mix of touch interaction design challenges, verbal interaction design challenges, and user changes in verbal and touch behavior with respect to difficulty of dealing with both touch and verbal interaction design challenges. In other words, while verbal UI designs make users' tasks hard in external context, users also make designers' tasks harder. This creates a closed loop that doesn't produce s a final output or results with which users are happy.

Emotion-centered design method as described in Section 5 is considered a solution for reconnecting users to their original contexts and for reducing the level of complexity of the verbal UI design problem by providing alternatives to users in dealing with dependent conditions in their own contexts. Two user studies were run to test implementation of the new design method. User emotions were recognized from their typing activities on mobile devices, and a recognized emotion indicates human evaluation of current contextual conditions that would be helpful in identifying the next human action. By using predicted affective values at different levels, designs of human interaction, user interaction, and device interaction could be identified. Device interaction reflects low level user interaction with the computing devices, such as typing activity, user interaction points to medium level user interactions with devices, such as texting or talking on the phone, and human interaction points to higher level social interactions performed through the computing devices.

6.1. Design of Human Verbal Interaction: Speaking Activity

Verbal activity is a complex human action and/or activity that includes both serial and parallel behavior. In the context of verbal action, subjects act on objects and create verbal message in response to a received action or an event from the context. Subjects' actions in the context are situated actions and include evaluation of results of received actions with respect to human needs, values, and goals in terms of planned actions and human goals.

When reviewing human verbal activity studies, the literature reveals results parallel to the models of action and interaction given in Section 4. Cognitive research related to verbal memory recall includes research on modeling both serial [89][90][91] and parallel behavior in accessing required records in human memory [92]. Serial order in behavior shows that human cognition is embodied [24] in an ordered activity. Verbal activity also has a parallel [112] nature, and both serial and parallel verbal behavior are constituents of distributed [25] cognitive verbal behavior.

Parallel behavior helps us to access records in memory, and serial order in verbal behavior helps us look for details of verbal records in memory. In other words, parallel behavior helps to access words in memory, and word action controls accessing letters of words in order. In addition, letters are controlled and operate in the body to vocalize related sounds. Simulation of user-texting activity through analysis of skilled typists confirms presence of serial order in serial and parallel behavior. The study provides a simulation model in which there are two levels of control: a parent controls child motor programs, and a child motor program controls human fingers to press on keys [28].

6.2. Design of User Verbal Interaction

6.2.1. Creating verbal action responses with mobile devices

Figure 28 shows design steps of user verbal interaction and how UI designs negatively influence user verbal activity structure. Referring to Figure 28, humans select an action from their interactional responses. The selected action, the one to be designed, is called user interaction. A user sentence corresponds to development of a meaning with words. Words are operational elements to create a message in a sentence. Sentence-making is an action design, considering external conditions and influence of the context on human needs, values, and goals.

Verbal interaction design considers implementation of the principle that actions in an interaction are independent of one another. When subjects receive actions from an external context, they create goals and develop activities, and they would like to develop situated actions in response to changing conditions in the context and the influence of such changes on themselves.

6.2.2. Design for independent actions on vertical hierarchy of human verbal action

Figure 29 shows the steps in creating verbal responses with keyboards on mobile devices. Referring to Figure 29, a human action response to an event in a context is a situated action, an affective evaluation of external contextual conditions. The situated action includes a task with multiple actions indicating intention in cognitive behaviors, but it is a goal in affective behaviors in terms of evaluation of new contextual conditions. In other words, situated verbal action represents a human message in which the subject has something to say. It may in the mind be either a feeling or a verbal message. The situated action is created by human action responses based on the implication of contextual condition (external) on human need, value, and goals. This step includes cognitive evaluation. Need, value, and goals are previous actions (act, operation, and expression) in the action hierarchy. The design of human interaction corresponds to action components selected by the human, and people choose an action based on what consequences they are dealing with.

Referring to Figure 29, if the situated action is considered to be independent of natural context, actions in human interaction created for a specific situation in the natural context are considered independent of one another. The verbal UI design follows from top to bottom of human verbal action development, and individual user messages are transferred to the tmultiple operational components of user interaction given in Figure 29. When a user chooses an action, the selected action has a message to be communicated. From action to operation, a message has multiple sub-components based on contextual conditions (externally), and an action has operations with which to communicate components of the message. When one experiences difficulty in communicating through the device, one should concentrate on communicating one by one, as in providing discretization of the message in speech to texting, and ordering the events and/or messages in time, as when describing live events [118]. Then a user chooses one of the human messages and turns her/his focus on communication of the message with the device. When users choose an operation belonging to an action at the upper level, they choose a message to communicate. Implementation of planned actions then becomes a typing action,

6.2.3. Accept or reject UI verbal design rules

Users must deal with complexity of verbal interaction design. Within the verbal experience design problem, it can be seen that, without solving the underlying interaction modeling problem, every effort to solve the present problem influences the user, and the user is forced to adapt to the change by changing her/his behavior. Users either agree or disagree with the design rules and, based on their preferences, they may change their behaviors in different ways. As a result of a change in behavior, they become disconnected from natural context, and start having difficulty in communicating using face-to-face verbal interactions. Users may agree with the design rules and change implementation of their dependent actions to the designed actions. If not, they must find ways to relieve the negative effects of UI designs on users.

Figure 30 shows a situation in which a user agrees with a design rule to reduce the effect of the design on his or her verbal experience. The design requires single touch decision, forcing the user to adapt her/himself to change behavior to be able to overcome the design barrier. However, when users accept current design decisions as universal design solution for all contextual conditions, they need to change their behavior.

If users disagree with design rules, they may correct and/or complete verbal UX and UI problems. Because of the described user interaction design implicit in context-free design logic, not only are design challenges at lower levels inherited by top-level design issues, but also each level may suffer from creation of a new set of design challenges.

6.2.4. Development of independent user actions while designing for human verbal activity

Humans would like to communicate their messages (in the form of feeling, idea, emotion, etc.) through the use of speaking action expressed as a combination of multiple nonverbal (NV) and verbal (V) expressions. NV and V expressions are body actions used to communicate the message. The goal of user verbal interaction design is to transfer human verbal activity from face-to-face contextual settings to the virtual context in which computing devices can be used to exchange verbal messages.

Independent actions create three different user actions with mobile devices. From speaking to tweeting, the assumption that actions are independent helps designers in addressing requirements of individual actions, but at the same time designers are not able to see dependent actions as initial actions in the design, negatively influencing UI designs related to human verbal activity.

6.2.4.1. User activity of talking on the phone

Talking on the phone represents a communication of voice-based message components of speaking activity. When designing for user verbal interaction, one NV action, to talk on the phone, is taken as independent of other V actions. The device is able to transfer human verbal message to a remote place. This is a space-based division from human context, in that people are no longer sharing the same space.

6.2.4.2. Texting activity

Texting via phones means sharing many components of a message communicated through a voice medium. This corresponds to a change of context, from face-to-face to virtual communication mediums. People change their communication methods in various ways, from face-to-face to talking on the phone, texting to others, and tweeting on social media, and a message with talk action is divided into multiple components to permit communicating messages at different times. People may not be able to share the same time (moments) together, and the messages may be sent at different times, but the recipient of the message can bring the messages together in his or her mind to extract overall messages. Because humans can communicate a message or intention of selected action via a body medium (including audio/vocal features of a body), they must have some method for choosing one important aspect of their messages. Based on this situation, a user therefore chooses to use simple sentences to communicate one message at a time.

Texting is a way to quantify human speech messages into speech with multiple components. People combine their messages in groups of messages, and the frequency of sending text messages increases to add coherence to their overall communication quality. In other words, because people may only be able to share text-based message communication and may not be able to use facial or body gestures and voice specific prosodic features, they must increase the frequency of their messages if they wish to report details about the context in which an event occurs. When they increase the frequency of messages, the overall message would live in memory.

Texting activity includes a use of a device to create a verbal message, i.e., it is not only verbal activity or body activity to operate a device, but is the use of a device for the purpose of generating verbal context via the interface. It is therefore a complex action combining verbal activity with body activity for device operation. User texting corresponds to ideal design output; with each touch corresponding to a letter, one can communicate the message with fingers. User texting is possible if underlying design challenges are solved, so human messages would turn into user messages and each would be communicated with typing activity. However, due to underlying design problems, ideal texting, in which user typing activity would be modeled, is not possible.

6.2.4.3. Tweeting activity

Text messages are turned into tweets and sent to multiple users through social media platforms. Tweeting via online social platforms means that any individual message is open and the message is accessible to the public. For such platforms, tweets are not mostly addressing any specific user, but it is assumed that there may be people who would like to respond when they have time. That level of human verbal communication indicates social division from human context, in which people are sending messages to someone who may show interest in reading tweets.

6.3. User Touch Interaction Design Challenge

6.3.1. Typing activity

After choosing a message showing one aspect of an intended message, users begin typing the message into a device via touch actions. Referring to Figure 28, there is a difference between texting and typing; from action to the operation is considered texting; while from operation to expression is considered typing. Texting is communication of a human message, while typing is communication of a user message, only one aspect of the human message. We assume that there is a difference between human and user, because a human is a person in natural context, and a user is a person in virtual context.

Typing of a selected message is a problem of implementation of situated action, because the situation is created via verbal UI design problems, like those inherited from touch gesture recognition problems, and the typing interaction does not have contextual adaptation, increasing the complexity of future interaction designs. It is user response to current contextual condition created via design problems. Because a user goal is challenged, user activity turns into dealing with implications of the design with respect to her/his needs, values, and goals in terms of repairing affected previous action, operation, and expressions.

User action response is a situated action developed based on design implications with respect to user internal context or state (cognitive evaluation), and it would involve individualized and random selection of situated actions by the user, but how UI designs would affect previously gained human action skills is not known.

6.3.2. Touch recognition as inherited verbal UI design problem

User verbal experience design is based on user touch gesture design. Verbal interaction design inherits design problems with touch activity design, and also has inner problems of considering human verbal actions during interactions as independent from one another. The design of verbal experience via touch actions requires knowledge of touch activity, in which case we will be able to identify the problem through verbal experience. User touch gesture design is based on user touch activity design based on user body expression design. User body expression design is based on user interaction design and the design of touch activity via nonverbal body actions requires body expression knowledge. If we have information about body expression, we will be able to identify the problem with touch activity.

Nonverbal body expression design requires interaction model knowledge. If we know information from an interaction model, we would be able to identify the problem with body expression. An interaction model requires knowledge of an action model. If we have information about an action model, we will be able to identify the problem with interaction. An action model requires knowledge of influence, an affect.

The verbal activity design problem inherits challenges from the touch activity design problem in terms of recognition of touch gestures on a touch display. Transformation of body movement into touch activity is another inherited design problem that has not yet been solved. Due to an underlying interaction model within the design method, touch activity has evolved from center of the finger-contacted area to the top of the finger-contacted area but, depending on the richness of contextual conditions in the external context, a user should have both types of opportunity rather than directing user behavior into a single direction.

The touch gesture design problem relates to recognition of letters from touch actions. It is an identification of the goals of touch gestures. Touch gesture recognition is related to the human goal, not simply due to finding the target on the device screen. Touch gestures are created with the integration of multiple actions, including find and press actions. The problem is that the size of the device is very small while human fingers are relatively large, so users find it difficult to point at the correct targets on the screen.

Previous methods have assumed that if they meet users' challenges by calculating the difference between the real target and where a user finger touches the screen, and push that finger-touched point to the place it is supposed to be, the problem will be solved [119]–[121]. However, many studies in the field show that human touch action error is subject to another reason [119], so the correction does not help at all. Other methods are for educating the users via visualizing the finger-contacted point on the screen by marking it with colored dots so that people will try to self-correct their behaviors, but this did not work well[119]. Designers have also increased the target visibility by shifting labels of keys while a user is texting on a mobile device keyboard, assuming that the reason that a visual target is small is that people are not good at identifying it. None of those methods work well[119].

Touch action design is about recognition of targets of touch activity from body expressions. User touch action is a descriptive word given to represent underlying body action. It is a sensory physical action with/out making contact with the surface. The user executes a pointing task using a mouse or just bare hands. Input devices that a coordinate are called pointing devices [122]. And they may be used for simple tasks of hitting a target on the screen or a more complex task like typing a list of serial data. Research studies have compared finger, stylus, and mice used in tap, dragging, and radial pointing drag conditions and they show that, while a finger may be better for target selection, because of the size mismatch between objects on devices and fingers, user inputs can result in generation of many task errors [123]. Experienced device designers make design decisions related to the visual target identification and find that objects positioned at the center of a finger-contacted area are the ones users would like to select[124], but recent research into how users apply touch activity on screen surface show that people more often use the finger top to point at a target on the device screen[125].

6.4. Influence of UI Designs on Human Interaction Skills

6.4.1. Errors while applying designed user typing activity

Users are often challenged by a design because user actions are selected based on contextual conditions, and they make various errors in typing their statements into the device via the design interaction interface. Errors in typing point to the underlying interaction design challenge addressed in this study and prevents us from considering only modeling of verbal activity. For this reason, a general activity modeling method will be implemented by considering interaction design effects with respect to user texting activity. User verbal activity modeling can be generalized via inclusion of errors into sentence typing activity, and both are considered to be actions selected by users within current contextual conditions. This creates the idea that a user may generate the same action response within the same contextual condition if the user interacts with the same verbal user interaction design.

The challenge with verbal interaction design is that UI designs consider that actions in an interaction are independent of one another and every UI design influences human action skills. Whenever the design challenges a human goal, human behavior becomes unpredictable, because design influences unknown parts of human actions, and humans must deal with repairing some of those sections. In addition, every verbal interaction will cause different effects on different parts of the action hierarchy; there would be no order in development of actions occurring following one another. That means that user actions are only user responses to current dynamic contextual conditions created via UI designs, and ensuing user responses are unknown to not only to designers but to users as well.

Typing is an action that turns user intention into activity design, and typing a selected aspect of a message with a device is an implementation of planned actions, so this study will consider modeling typing activity, in terms of analysis of user behavior via dimensions of user typing activity. This will be a cognitive analysis of user behavior, and it considers only one dimension from four different content and form dimensions of user typing activity. That is a predictable aspect of human emotion with fast/slow or entropy/motor/automatic characteristic of user typing activity. User activity is divided into two and three groups to understand whether user behavior is fast or slow.

6.4.2. Change in user behaviors, and disconnection from user contexts

As a result of making a decision about actions dependent on the designed action, a user may be separated from her/his natural context. This type of design logic enforces behaviors to be divided, influences other connected behaviors, and creates separation from other contexts to which users may feel that they belong. User behavior has evolved to a single dimension and challenges with other parts of the behavior are ignored for a while when they become significant for completing the user behavior.

Phases ranging from face-to-face communication to mobile communication exemplify the effect given above. People start talking on the phone because they are not able to share same space with other people. Then they start texting to others because they are not able to share same time with others. Finally, they tweet to others to seek some social support from the mass community of Twitter, because they are not able to share similar social values with others. For example, people tweet about their feelings and ideas by considering that someone at a suitable time will see what they think about any topic, because their friends or partners are busy and not interested in with them.

6.4.3. Reduction in human interaction skills

When a message is ready for tweeting, tweeting action uses typing activity designed for verbal communication. The typing interaction is based on touch interaction and touch gesture design, and both touch interactions and typing interactions assume that touch actions following one another are independent. Although interaction design for single touches agrees with that assumption, when the design task turns into a design of typing activity with multiple tasks, it can be seen that touch actions in a user interaction are dependent on one another. User interaction corresponds to representation of a message stored in action form in the mind and turning it into an activity.

Challenges with touch interaction design are inherited from typing activity, and can spread to higher level of user actions like texting and human actions like speaking. Looking at real world examples will clarify how much this design view negatively influences human activity.

6.4.3.1. Behavioral skills

At first users of devices lacked social face-to-face communication skills [70], and there are also generation-based differences between people [69], including kill deformation, creation of new communication languages, encoding standards [51][52][53][52][54], and being self-centered [77][78].

6.4.3.2. Language skills

Influence analysis deals with analysis of deformation of the structure of human verbal activity with respect to user and design. Because of challenges that users experience because of unresponsive design, user activity must be changed if a user wants to survive under current contextual conditions, so the content of the first forms of user behavior changes. In other words, starting from the external world and going to internal context, objects influence users. The form is related to visibility, and those changes may be easily visible, such as in the case of word writing rules on social media. (Given, for example, by the social media entry of typing "cooollllll!!!!!" [51]). Content is related to meaning (transformation of goal into intention), such as alteration or modification of meaning of the words (either reduction in meaning or a word means something else entirely)

When user texting behavior on social media is analyzed, it can be seen that people change language rules or norms, and add emoticons, repeat letters within words to communicate nonverbal prosodic features of speech [51], turn parts of words into symbols with the same sound groups (syllables) (such as great > gr8), [52] remove vowels from words to communicate their intentions [53] and many other nonstandard methods (letter insertion, deletion and substitution) [52]. Users also may reflect their identities through their word typing behavior user [54] , such as for the purpose of expression of social identity, emotion, geographical dialects indicating membership in a group, etc. From such user behaviors, it can be concluded that sometimes a user would like to imitate human speaking activity via the texting activity designed for computing devices, and there is a human need is to speak to be able to communicate ideas about an event in a context via the devices as a medium.

Current user verbal experience design creates challenges for users for typing their words into the devices, and devices may not recognize nonverbal expressions like prosody in speech. Such challenges cause people to alter natural language rules and find ways to add many nonverbal expressions (via emoticons) and correct mistyped words. Users may create their own conventions in typing sentences by breaking natural language rules and creating their own virtual communities that share many characteristics with one another. Furthermore, a user may change the words in sentences depending on difficulties that they experience. For instance, social media messages have their own writing style, including include short words and compact and interactive language[126].

6.4.3.3. Social skills

The topic of alienation has been studied in two studies using the terms familiar stranger [79], and alone together [78] to seek understanding as to why people expect more from technologies. In designX [15], [16], that aims to design relationships between designs, a selected group of users is brought together to create new classes to create a new elite community able to use the designed devices and new social groups in which users can talk via their new typing conventions. This has caused the creation of phenomena like the digital divide, and Generations X, Y, and Z [69]. New social groups may cause changes in social trust, like in the tele-cocooning hypothesis, indicating that frequent texters take different meanings from various words, e.g., the phrase “all people”[77] becomes the people they communicate with. Except for their close friends they are indifferent to other people's difficulties. Networked individualism causes people to create new strategies and skills while dealing with challenges[77]. Both approaches cause changes in a person's social aspects and people sometimes find face-to-face communication an extremely challenging task[70]. People on social platforms become networked individuals[77], alone but together [78].

6.5. Consequences of User Interaction with Verbal UI Designs

User verbal experience design primarily means the design of verbal experience using a computing device. It is a complex research problem with the multiple levels letter, word, and sentence. User verbal interaction design means recognition of user words from touch actions. User verbal experience design means recognition of user messages in the form of feeling, idea, sentiment, mood, emotion, or affective values. Figure 31 gives an overview of the development of user verbal experience and challenges with the user verbal experience design problem. Each level has its own set of problems and designs, and because of problems at the lower level; the upper-level research problem might be misaligned.

Referring to Figure 31, there are two sets of verbal UI design problems: design of user verbal interaction, and design of user verbal experience. UI design problems include recognition of words, recognition of letters from touch actions, and recognition of touch gestures from user body expressions. UX design problems involve subjective expression recognition conveyed within sentences.

6.5.1. Design problems

6.5.1.1. Inherited design problems from user touch interaction design

The challenge is that user typing behavior is affected by design challenges. Typing action is based on cognitive evaluation of implication of design based on user needs, values, and goals. As design challenges human goals, and human goals become unpredictable, each typing action is a single action with no relationship to previous typing actions, and either typing action acquires problems with touch design or user verbal interaction is affected due to the UI design challenge. Every design creates new situations within the external context of the users

In other words, the problem is about design of verbal UI and inherited design challenges with touch gesture recognition. Because an action during an interaction is considered to be independent from others, every action is independent, every experience is independent, and every recognition is based on users internal conditions in terms of how much the UI design influences human action skills.

6.5.1.2. Missing design states, incomplete designs and unresponsive designs

The topics of incomplete, unresponsive designs are not among currently studied design topics in the user verbal activity design field.

6.5.2. Design features related problems

The design of software keyboards on mobile device may include a number of special features. For example, autocorrection and completion features for keyboards apply different methods to relieve challenges with user verbal interaction design challenges.

6.5.3. Internal design problems with design methods

Components of user experience and interaction, including user experience components such as feeling, evaluation-related subjectivity recognition, and user interaction components such as word, phrase and sentence recognition are still largely missing in verbal activity design.

6.5.3.1. Recognition of NV components of user messages in the mind

Emotional expressions help in understanding nuances in an expression, to clarify and stress what is said in human verbal expression in social communication [127][128], and to signal comprehension, disagreement, and intention to regulate interactions with the environment [127][128]. For example, an angry person might raise the volume of her/his voice. to indicate that a person should highlight something significant within the message.

There are different methods for recognition of emotion in human expressions, specifically from those people who are users of computing devices. Emotion is detected from user verbal expression created, either through social media tools such as Twitter or Facebook, or social communication tools for personal use such as SMS or messaging. Words in text messages are evaluated based on developed affective dictionaries created from reactions of groups of people participating in behavioral research studies.

A second method is to recognize emotion from verbal expressions. Social media messages (Facebook, Twitter, YouTube, and other online texts (blogs, news, comments, etc.)) are collected from online platforms to seek understanding of user reaction to external events (like weather [129]) and estimate their sentiment, emotional values, and moods[130][131]. Subjective words within sentences are identified, and affective values of those words are identified using various methods. For example, affective dictionaries[132] match words with affective values. The values of those words are extracted and then the total values of sentences are calculated. If the "joy" value of a sentence exceeds a threshold, that user emotion is identified as joy [133].

Such studies generally are referred to as sentiment extraction or detection., and they have challenges regarding the applicability of one sentiment detection method from one contextual data set to another contextual data set [131]. It is suggested that researchers often require more contextual information to analyze the collected data, such as for political topics used to estimate political alignments of people [39]. Various methods can be applied in sentiment analysis methods that cause the replication capacity of the methods. Some studies normalize words in social media messages[52], but that is a user-invented method to deal with challenges in user verbal experience design. In other words, social media messages like Twitter messages have a structured nature [126], but the rules applied to construct social media messages follow somewhat different natural language rules, because they have a unique style due to the projection of a formal style into a size-limited space. Emotion recognition from words is not helpful in discriminating user emotion from the verbal expressions unless information about how to say what is said is included into the study, such angrily talking, etc. The design of verbal activity with mobile touch devices can include touch gesture recognition, various word prediction tasks, and nonverbal expression recognition problems.

Emotion is detected from nonverbal expression or interaction using input technologies such as touch activity [110], body expression [134], correlation between emotion and body expression with device [135], user behavior with computing device, such as keyboard activity [136][137][138], mouse movement [139], keyboard and mouse use [140], device usage behavior [141][142][143][144], [145][146] (in terms of intensity of phone features usage from behavioral logs of the device), physiological body data [147][148] correlated with device use, and voice on the phone [149].

Recognized subjective states are happiness [143], mood [144], personality [145], stress [146][147][139][138][148], boredom [110][136][141][142], confidence [137], hesitancy [137], nervousness [137], relaxation [137][110], sadness [137] tiredness [137], excitedness [110], and frustration [110]. One study researched basic emotion [150] recognition and tested it with a single user.

The method with texting uses a fixed and pre-determined text method involving selection of text from a previously-selected text collection. The frequency device feature usage many times indicates the implementation of expected behavior in everyday life. In terms of meeting communication needs, use of phone features reflects many values on device feature use frequency. This is related to motor skill development, and frequent use of such skills in everyday context.

The above methods have significant dependence on active listening of user behavior to improve the performance of emotion recognition results, and user-independent recognition rates are low. Mobile phones have many usability problems, including touch input recognition. Previous solutions are related to changes left by user actions that provide limited information about user behavior, and methods are open to change based on device design changes. When mobile phone usability problem (i.e. touch interaction recognition challenges) are taken into account, including active observation of user behavior with a device under usability-challenging situations, the results may not be as reliable as expected and may indicate user subjective response to a device problem rather than a subjective response to external events in the context.

6.5.3.2. Recognition of verbal components of user messages: Words, and phrases recognition

Word recognition can be a problem because devices are not good at identifying letters from user touch actions, so keyboard software has many features to improve user texting performance. Either verbal expressions are corrected by changing words into predicted words, or verbal expressions are completed before a user finishes typing the words. Such methods are based on previous experience results, and do not consider the mutual influence effect in the design of interaction, the topic of this research study. In other words, every design for word recognition may influence user behavior and cause it to change, so previous experiences may change frequently in a way that is not beneficial to development of human verbal skills, but rather creates negative change that degrades human verbal skills. It is clearly visible that online social communication language is quite different from natural language, both through the use of new conventions and through assigning new meanings to communication objects.

When we look at the user texting research literature, we see that there are two approaches in the literature: to correct user behavior, to or complete user behavior. This is reflected in the design of smart keyboards that rely on language models or a dictionary to correct touch errors, or to auto-completion of partial letter strings to complete words by predicting what a user may type

next[57].

1. Correct User Words

One method for dealing with word recognition challenges is to look for possibilities to identify typing errors and auto-correct them. Word correction occurs after a user types the word, specifically uses previous verbal behavior as a reference, calculates the probability of using similar or identical words in the expression, and change mistyped letters in the words based on that relationship. For example, automatic correction by a keyboard is usually delayed until a full sentence has been typed [151].

2. Complete User Words

Another method is to complete user behavior via word suggestion from the keyboard, with word completion occurring before the user types all letters of a word. For an iPhone's keyboard, word suggestion is based on a scoring system produced by the keyboard and based on collected data from the user's personal message history [55]. Designers use information about user behavior to support their decisions. For example, while they may use syllables as cues to complete and/or predict user words before they are typed, the user may change her/his behavior by changing to words that communicate the same meaning. Thus if a user adapts to this design feature, many words are gradually removed from a person's vocabulary based on interaction between the design and the user. The user uses "word suggestion by the design", and the design changes the user vocabulary.

3. Combined Methods

Some researchers combine both correction and completion user behavior methods to remove errors related to user typing behavior. They apply touch correction and word completion method in combination to create an optimized solution to the typing problem. A study showed that computational optimization could improve correction accuracy by 8.3% and completion power by 17.7%. When a keyboard works to achieve both purposes, it suffers only a minor loss in completion capability (1.5% loss) [58].

Some studies combine probabilistic touch behavior models with a touch model. They use two models, one for touch, the second for word prediction. The touch model reduces the error rate by 7% with respect to a baseline method, and by 1.3% with respect to commercial keyboards. The second model improves user performance [56]. Some researchers have developed language models to create a structured list of words and check touch inputs to predict the typed text via the correlation with both touch input and word model[57].

6.6. Emotion Recognition from User Activity

This section provides details of emotion recognition from user activity, including experiment design, experiment protocol, and emotion recognition results, and provides details of two different user studies in which users reacted to contextual events via texting activity designed for keyboards on mobile devices.

6.6.1. UX designs for experimental purposes

6.6.1.1. Story development

Stories are events that happen in an external context. The human mind may give a particular and unique response to events happening in external context [85], so stories likely to happen in external context are developed for users. Benefitting from story generation behavior of human mind, two different story-based experiences were selected for study: TV content, and stories on online platforms, selected as two contextual events with which users interact.

Those two experiences represent part of the human experience set, and many users experience both types in their everyday context, but we don't know of previous contextual conditions that may cause people to adopt both technologies (TV and story), and what the next state will be after use of those technologies. However, we can keep its connected structure during the design process, so its inner structure is unchanged and only carried into the newly created conditional environment. The structure includes all conditions and responses to all conditions. To improve the skills, that united structure should be kept confidential.

6.6.1.2. Events in the stories

After it has been decided in terms of what context the user will interact in, selection of contextual events is required for user experiences. Previous studies have used video interaction as external conditions, and studied relationships between the video's affective content and user physiological [152] body responses to relate human emotions to autonomic nervous system activity. In [153] [154] [155], users rate the affective content of videos to identify inter-agreement between participants about the type of emotion conveyed by the videos and the affective quality of the videos (valence, arousal). Pictures with different positive or negative neutral states are selected to stimulate human affective states [156]. Another method for triggering human emotions is to have people read a textual description of an event in the form of a short story called a vignette [157] [158]. In addition to those methods, live events such as TV talk shows can be used for emotional event creation [152].

6.6.1.3. Human computer interaction

HCI designs benefit from the development of stories based on collected user data. Storyboarding based on human-centered design can be used, but it is hard to address each one of the user experiences [159][160]. However, it can be limited to the researcher's performance in observing user behavior in context and reflecting her/his observations into the story created on storyboards. In addition to storyboarding, scenario design providing a dialog between two objects [159][2] can be used to accomplish HCI in field tests.

Contextual cues can help people to remember [161], i.e., to activate memory records. Optimal flow in experience is also established when the experience is fed with sensory components [162].

6.6.2. Modeling user typing activity

User typing activity corresponds to human interaction with keyboard software designs. Such keyboards may include a combination of various verbal UI design features. Human nonverbal activity with the device is modeled based on the serial order of activity development. In this way, selection of action would be left to the user, and parallel behavioral analysis of human activity would be excluded from the analysis. When interactional errors are removed from the design, parallel analysis may also be included.

6.6.2.1. Modeling one of 4 dimensions of user typing activity

Generally, if an object is in serial order, there should be three objects in the order, and the first one followed by the second, and the second followed by the third. Being serial exemplifies the first dimensions of human affect, i.e., the unpredictability dimension of human affect, and the first dimensions of human action, i.e., the automatic nature of the human activity. According to this principle, touch data can be divided into three and two groups to meet the requirement of being serial or not. Non-serial components may reflect the parallel behavior requirement throughout the user's verbal action, a sentence, so it is included in the analysis.

6.6.2.2. Identification of actions to create complex human activity in the model given above

The user follows the following order in the execution of an action: the action of intending to touch, the action of touch, and the evaluation of touch action results, so there is an intention before there is a touch action. Table 1 shows how to identify actions to create complex human activity.

An action may be a touch action in its simplest form or include more complex actions through a combination of multiple touch actions. A gesture implies body movements to communicate a message. Touch gestures communicate letters as keyboard symbols via finger movements. A touch gesture is implemented in two main steps: finding the location of the target on the screen, and pressing on that target. Depending on challenges with parallel behavior modeling, identification of word first touch activities are omitted because it cannot be known whether a first touch activity may indicate the beginning of a word or not, so touch activity for first touches in action groups is excluded from analysis.

6.6.2.3. Total actions to be executed by the users to communicate messages

Modeling Verbal Action in Being Serial Condition

Touch activity data is divided into three touch action categories, and for each operation with three touch actions, eight actions to complete an operation can be identified:

- 2 touch activity
- 3 touch action
- 2 intention
- 1 action

Modeling Verbal Action for the Being Not Serial Condition

The entirety of touch activity data is divided into two touch action data categories. For each operation with two touch actions, five actions for completing the operation can be identified:

- 1 touch activity
- 2 different touch actions which are part of the operation with two touch actions
- 1 intention

- 1 action

6.6.3. Extraction of features of user typing activity

In addition to the above limitations, some features of user actions are missing in user action modeling task, as state of art in feature extraction from certain aspects of user motion signals is not present in the literature.

6.6.3.1. Dimensions of actions

Because intention, touch gesture, and action are different types of actions used for creating more complex actions, once they are identified, their content and form dimensions are included in the model. The content of action includes four dimensions: entropy/motor features of the activity, fluidity, energy, and power, and the form of action includes four dimensions: fast/slow, smooth/jerky, even/uneven, large/small.

6.6.3.2. Identification of features for user actions

Activity and goal are the two main components of human action in which a human turns a goal into an activity. Related features can be found in the literature on similar topics, such as activity recognition via change acceleration signals, touch, and user-related recognition studies. For example, the location of taps on a mobile phone screen can be identified from features collected from acceleration signals from an accelerometer sensor [163]. A password entered for unlocking the device can be identified from acceleration signals collected from phone motion sensors [164]. The identity of a person using a mobile device can be determined from motion sensors signals for user verification purposes [165].

Verbal expressions created by a standard Mac keyboard can be recognized from acceleration signals collected from a mobile smartphone (iPhone) positioned on the same desk as the Mac keyboard[166]. The study, with the help of a dictionary, identifies the letter key pressed on the keyboard from acceleration signals [166]. The study applies calculation of Fourier, cepstral and mfcc features from acceleration data to sense the smallest differences in body-movement (hand, finger)-based expressions. Popular features computed from the acceleration signal are dynamic features (mean, variance, or standard deviation), energy, entropy, correlation between axes, and discrete FFT coefficients[167].

Absolute values within a time window and finger peaks when touching down and up from a keyboard are calculated [165]. A previous study employed a method based on the extraction of touch peaks during touch action behavior as an indication of relative pressure applied by the user on the screen [168]. The number of local maxima and minima [164] are also calculated. A statistical summary of signals within a time period (min [163]–[166], max [166][163][164][165], mean [166][163][165], root mean square (RMS) [166][164], standard deviation, variance [166], skewness [163], kurtosis [166][163], higher moment [163]), and energy [166] and entropy are calculated. Absolute gradient, first-order difference, and second-order difference [163][169] are also computed. First and second order differences of raw signals were used in a previous emotion recognition study that demonstrated high emotion recognition accuracy (81% accuracy) [169]. In addition, Interquartile range, zero cross value and mean cross value of signals, pairwise correlation of acceleration in x-, y-, and z-direction were calculated.

Correlation between accelerometer and gyroscope data is computed using three sets of features: The angle between gyroscope and accelerometer data, its rate of change, and pairwise correlation of 3 axes of gyroscope and accelerometer data [163]. Entropy, related to how much human learn during an activity [104], is calculated based on the Shannon entropy calculation method. The literature reports that applied force on a device screen has correlation with touch peaks of motion signals [168], so discrete FFT coefficients are computed along each time window given by a keyboard dynamics model [166][163]. In activity recognition tasks, FFT coefficients perform well for the activities with moderate to high intensity levels [167]. Because touch action behavior is modeled in this study, FFT coefficients may be helpful to extract more information about the behavior. The FFT coefficients were grouped into five bands, with spectral power [163], spectral entropy, and band area values for each of the five bands computed separately. Discriminative features of the spectrum are computed for each of the axes: Those features include spectral roll-off frequency, spectral fluctuation, spectral centroid, spectral flux, bandwidth, and peaks of the spectrum. A statistical summary of Fourier spectra is included in the features. Those computed statistics are the magnitude of RMS, flatness, spread, skewness, kurtosis, and high moment. In addition to Fourier transforms, cepstrum, Mel-frequency cepstrum [166], and log-FFT transforms of motion signals along three axes are calculated as well. Finally, the effect of gravity on user actions is modeled with center of earth gravity features.

Table 2, Table 3, Table 4, and Table 5 show features for calculating activity dimensions and goal dimensions. Features of user activity are calculated for the three dimensions (x, y, z) of the activity. Table 2 shows features used for calculating dimensions of activity description. Table 3 shows features used for calculating dimensions of activity definition. Table 4 shows features used for calculating dimensions of goal description. Table 5 shows features used for calculating dimensions of goal definition.

6.6.4. Evaluation of learning performance using a Bayesian networking classifier

A machine-learning classifier based on learning function modeling is given above, and recognition results of core affect (valence and arousal) from user body expression are given below.

6.6.4.1. Ten-fold cross validation

A ten-fold cross validation method was applied to test the performance of the classifier. This method [137], [150], the most-used method for various recognition tasks (activity recognition, emotion recognition, social activity classification, etc.) when the data sample size is small, is based on dividing data into ten samples, and the input classifier into nine samples to learn the pattern within the sample, and to predict class outputs from one unseen sample, then apply the method ten times and average the results of all 10 classification results.

6.6.4.2. Testing classifier performance with leave one person out method

Another most-used evaluation method for classifier performance is the leave-one-out method [110][169]. In this method, for example, one person's data is removed from the collected data, and the classifier first learns patterns from other people's data then predicts the unseen person's behavior. The method is called leave-one-person-out [110]. Depending on the experiment design, leave-one-out may be implemented as leave-one-day-out [169], indicating that data collected through a day will be removed from the learning data sample, and the classifier will predict user behavior.

6.7. User Study 1: Interacting with TV Content

6.7.1. User interactions with TV content

Users often like to socialize and get together with friends to talk about common interest topics on TV. Television provides a cultural forum for people on various topics of interest. Television can physically connect two or more people into a common space where they can interact with one another. According to Nielsen's 2009 Television audience report, 54 percent of US homes had three or more TVs in 2009 [170]. However, because an increased number of people can afford TV, it may start to become an individual rather than a communal experience, and people who watch the same TV content may come together on social media platforms to discuss TV content by sharing their viewing experience via social network sites. People may watch videos and leave messages indicating their opinions related to the content of the video. People comment on internet-based videos, including YouTube [171] videos, for example, and on social media, such as videos on Twitter shared by other users. Social TV viewing is a recently emerging type of user experience in which people use mobile devices and social media apps to share their views regarding TV episodes. For example, users may comment on live TV content [172][173], TV programs [170], TV series [174] [173] and movies [175]. When users interact with video content, they may feel close to the characters and share their feelings and may like to create verbal expression via social media tools or apps on mobile devices.

Social media use in daily context does not use synchronous communication requests with social peers, but rather users leave messages to the social platform[176] and, at some later time, other users may see the messages and may themselves create a verbal response. A user's motivation for tweeting about TV content may include finding someone interested in what say about a TV program because they are not able to find someone in their physical context to listen to their sayings[173].

TV content, videos, and movies have similar effects in that people engage with content, and usually cannot differentiate whether a story is real or not, so this is another method of story creation that helps bring together unrelated or unreal things and trigger reactions in others. In this study, we selected TV content from popular movies and other sources, and asked them to create reactions in textual form related to the TV content presented to them.

6.7.2. Study materials

6.7.2.1. Description of context in social TV viewing experiences

Table 6 gives details of the video contents. Affective scenes cut from films were used as stimuli to elicit desired emotions of users. 14 videos were selected for viewing by the participants. Selected topics for the eventual video contents were issues dealing with money, baby voice/smile, older adults/parents living alone, dying in cold water, earthquake, customer service, social behaviors, daily conversations, travel conditions, unexpected response in conversation, and dreaming.

Users viewed videos on second LCD computer display screens. A web-based user interface was developed to help users view each item of video content. Users could view the content at full screen. When a user finished the assigned task related to each video, they took a 30-seconds break before starting the next one.

6.7.2.2. Development of social TV interaction tool

Figure 32 shows two interfaces of the application designed for creating a message and reporting user emotional state. User touch action and body movements are sampled at a frequency of 100 Hz via on-device touch and motion sensors during each textual message creation time period. The emotion-reporting interface includes tools for reporting user emotions along with face images and dimensions of user emotions using a horizontal slider with nine different levels.

6.7.3. Experiment protocol

IRB approval (IRB Number12-414; Appendix A) was obtained from the Institutional Review Board at the university. Participants were undergraduate students who gained course credit for their participation in the study. They were informed about the experiment and had their rights explained by an experiment introduction through a participant call on an online participant recruitment board prior to the experiment, with a verbal introduction at the beginning of the experiment, and through a consent form before starting the experiment. The study had three components. Users filled out two questionnaires, one at the beginning and one at the end of the experiment, to evaluate their mobile and video or TV viewing experiences and the content of videos that affected their emotions. The experiment took about 50 minutes on average. Participants were trained about the web interface and the mobile application interface before the experiment. Participants were also introduced to the meaning of arousal, valence in the self-assessment procedure, and the nature of the video contents in the study. Each user sat in a chair and watched video on a second screen rather than on the mobile device. Users wore headsets to engage more fully with the content.

6.7.4. Results of user study 1

6.7.4.1. Evaluation of core affect recognition with ten fold cross validation method

Table 7 below presents overall recognition rates of core affect dimensions, valence and arousal. User feelings of valence were recognized with 83.4% accuracy. Kappa statistics related to valence classifiers performance was 0.7395. Precision, recall, and F-measure of the classifier were above 83%. User feeling of arousal was recognized with 82.6% accuracy. Kappa statistics related to valence classifiers performance was 0.7459. Precision, recall, and F-measure of the classifier were above 82%.

6.7.4.2. Analysis of discriminative features used with 10-fold cross validation method

Table 8 shows the distribution of features used for valence recognition in the TV interaction scenario. Only 47 features were used for valence recognition in the scenario of user texting activity related to interaction with TV content. Table 9 shows the distribution of features used for arousal recognition in the TV interaction scenario. Only 45 features are used for valence recognition in the scenario of user texting activity in interaction with TV content.

6.7.4.3. Evaluation of core affect recognition with leave-one-out method

Table 10 presents overall recognition rates of core affect dimensions, valence and arousal. User feeling of valence was recognized with 79.6% accuracy. Kappa statistics related to valence classifiers performance was 0.6886. Precision, recall, and F-measure of the classifier were about 79.6%. User feeling of arousal was recognized with 78.9% accuracy. Kappa statistics related to valence classifiers performance was 0.6828. Precision, recall, and F-measure of the classifier were about 79%.

6.8. User Study 2: Interacting with Multimedia Story Contents

6.8.1. Interacting with online multimedia stories

HCI designs benefit from the development of stories based on collected user data. Storyboarding is based on human-centered design, but it is difficult to address each of the user experiences [159][160] because of limitations in the researcher's performance while observing user behavior in a context and reflecting her/his observations into the story created on storyboards. In addition to storyboarding, scenario design [159][2] was used as a HCI in the field test. The scenario provides a dialog between two objects. Contextual cues help people to remember [161], i.e., can activate their memory records. Optimal flow in experience is also established when the experience is fed with sensory components [162]. Information received from friends on online platforms is much trusted and people tend to distribute information coming in via friends' references. Rumors are one type of information often spread on the media. People also may exchange information details while sharing the rumors, and the new versions may also be shared among users [177].

Social media can be used to report everyday activities or results of everyday activities, so it can be said that social media is a platform for exchange of everyday life stories with friends, and/or other people with the same or similar interests. People can use various methods to improve their online experiences, such as integrating audio, visual and other media forms into their text messages [178][179]. Social media can also be used to read stories about other people, most of them coming through media or news channels on social media. Some also come from friends' networks, and people tend to believe them due to their friends' references. Predictability ratings of information, in terms of whether it is true or false, are determined via some references. For example, user emotional engagement with news or stories on the media is dependent heavily on friends who share common beliefs and/or interests. People are strongly influenced by behaviors of their friends with similar interests. Users with same shared beliefs can become a determinant factor in the rate of virality of false information[180]. People who use a heuristic approach to evaluating evidence to form their opinions check compatibility between beliefs presented in the spread information and their own beliefs and use it as a resource to share with others [181].

In this study, we created stories for users to consume and then asked them to create reactions in textual form related to those stories [162]. Stories had visual, descriptive, and audio features for providing improved and extended virtual reality to the users and provide optimal flow[162] with content. For story sharing, the core affect and appraisal is taken as an emotion description. Through emotion recognition, people can try to understand which story is real and which is not. People can observe real-time event management or visualization to observe what is going on in online social media.

6.8.2. Study materials

6.8.2.1. Description of context in story developments

Table 11 shows that nine different everyday experiences of mobile device users are created with multimedia (audio, picture, textual) experience. Each story gives eventual details of a human experience that might be likely to happen in everyday context.

Table 11 gives details about everyday experiences based on stories. Nine stories to be shown to participants were created with music and picture components. Selected topics for the eventual video contents were issues related to love, having time with your relatives, homeless people needing help, dying in another city, leave a partner alone, subsequent terrible events, bad people, and a woman walking on the street.

6.8.2.2. Application development for story interaction

Figure 33 shows interfaces of the application designed to walk through the application before using it, to present a story, to create text messages about the content of the stories, and to report users' emotional states. At the end of the walkthrough interface, users learned how to use the interfaces during the task. The emotion-reporting interface includes self-assessment mannequin images [182] and self-produced images to report nine different levels of dimensions, event predictability, valence, arousal, and dominance of user emotions. User touch action and body movements during texting activity were sampled at a 100 Hz frequency rate via on-device touch and motion sensors during the textual message creation time period.

6.8.3. Experiment protocol

IRB approval (IRB Number12-414; Appendix A) was obtained from the Institutional Review Board at the university. Participants all volunteered to be part of the experiment, and there was no compensation given to participants. 27 participants volunteered to participate in the user study, including both American and international students. 11 participants were female and 16 participants were male. 13 participants were undergraduate students, and 14 participants were graduate students.

The study had three components. Users filled out two questionnaires, one at the beginning and one at the end of the experiment, to evaluate their multimedia experiences and content of stories that affected their emotions. Behavior tendencies were related to device, multimedia, and personality. The participants were informed about the experiment and their rights by e-mail for participation before the experiment, and were given a verbal introduction at the beginning of the experiment, through a consent form, and about the interface during the walkthrough at the beginning of the social media application. Participants were trained about the mobile application interface before the experiment. They were also introduced to the meaning of arousal, of valence in the self-assessment procedure, and the nature of the story contents in the study. Users sat in a chair and wore a headset to engage with the content of stories on a mobile device. The experiment duration was about 30 minutes on average.

6.8.4. Results from user study 2

6.8.4.1. Evaluation of core affect recognition with 10 fold cross validation method

Table 12 shows overall recognition rates of core affect dimensions, valence and arousal. The user feeling of valence was recognized with 86% accuracy. Kappa statistics related to valence classifiers performance was 0.7798. Precision, recall, and F-measure of the classifier were about 86%. User feeling of arousal was recognized with 81% accuracy. Kappa statistics related to valence classifiers performance was 0.7021. Precision, recall, and F-measure of the classifier were about 81%.

6.8.4.2. Analysis of discriminative features used with the 10-fold cross validation method

Table 13 shows the distribution of features used for arousal recognition in a story interaction scenario. Only 46 features were used for valence recognition in the scenario of user texting activity in the interaction with online story content. Table 14 shows the distribution of features used for arousal recognition in the story interaction scenario. Only 49 features were used for valence recognition in the scenario of user texting activity in the interaction with online story content.

6.8.4.3. Evaluation of core affect recognition with leave-one-out method

Table 15 presents overall recognition rates of the core affect dimensions, valence and arousal. User feeling of valence was recognized with 82.6% accuracy. Kappa statistics related to valence classifiers performance was 0.7264. Precision, recall, and F-measure of the classifier were about 82%. User feeling of arousal was recognized with 79.8% accuracy.

Kappa statistics related to valence classifiers performance was 0.6831. Precision, recall, and F-measure of the classifier were about 79.6%.

6.9. Comparison of Learning Models in Different Contexts

6.9.1. Data analysis techniques and assumption of independent actions in natural context

The assumption that actions are independent of natural context requires some statistical methods to introduce that independency into the data analysis process. The following topics are related to data analysis of different dimensions of user activity.

6.9.1.1. Total numbers of features used in core affect recognition with 10-fold cross validation method

When we consider the number of features used in user recognition (127 features) [165], location of touch on mobile devices (273 features) [163], and password recognition on mobile devices(46 features) [164] that are relatively simple tasks compared to emotion recognition from user body expression with computing devices, the feature count is low. These selected features also deal with specified contextual conditions and complexity of recognition tasks given within each study.

These are relatively simple tasks compared to emotion recognition from user body expression with computing devices, and the feature count is low. Also, selected features are related to specified contextual conditions and complexity of recognition task given within each study.

This study concentrates on recognition of basic emotions and affect dimensions (event predictability, valence, arousal, dominance) from user body expressions with computing devices. Feature calculation wa done using three dimensions of motion signals, so when the total number of features for each recognition task in TV and story interaction scenarios is roughly divided by 3, and the total number of different features used for each recognition task was about 15. Calculation of the rich set of features was done during early steps of the analysis to represent the user texting activity model in both time and frequency domains. Not all the features calculated for the user texting model were used for the emotion recognition task, and only a small subset of them was used for recognition of valence and arousal.

6.9.1.2. Reviewing development of person dependent machine learning classifiers

If one would like to have a person dependent classifier, all user data for that classifier should come from the same user with respect to training the learning classifier. The frequency of features usage is used to estimate user emotions. With these studies, a person dependent emotion classification is possible when the classifier is trained with all data coming from the same person. The study [144] shows that a person-dependent classifier provides better recognition results (93% recognition rate) than a person-independent classifier (66% recognition rate), but the person-dependent classifier should be trained on a daily basis or else the recognition rate might be reduced.

In [137], 15 machine-learning classifiers with 2 or 3 levels of outputs (agree, disagree, neutral) were trained with normalized aggregated data (person-independent data). For every emotion, one classifier was created, and the set of emotions to be recognized was related mostly to mind states rather than basic emotions or higher-level social emotions. They included frustrated, focused, angry, happy, overwhelmed, confident, hesitant, stressed, relaxed, excited, distracted, bored, sad, nervous and tired. From this set, two level classifiers for confidence, hesitance, nervousness, relaxation, sadness, and tiredness can be identified from keyboard dynamics, with accuracies ranging from 77 to 88%. In [110], six emotional states related to user mind states were used to estimate emotions from touch patterns while playing games on mobile devices. Those emotions were excited, delighted, annoyed, frustrated, satisfied, and relaxed.

By themselves, emotions are human affective responses to contextual conditions in external context, and the classifiers were able to identify human emotions in individual contextual settings. From outputs it can be said that while classifiers were able to provide person and condition-independent solutions, they were not able to transfer results from one context to another. It should be noted that conditions and contexts were different from one another and conditions are within a context and show different states of an individual context.

The problem is not related to emotion recognition but is related to human affective response to condition-based changes in an individual context. The problem lies with the basic assumptions that user interaction design methods are built upon. User verbal interaction is built upon user touch interaction designs, and the assumptions that touch interaction designs are using results of users touch actions being permanently changed and individualized in terms of being unique. Because of this, independent touches were brought together to create a group of touches not different from the group of touches belonging to the next typing action, so not all typing actions are the same, nor are all contexts for the typing actions the same. The context shows the dependency between actions in an environment, and the reason that independent actions are brought together lies with the internal requirements of users to satisfy their goals. When user requirements are finished, there is no reason to keep those independent actions together. The following sections provide an overview of the whys and hows of UI designs.

6.9.1.3. Application of data normalization to deal with idiosyncrasy of user behaviors

The assumption about actions in natural context may create challenges in making decisions about analyzing user activity in the context. Normalization of action features may be performed to remove dependency of actions on initial user actions. This is useful not only for removing user experience design effects from human activity, but also for studying an action of the object in a context that is mostly understood because it is independent [7] from other actions in the context.

It has been reported that normalization is seen as a method to remove idiosyncrasies, so it is hoped that, without normalizing, emotion recognition rates would be high. However, researchers report that when they normalize the data by removing idiosyncrasies, they obtain higher recognition rates (~81%)[101]. Before normalizing, the recognition rate was 50% [101] and, as discussed in [110][101], this was surprising for those researchers because they expected idiosyncrasy would be valuable information for discriminating users' subjective states from one another. Considering the effect from those rippling effects in the data being removed, recognition rates were high, possibly due to the dominant singularity design view, as given in the literature.

Because the dominant view in design forces users to change their behavior because of unresponsiveness of the design to user requests, users have evolved toward a single state. Human interaction with natural context has multiple conditions and may cause an experience of multiple states, but the design limits users to experience many of those states, so those seen as idiosyncratic may not be the real expression of subjective characteristics of people, but may be related to people's dealing with external contextual conditions created by device designs. Normalizing values related to user behavior may be related to a research method develop to find a starting point in time for the analysis.

6.9.2. Testing learning skill of the (cognitive) sense model in user study 1

The learning model from interacting with TV was tested with user behavioral data from the study of interaction with a story. Table 16 shows general recognition results when testing data from story interaction with the emotion recognition model from the TV interaction scenario.

Table 17 shows valence recognition results when testing data from story interaction with the emotion recognition model from the TV interaction scenario. Table 18 shows arousal recognition results when testing data from story interaction with the emotion-recognition model from the TV interaction scenario.

6.9.3. Testing learning skill of the model in user study 2

The learning model from interaction with the story was tested with user behavioral data from the study of interacting with TV. Table 19 shows general recognition results when testing data from TV interaction with the emotion recognition model from the story interaction scenario.

Table 20 shows valence recognition results when testing data from the TV interaction with emotion recognition model from the story interaction scenario. Table 21 shows arousal recognition results when testing data from TV interaction with the emotion recognition model from the story interaction scenario.

6.9.4. Testing learning models' dependencies on users

Both 10-fold and leave-one-person-out approaches provide better recognition results for emotion recognition tasks. The results show that learning emotion from user activities works well in the present context for user interaction with both TV and stories. To test generalization of the performance of both learning models, two comparison studies were performed. Tables 16-21 show the rate of recognition in both contextual conditions. The results show that when contexts are changed, classifiers are not good at recognizing user emotional states with the recognition rate decreasing to ~30%. This result shows that learning emotion from user activities is affected by changes in user tasks.

These study results show that classifiers are context-dependent. Internal contexts are created dynamically for users for dealing with requirements of their present tasks. The influence of UI designs on user verbal activity causes users' to focus on their tasks, and each of their experiences becomes unique for them. This uniqueness is provided by the initial design assumption, that actions in a natural context are independent of one another.

To be able to differentiate whether a classifier is person-dependent or not, the following study is proposed: test classifier performance with the same participants in two interaction settings. Participants in the first study would participate in the second study, and user behavioral data would be collected in the second study. The study would test machine learning classifier performance of the first study with second study data if both experiments were run with the same participants. Another connected study would work in the opposite way: Participants in the second study would participate in the first study while user behavioral data would be collected in the first study. Such a study would test machine learning classifier performance of the second study with first study data if both experiments were run with the same participants.

6.10. Development of Virtual Contexts for User Interactions

6.10.1. Use of UI designs connects designed independent actions to one another

Every use of UI designs causes users to order UI designs in time and create a relationship between them. Users may need to be simultaneously dealing with various problems, so the connection between UI designs is set up from the requirement of interaction with a single object in natural context, but it is due to a mix of manageable action components of different tasks belonging to interaction with multiple objects in the context. This means that the connection rule is not based on interaction with objects in the natural context, but is instead based on users' requests and constraints at the time they are needed.

With respect to natural interaction, a new human interaction model created via UI designs is dynamic, and a connection between UI designs exists only until the time they are needed by users. When users do not need them any more, the connection will begin disappearing in terms of losing connections between UI designs.

6.10.2. Users create internal contexts to complete requirements of their interactions

6.10.2.1. User virtual context is different from human natural context

User context is different from human context. User context is an actively created virtual context to help users to perform their tasks. Human context is static when compared to virtual context, and all natural, man-made, or artificial objects share it. The order in time creates an interrelationship or connection between UI designs. The rules for bringing together UI designs provide the basics for creating a context for human actions.

If this context is created based only for user wishes, and users' actions are considered independent from their natural contexts, the new context will be a virtual context created to help users deal with everyday challenges at the time. Context can be understood as an abstract group-forming rule, showing dependency between actions. Dependent actions will come together, create a group, and show a complex action, and that group (complex action) will be dependent on another group (complex action) at the same level.

6.10.2.2. Dynamic user context creation

Figure 34 shows how user context can be modeled based on the principle that actions in an interaction are independent of one another. Typing action includes multiple touch actions considered to be independent from one another. Typing behavior is dynamically created at the time when a user is dealing with the implication of user touch interaction designs on user verbal interaction. The thing that brings independent touch actions together is the user requirement to communicate their messages. When the user is finished, the independent actions would be free, and in the next typing action, other independent touch actions will be brought together. The existence of multiple touches as part of the complex action at the top level ic present for only a short time, and whenever individual touches are required for other user tasks, the connected view of typing actions with multiple touch actions will disappear.

6.10.2.3. Mental models of action, and virtual context

These types of virtual contexts are different from natural context in several ways: user virtual contexts are temporary and artificially build-up environments or settings to help users achieve their goals in timely fashion. The virtual context provides an embodiment of users' intelligence via selected actions and helps users visualize their messages in some form with the help of selected actions. In other words, the virtual context enables a user's mind to turn feelings into manageable and understandable discrete forms and perform mind-based operations such as comparing and contrasting information.

The embodiment of user messages can be called a conceptual or mental model [11], helpful in management of everyday tasks. The model shows how steps of action to be performed are related to one another. The virtual context could be thought of as the connection among the actions of user interaction. Both actions and connections between actions create the model of user action that can also be called a user interaction.

6.10.2.4. Temporary contexts created for user tweeting activities

Referring to Figure 34, in the context of user typing activity, while two typing interactions following one another are similar to one another when looked at from an outside view, because of the underlying assumption about action independence from natural context, two different virtual contexts are created for the two typing interactions.

6.10.3. Adaptation problem: human versus technology

Figure 35 shows that a change in user behavior due to limited design features can cause a change in human behavior. Referring to Figure 35, there is an invisible competition between human and user in terms of adapting to a new context or preserving previous human skills. A user represents a person who will be interacting with UI designs. Norman mentioned this challenge in terms of whether humans should adapt their activities to UI design rules, or vice versa[1].

With every typing activity on computing devices, the negative aspects of verbal UI design influences different aspects of human activity and, at the end new user action skills become independent of one another, so every experience results from current contextual conditions and is not repeatable. Situation-specific user responses are due to design challenges, and because users have situation specific responses, emotion recognition tasks are also situation-specific. The main challenge is with UI design and its influence on human action skills.

The effect of design spreads from low-level action designs to upper-level action designs and every user action is independent of all others compared to human actions that are dependent on one another. The direction of change in human skills is from expression (i.e. body actions) towards action response, creating a possible risk to influencing future action skills.

6.11. Future Challenges in the HCI Design Field

6.11.1. The underlying assumption of the UI designs should be corrected

These results show that while learning tasks work inside a context, outside of the context, learning tasks are not working at all, so virtual context rather than external context should be considered in terms of the dynamic connection between independent actions depending on users' timely needs.

The problem with generalization of performance of learning classifiers is due not to the contextual adaptation of the learning models, but rather to the understanding of independent actions in natural context, and how that action independence causes creation of unrelated contexts. The contexts are virtual, they mentally exist, and they are dynamically built up based on requirements from users' timely needs considering the influence of all other tasks that users may have to do.

Recognition studies are about learning user features based on the use of previous experiences. Recognition is based only on current single experiences in given contextual conditions (internally and externally), and under such conditions, because humans may be confused by the design, any probabilistic classifier based on previous experiences would not produce an ideal solution. Because contexts are temporary and not dependent on one another, any recognition in a context will not be transferable to other recognition tasks in another context. On the other hand, if the emotion recognition method of this study were to be applied to human actions in natural context, the solutions would likely be transferable between different contexts.

Referring to Figure 35, analysis of user texting activity would normally be enough to recognize emotion, but typing activity is different each time based on design effect. Typing is based on situated user action response depending on the influence of the design on user need, value, and goals. Because it is unexpected, each experience would be different in terms of feeling different based on influence of different sections of the human action hierarchy. To achieve general emotion recognition in every external contextual condition, the design problem influencing human internal context should be solved or else no reusable action and experience would be possible for users, and recognition tasks would be solving the emotion recognition only under current conditions. Because of this, the big challenge ahead of UI designs is to complement missing states of design and to give UI designs a dynamic switch between UI designs based on human interaction with contextual conditions.

The underlying assumptions related to interaction should be revised and turned into those dependent actions in an interaction. Within the context of this study, if user touch interaction design is re-designed while considering the revised assumption about interaction, the challenge with the transfer of emotion recognition from one context to another will be solved. To accomplish this, an emotion-centered design method would be useful. If emotion centered design is not applied to user touch interaction design to deal with design effects on user verbal experience, deep learning methods may be applied to create learning classifiers directed toward learning every change in users' lives based on previous knowledge about effects of the change on human skills.

6.11.2. Interaction with UI designs causes creation of a mutual component of actions in user interactions

Mutual action in an interaction corresponds to the following concept: If subjects act on objects, then the objects act on the subjects, and actions belonging to subjects create mutual action. In other words, objects' actions are triggered by subjects' actions. By not following rules of natural interaction, a human creates objects by identifying their actions in natural context. This behavior somewhat indicates that humans would like to create an object via picking helpful and usable features and bring them together in the formulation of an object in the context. This object becomes a cognitive artifact of the human mind, and it is a computing device designed with UI designs. UI designs are based on the understanding of independent actions and that supports choosing features from nature based on users' wishes.

CHAPTER 7 DISCUSSION

This section first discusses the emotion-centered design method, followed by action and interaction models. It also discusses limitations of the study and suggestions for future research.

7.1. Emotion Centered Design

HCI design predicts the development of user activity, representing an embodiment of influences that users have. Humans need an action design to achieve their goals and/or intentions. User-centered design is based on collections of contextual behavioral data from different users who share similar contexts and/or contextual conditions.

Designs can miss connections between user actions, and this tends to increase design complexity. To overcome this challenge, user activity, embracing multiple actions and their sequences, are explored for real contextual data and, depending on identified actions and the sequences, the design is prototyped and tested until user satisfaction is achieved. Both UCD [1][2][3] and ACD [1][4] methods can be used for the design of user actions under both simple and complex conditions, but these methods do not cover the mutual relationship between people communicating with one another. The DesignX [15], [16] method has been proposed to deal with the challenge of dealing with sequences between two people.

An underlying assumption is shared by these design methods above, i.e., the independence of actions within any contextual interaction allows to think that users of computing devices can change states of the devices, but that devices are not able to change states of the users. Because present interaction modeling is based on modeling one-way influence, from the users to the devices, single-state designs are generated that are unresponsive e to changes in the users' contextual conditions, and this forces users to change their behaviors. Users should decompose or serialize the complex action skills gained from their interactions within their natural contexts. Since such action skills are oriented toward command and control of the devices, they will have a relatively set of simple actions when compared to early action skills. This effect may not be visible in the skills of a homogenous group of individuals, but if action skills of people from different generations are compared, it would be more evident as people from newer generations will develop their action skills within the context the earlier generation created for them. Other implications of the present interaction modeling are as follows: Users regroup or synthesize decomposed action units based on requirements of current user tasks, generating new stories in terms of ordering different actions based on requirements of the users' present tasks. New UI designs will be developed with various features enabling them to adapt to the present states of users, but the designs may miss having design states applied for different contextual conditions of users, and users may feel they are alienated from their natural contexts in terms of exclusion from activities applied by the user in space, time, and social aspects of the natural context Finally, rules of user communication will change as they are built up based on previous conditions.

Current design methods put users and theirs need in the focus of interaction design, and this causes singularity in design that removes states of designs considered to be unrelated to the requirements of users' present tasks, providing improved features that will compensate for challenges users feel when interacting with the natural context through UI designs with single states. Both user experiences and features of the devices are thereby improved. A feature-based design method can be adopted from industrial design applications, covering the design of static tools that do not interact dynamically with their users.

Emotion-centered design connects users to contextual conditions through their emotional states and provides designs with multiple states to meet every change in user contextual conditions. Any received actions by the users cause generation of influence, and the users turn this influence into situated actions that show action preferences of the user in different contextual conditions or situations. The emotion-centered design method is based on identification of changes in users' emotional states when they are affected by external events and prediction of next likely actions that users can apply in present contextual conditions. When users change their context, the design will have multiple states and multiple responses and dynamically identify a user state to choose s related design response to s user request. The emotion-centered design method may be applicable not only to HCI designs, but also to product design in other fields such as mechanical design and industrial design.

7.2. Action and Interaction Models

The emotion-centered design method is based on a model of action and a model of interaction. To identify a model of action, findings from related studies, such as types of human actions in contexts, theory of human activity, action cycle during completion of tasks in contexts, and design of user interaction, can be brought together to provide temporary models with some placeholders for main components of the model of action. Those findings are then reviewed based on the dictionary definition of action, "to do something to achieve or accomplish a goal",; an interaction is described as "mutual action or mutual influence". Two actions in an interaction are connected to one another via an influence and action dialog.

An action is developed to turn influence into activity. An action has a goal, cognitive evaluation, and an activity component. Before an action is developed, humans have some type of influence that causes them to change their internal states. Based on emerging results in action and activity research described in affective science literature, a human affect, indicating a change in internal state, is connected to human actions. Based on this idea, a human has an emotion, s/he turned emotion into an activity, and so it can be felt. That feeling is the primitive level of awareness about things happening in contexts.

The action is one of the components of interaction happening in contexts; the dialog between action and influence is set up through a model of interaction. Interaction was previously considered to be a model of human interaction corresponding to the design of human actions. This study complements the missing components of the interaction model: action, mutual action, and mutual influence. The model of interaction not only connects actions of two people in a social context but also it provides identification of people's dependent actions with respect to their initial actions in the context.

The human affect is an influential component of interaction, and action is another component of the interaction. Findings related to the action model can help us identify various issues within affective science such as, for example, description of affect, emotion, affective dimensions, information about nature of those concepts such as just what an emotion is. This study shows that emotions are neural computational objects representing the object of emotional experience. This study also explains many components in the psychological construction of emotional experience.

The study explains the underlying dynamics of embodied cognition and distributed cognition and also gives us information about human memory organization in terms of cognitive or mind action selection and evaluation based on contextual conditions. The word memory refers to previous mind actions and activities, such as procedural memory and episodic memory, and it includes motor programs or skills as part of procedural memory.

Memory recall is related to serial order based on an evaluation of current contextual conditions, and this study supports Tulving's proposition of contextual cue [183] and improvement of memory recalling performance. Forgetting of memory occurs because of missing the evaluation part for complementary components of other states of design. Because of contextual change and challenge with dealing with design, people tend to change their old behaviors and access to old records can become a problem because they don't know how to find the address of old records in memory. Although people may have problems in remembering details of old events, they keep the feeling of being related to an event and that shows us that people would have a different memory for feelings and cognitive functions outputs as activities and actions [75].

Through the help of action and activity models, many human aspects can be explored on different scales. For example, activity, task, action, operation, and expression can be analyzed. Gestures also correspond to all of the movements for communication of meaning. They are types of activities showing contents of a function representing different actions. The model of action is based on turning goals into activities, with the model of a goal broadly the same as the model of current human activity, but in the frequency domain rather than the time domains. By use of the activity model, it is possible to identify intentions or goals of a person in contexts. On the other hand, the interaction model will work for social and/or artificial object interaction.

7.3. Emotion Recognition from User Activity with Computing Devices

User emotions can be recognized from typing activities on smart mobile phones. Users' feeling of valence and arousal demonstrates whether they feel positive/negative or aroused/deactivated. For example, remote TV viewers can understand each other's ideas and feelings while they are watching TV and TV producers and advertisers can function based on viewers' interest. Detection of social media users' feelings helps in monitoring live events on social media. Users report events on social media, and then followers of their social media accounts interact with the reported story or event. In this way, emotion states of both story developers and consumers of the stories could be predicted, and whether stories created would indicate truth related to the reported event could be identified. In addition, followers would be informed in the case where the story is created to provide false information to the followers, so that spreading of that type of attack would be prevented. False news of course means reporting occurrences of events that did not happen.

Previous emotion recognition studies benefitted from the challenges of UI designs by using either advantageous or disadvantageous users' positions in interaction with computing devices. For examples, features of user touch behaviors on mobile computing devices can be used to identify user emotional states, or errors users may make while writing text messages with software keyboards are considered helpful identifying user emotions. User actions are challenged by UI designs based on an underlying assumption about actions in interactions. Previous emotion recognition solutions such as device design, touch activity recognition design, and verbal experience design are design dependent, so all some previous methods will not work after certain times because the underlying context for user interaction is dynamically changing.

Predicted affective dimensions (event predictability, valence, arousal, and dominance) indicate cognitive evaluation output values, and they can be used to identify actions for creating situated action responses in the current condition of human context. Emotions indicate affective evaluation of external contextual conditions and, based on this information, identification of next likely situated actions would be possible. For example, on a behavioral level, people may exhibit basic emotions such as a feeling of surprise or anticipation, then feeling happy or sad, when they interact with a particular object in the context,. On the other hand, a recognized feeling of emotional state provides information about what users experience internally, and this are reflected in users' behavior. From that aspect, the design method helps provide user experience with design.

7.4. Identification of Human Activities' Models

7.4.1. Model of user activity with computing devices

To recognize emotional state of users, models of the users' verbal activities can be identified with the help of an action model. After models of the users' activities are identified, the model could be used to set requirements for UI designs. Activity models could also be used not only for emotion recognition but also on other research problems focusing on recognition of users' attributes from users' activities.

UI designs must have input information about models of users' activities in users' contexts. The information about how the users did activities in the contexts is based on estimations that use statistical evaluation of contextual user behavioral data. Models of action will fill in missing knowledge in HCI, computer science (CS), and related fields.

7.4.2. Model of user learning of how to use computing Devices

During development of situated actions, people evaluate results of user actions at three main levels: sense, perceive and interpret. Each of these evaluation steps is complex, and they include three internal steps. The model of user cognitive evaluation function of sense is also developed as a 7-step process on collected user data features. The sense function model may help us to design better machine-learning algorithms by providing us a cognitive learning method useful for identifying objects and features of the objects in contexts.

7.5. Limitations of the Study

7.5.1. Modeling user physical interaction with computing devices

The computational model of user typing activity only covers parts of real user behavior, and various parts of the model are not included in the analysis. The following gives information about limitations of the model.

a) **Studying Single Dimensions of User Actions**: This study considers only the serial feature of user actions, and its serial aspect may be related to predictability aspects of human action. Predictability corresponds to motor aspects of content features and fast/slow aspects of form features. On the other hand, being serial may imply even versus uneven aspects of human activity that may correspond to parallel versus serial nature of user activity. Being even means that user activity follows a serial order while creating the activity. That is explored via an action template using three operations. An action template with two operations covers general actions that have features or characteristics that are not serial.

Being uneven means user activity development reflects selection of actions based on user evaluation of current contextual conditions. This is related to user's contribution to development of activity. Users make changes in the development of the activity to influence their behaviors; this is related to individual characteristics of any user behavior. Other dimensions of human action such as valence, arousal, and dominance, should be analyzed,. They correspond to fluidity, energy, and power with respect to content dimension, smooth/jerky nature, and large/small with respect to forming dimension.

b) **Some actions are missing in the extraction of the model of user typing action**: Identification of initial touch action and final intention of the user typing action model are not included.

c) **Some features of actions identified as part of creating user typing action are missing**: Future research on the extraction of features of user activity might focus on identifying what statistical measurements should be proposed to unaddressed dimensions of user action.

7.6. Suggestions for Future Research

Previous design approaches are based on the assumption that actions in interactions are independent of one another. The methods are useful in designing for individual user interactions, but the design of an interaction between two people or objects in contexts is affected by this design view, i.e., user action skills based on frequent and multiple interactions with the same object or entity are affected. In the current design view, user actions dependent on an initial user action in a context are considered to be independent from one another, so the user will not develop new skills applicable in a natural context but will be able to use devices to perform tasks in the natural context. In other words, use of the device for daily tasks will not be the human preference, but it will be the only way to survive in the world.

To provide transfer of dependent actions to initial actions, an emotion-centered design method, by providing a connection or dependency among the actions in interactions, would be helpful. To achieve this goal, the next step in this research would be in the direction of dealing with reducing the effect of misaligned HCI designs. There are two aspects of this new research direction: How to correct previous misaligned HCI designs or, and then How to repair human skills adapted to misaligned HCI designs.

CHAPTER 8 CONCLUSION

This study proposes an emotion-centered design based on two models of action and interaction. The design method selects which UI design is required under what contextual conditions based on influence via user evaluation of contextual conditions. The influence is mainly to use user emotional states in a given contextual condition with emotions helping the design decide what actions users are about to choose as behavioral responses to events in external context. The design method is grounded in two main models: action and interaction. The action model shows how influences are turned into activities, and the interaction model shows how activity influences others in the same context as well as those preparing to react to the received action from the context. The implementation of the design method is illustrated using a user verbal activity design problem. User emotions are recognized from user activities with mobile devices. The emotion recognition method serves not only to recognize user emotion from general user nonverbal activity with the device, but also from user texting activity with current contextual conditions of verbal design and its many interaction design challenges.

By using the design method, improvements in many fields could be possible. Examples would include problems in automatic recognition, automatic personal user interfaces, agents, artificial-intelligence social computing, mobile computing, wearable computing, activity recognition, gesture recognition, behavior recognition, and internet of things (IoT) by connecting artifacts to people, doing ubiquitous and pervasive computing, and development of intelligent interfaces. Some examples are given below:

Previously personal computing has been made possible through addressing the most common and typical needs of users. Observation of repetitive interactions can be used to create units and build new things onto previously built units. Specific or idiosyncratic requirements of large numbers of potential users remain unsupported. Users of designs will become average users, and less skilled people will attain better skills via the designs. More skilled users may become only of average skill depending on how much they interact with the designs. By using emotion-centered design methods, identification of user subjective states and individual activity patterns could be performed and Individual differences in human activity might possibly be identified through use of action and activity models, with the design method demonstrating how to develop user interaction designs. UI designs could become personalized based on individuals' specific needs.

Through implementation of this new design method, design companies could obtain reasonable returns on their investment efforts as mobile and wearable devices and software could be designed based on user needs. User specific operating systems and device designs based on user needs are possible. User emotional states provide a human computer interaction platform between devices and users, and this interaction could be advantageously used in terms of turning user intentions to design of Internet of Things (IoT) applications.

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APPENDIX A: IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 9/6/2012

To: Kiraz Candan Herdem
1620 Howe Hall, 2274

CC: Dr. Julie Dickerson
3123 Coover Hall
Dr. Veronica Dark
W112 Lagomarcino Hall

From: Office for Responsible Research

Title: Study of Relations between Mobile Phone Usage and Emotions

IRB ID: 12-414

Approval Date: 9/5/2012 **Date for Continuing Review:** 9/4/2014

Submission Type: New **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

FIGURES

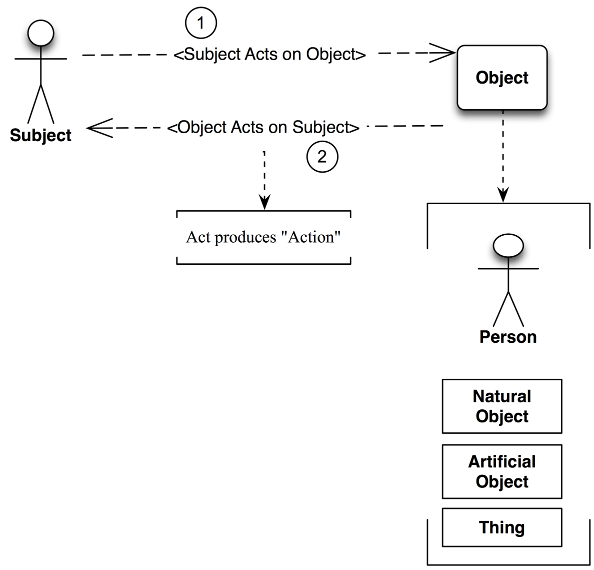


Figure 1: Interaction as mutual action

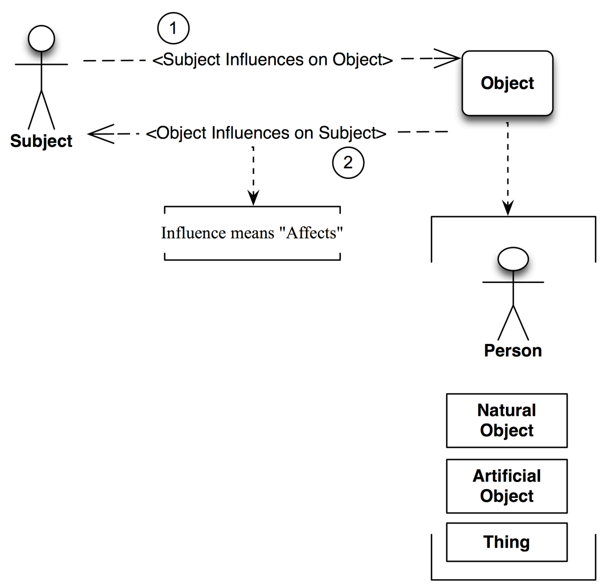


Figure 2: Interaction as mutual influence

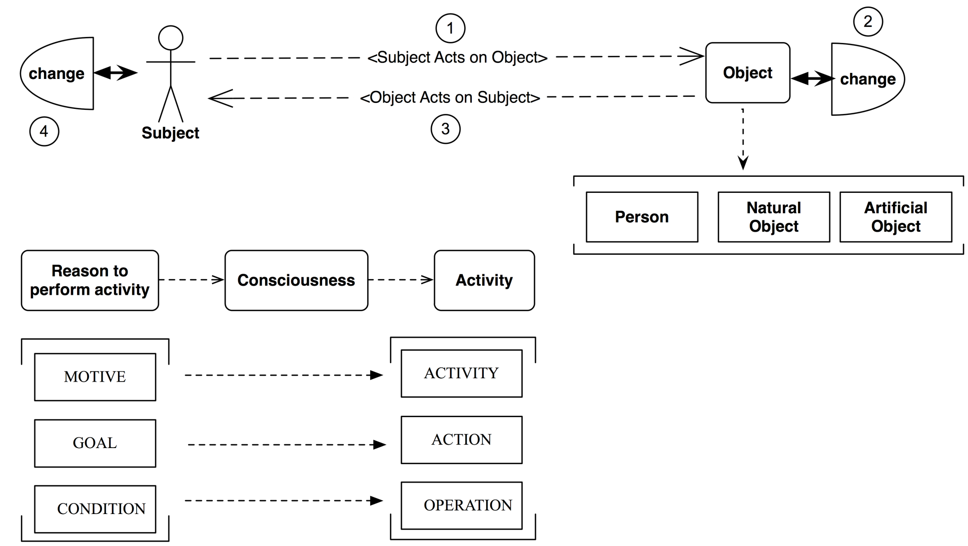


Figure 3: Development of everyday interaction between subject and object based on activity theory

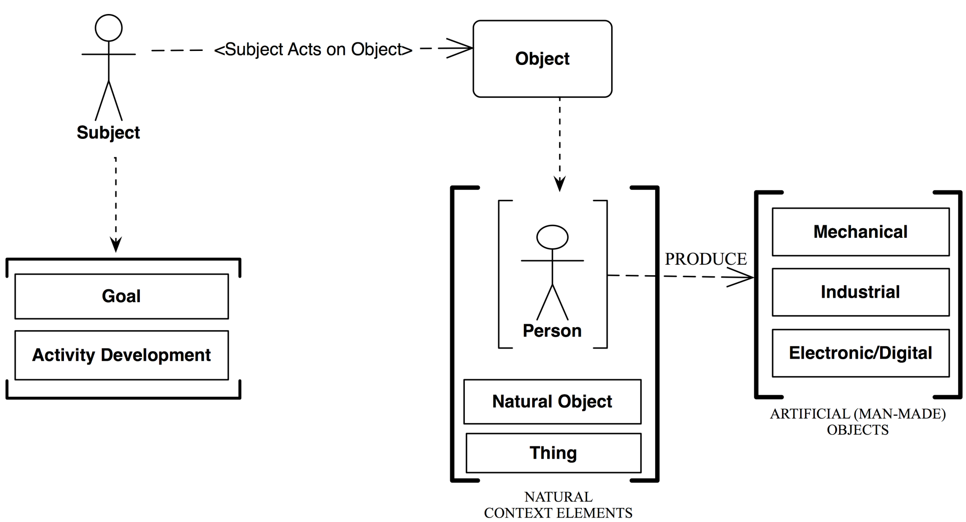


Figure 4: Initial assumption of interaction studies: subjects' actions are independent from objects in the same contexts

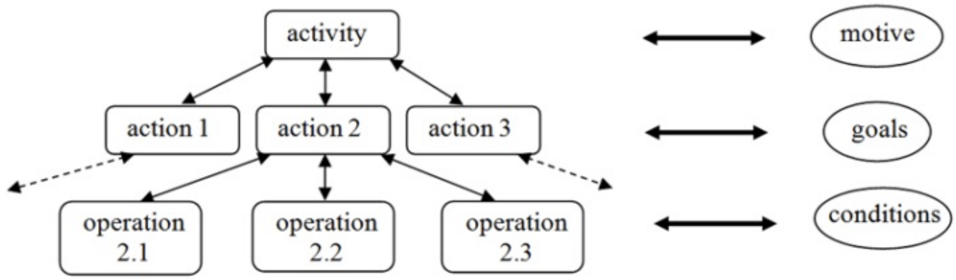


Figure 5: Hierarchical structure of activity and reasons for activity development[19]

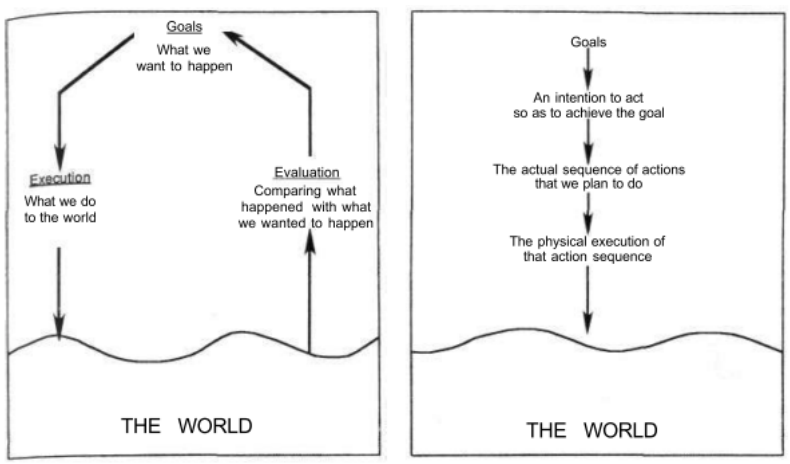


Figure 6: Cycle between goal, execution of action and evaluation of action[10]

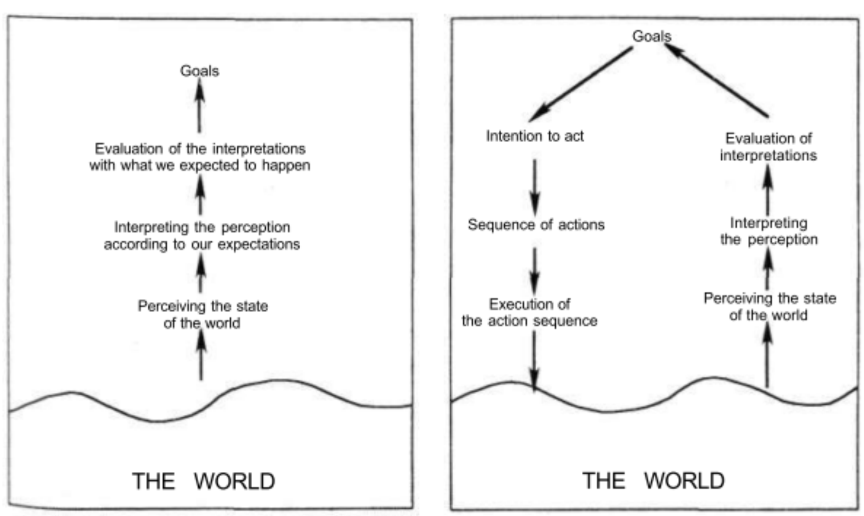


Figure 7: 7 steps of action cycle[10]

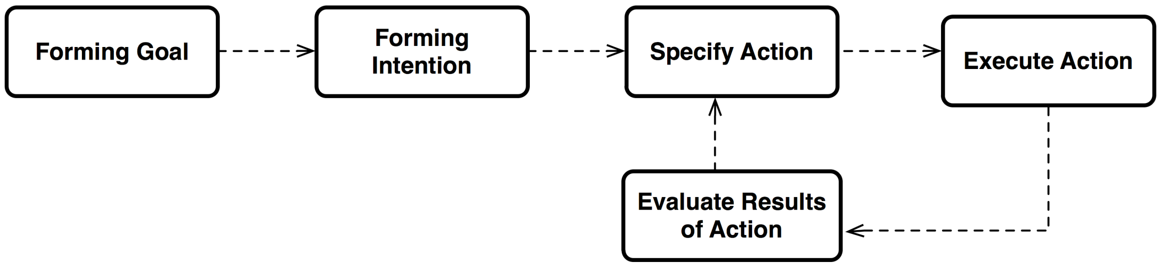


Figure 8: Running steps of the action cycle to develop human action response

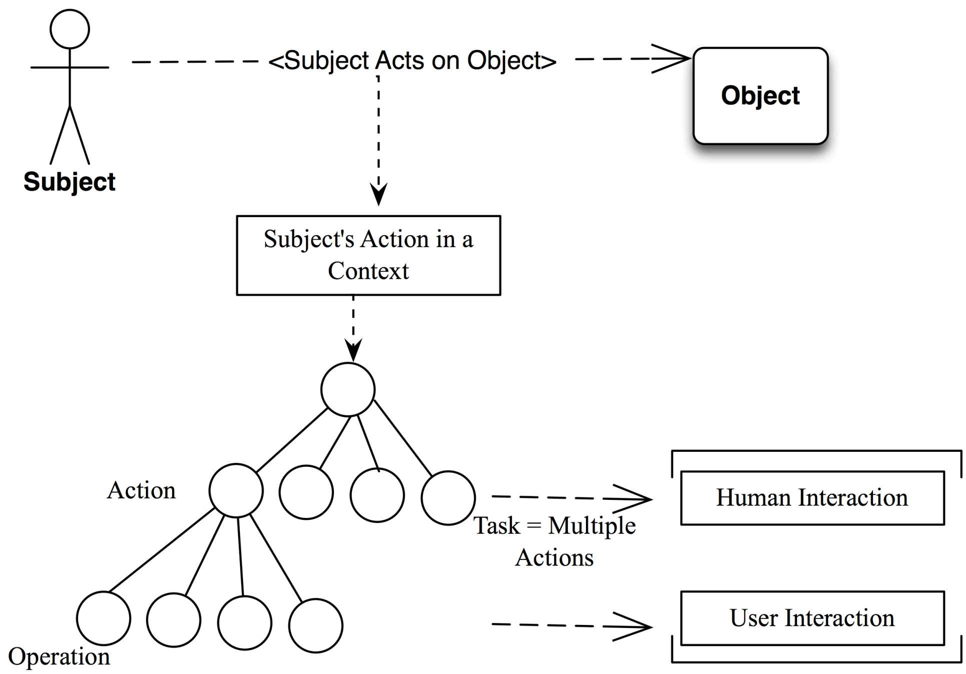


Figure 9: Relationship between human action, human interaction and user interaction

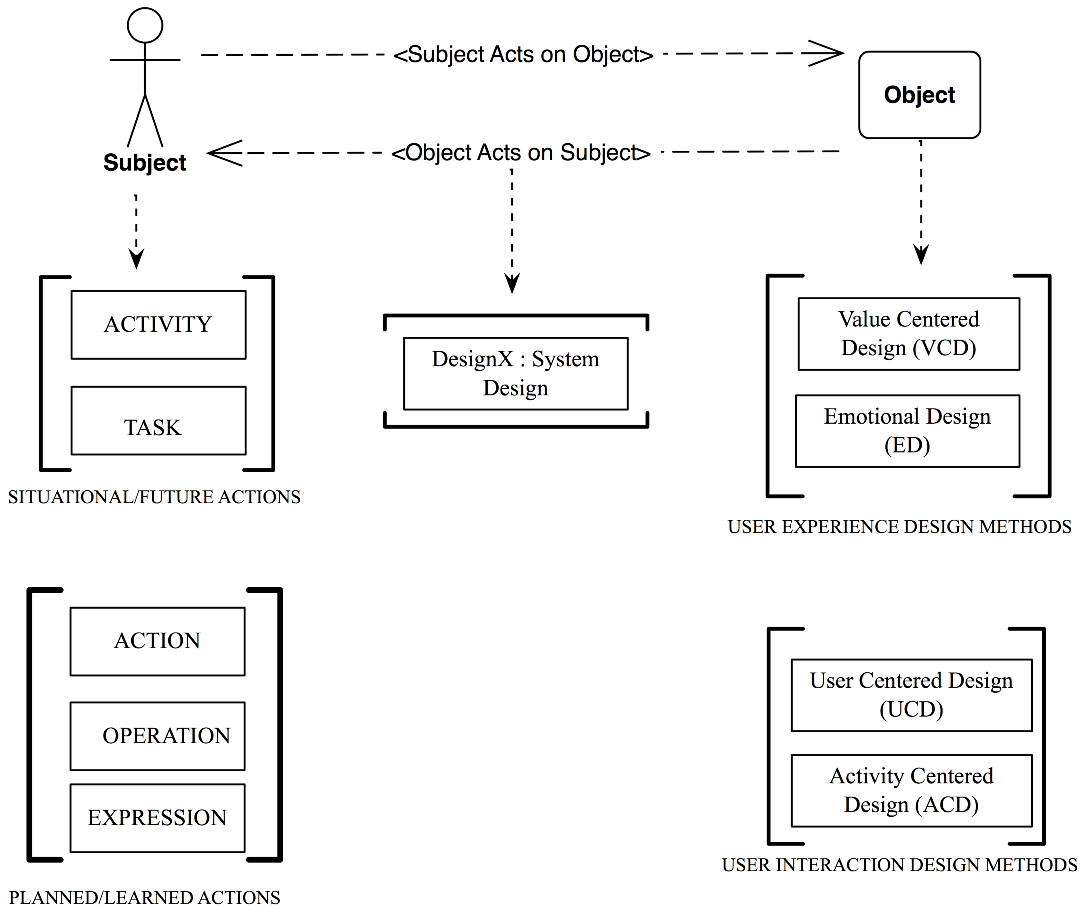


Figure 10: HCI design methods developed for modeling human activity and interaction

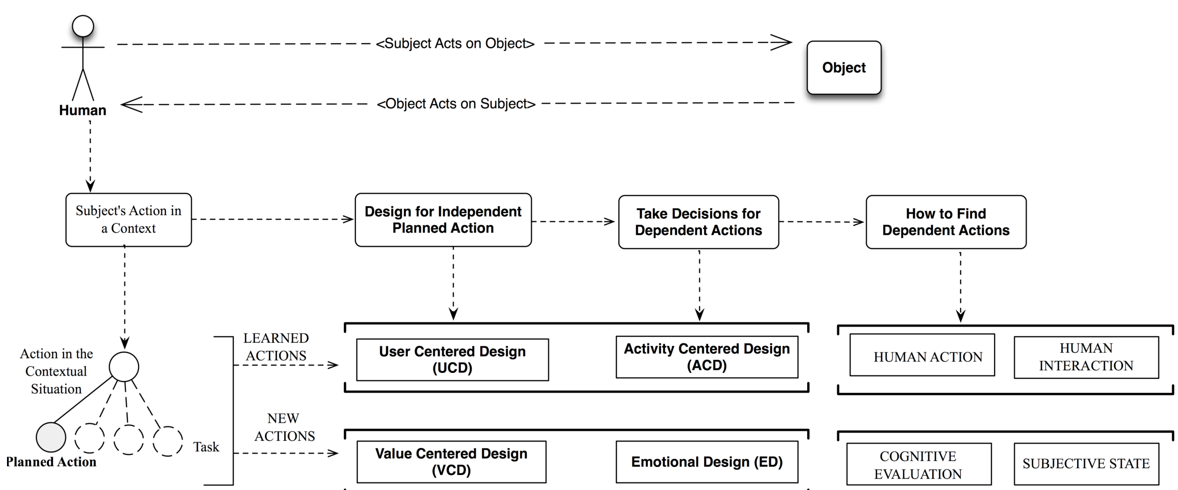


Figure 11: Human computer interaction design for independent and dependent human actions

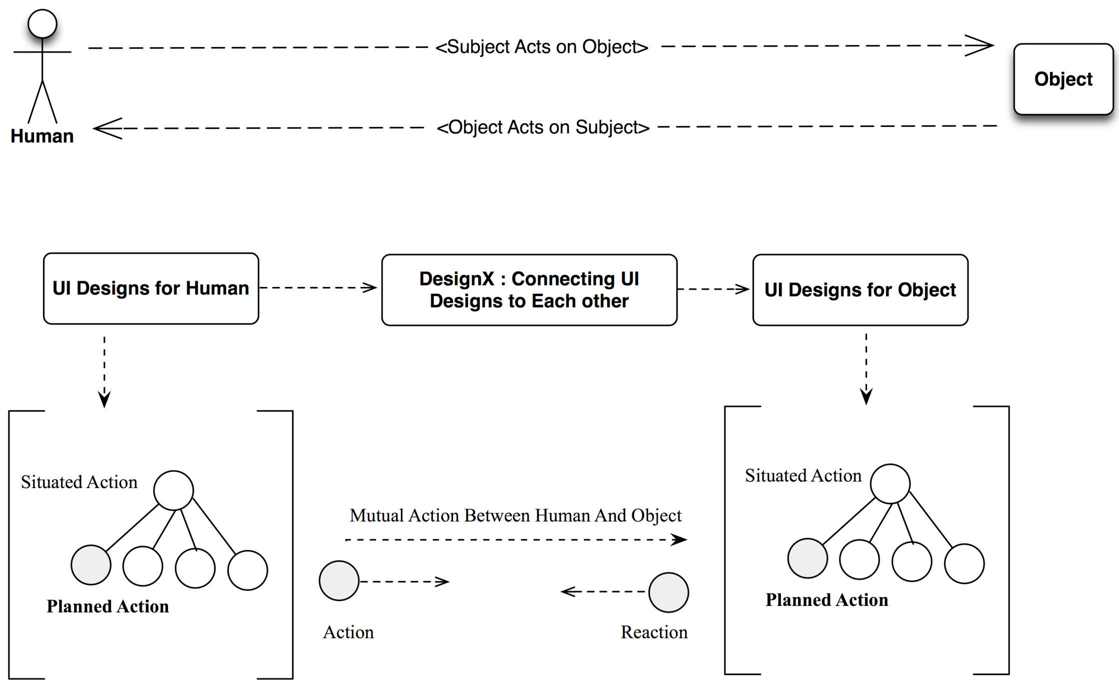


Figure 12: Development of designX method: connecting independent action designs to their contexts

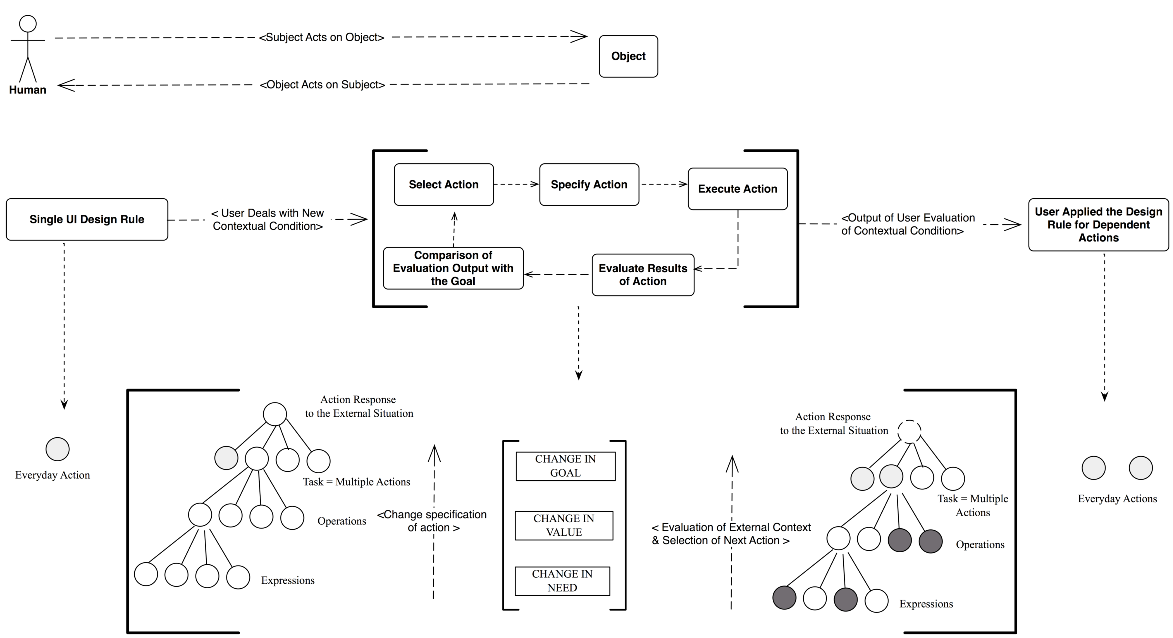


Figure 13: An example to users' adaptation to UI design rules: users apply the design rule for the second dependent actions

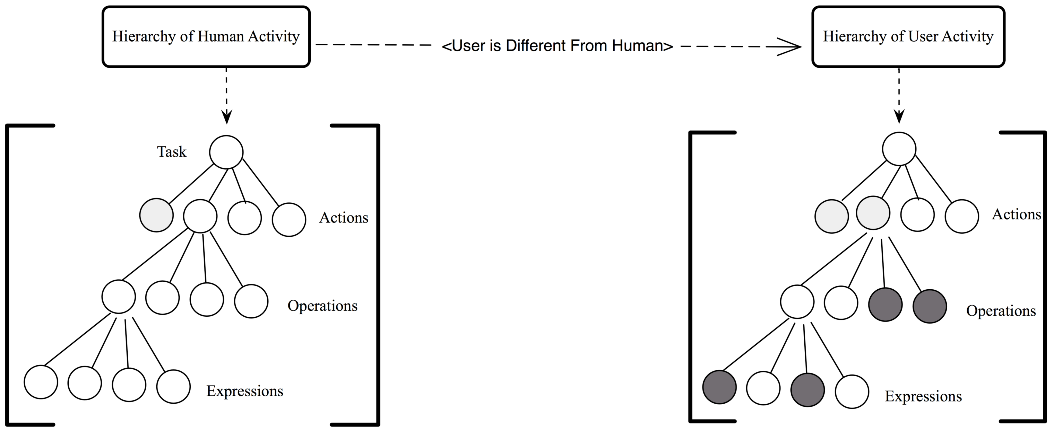


Figure 14: Situation after users interact with UI designs: user activity is different from human activity

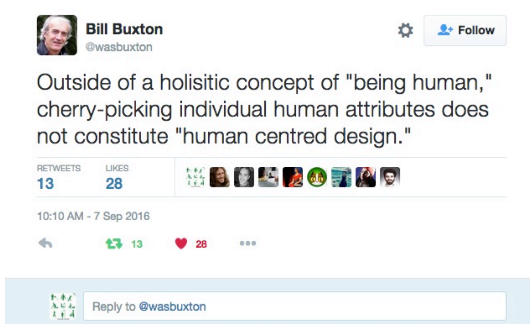


Figure 15: Buxton's view about HCD method: human centered design view is based on picking features of human attributes

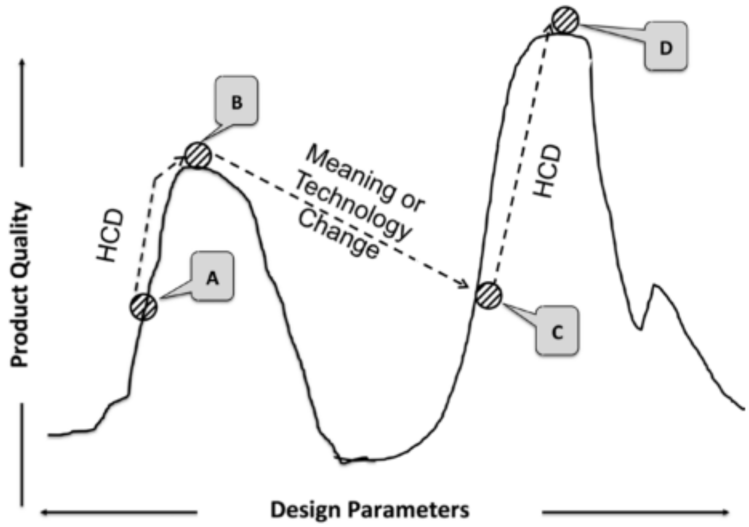


Figure 16: The hill-climbing paradigm applied to incremental and radical innovation[22]

Figure 17: Buxton's view about HCI designers and researchers reflection of their holistic views about human

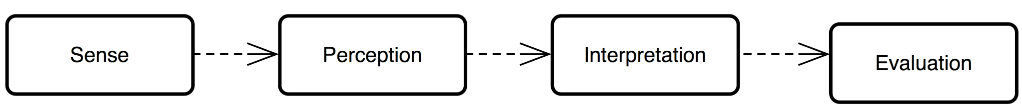


Figure 18: Cognitive functions in an evaluation cycle: sense, perceive interpret, evaluate

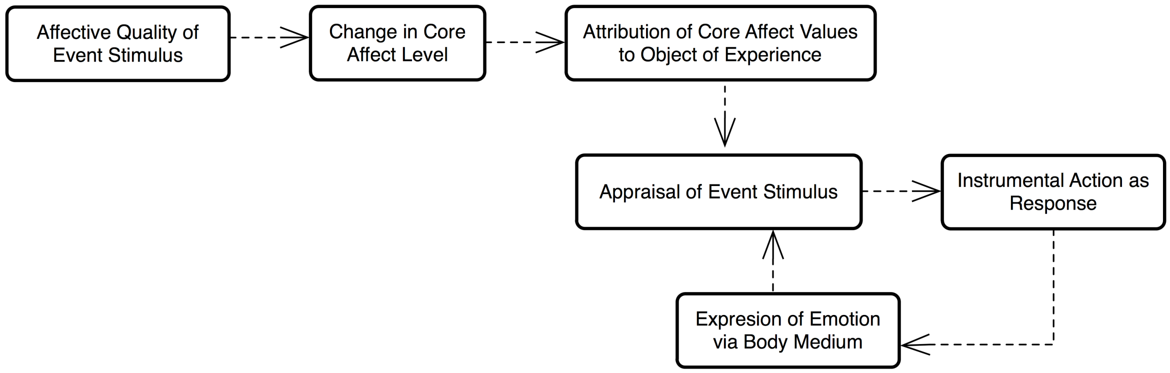


Figure 19: 2 times of evaluation during an emotional experience

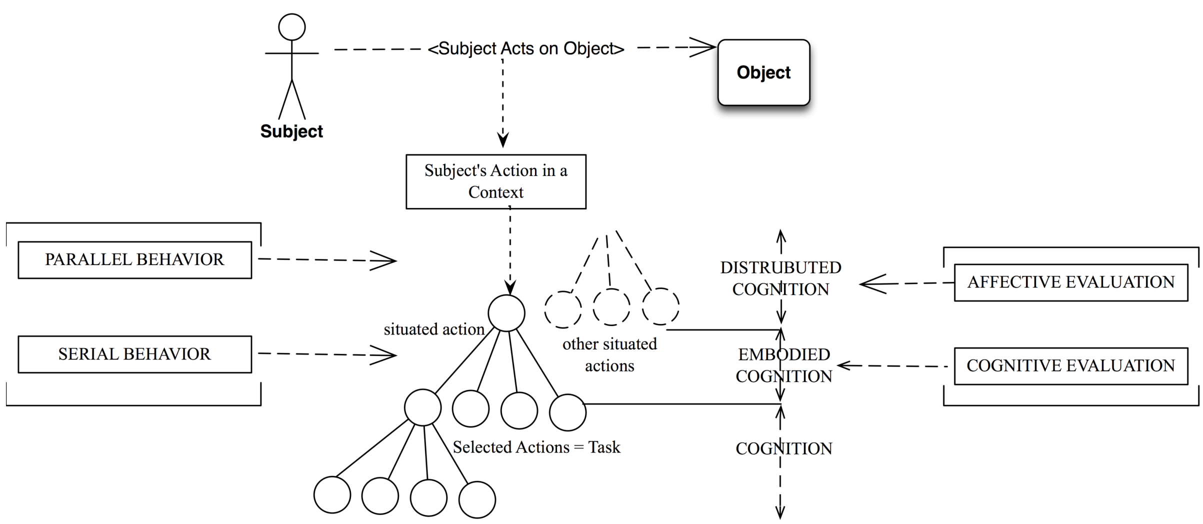


Figure 20: Development of a situated action via two consecutive evaluations and development of serial, parallel behaviors

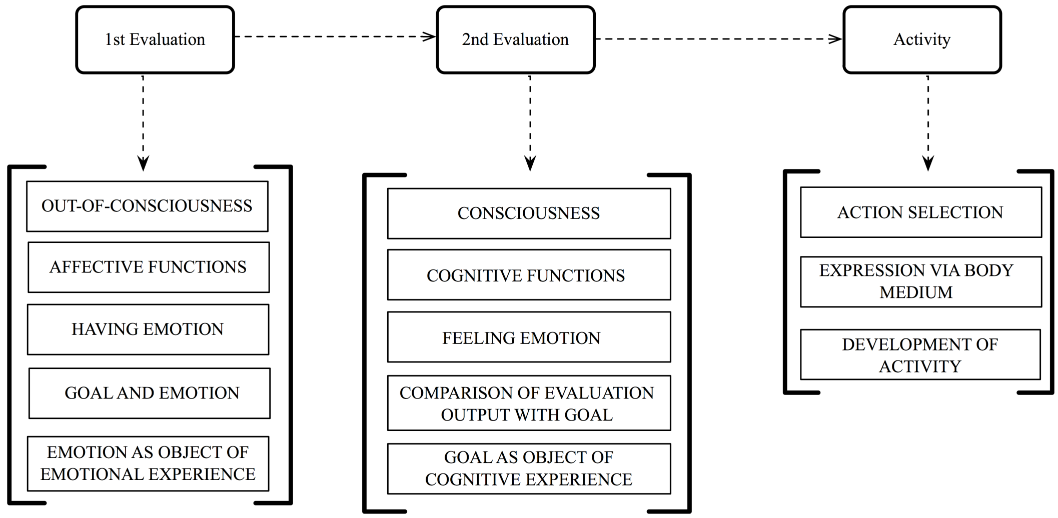


Figure 21: Main steps of two times evaluation during development of an experience

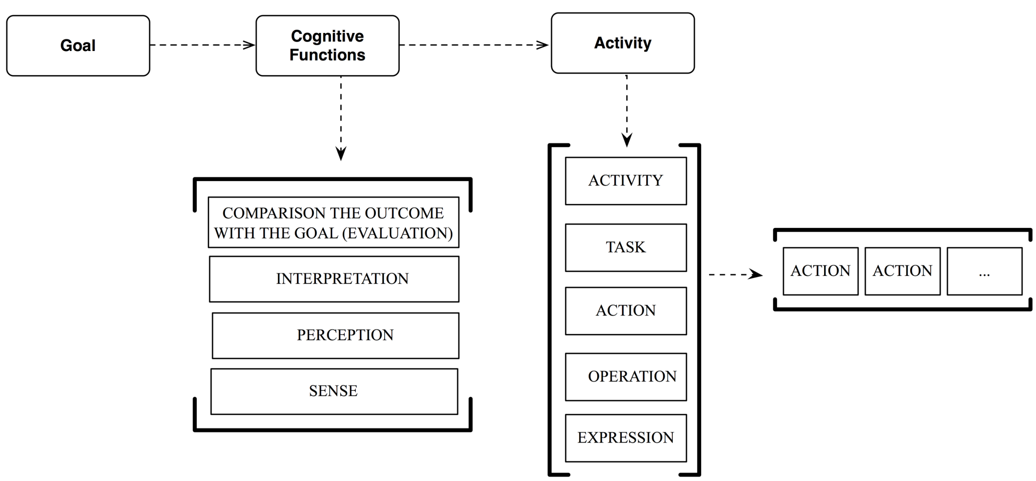


Figure 22: Developmental steps of creating an action response

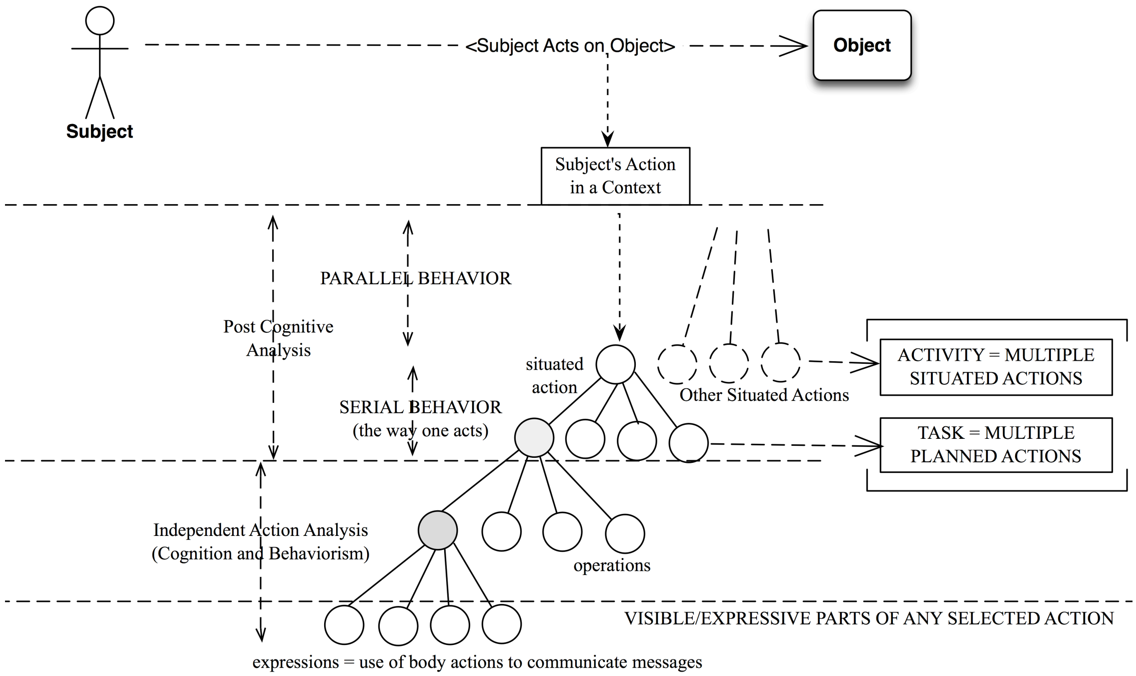


Figure 23: Detailed view of a situated action developed to achieve a goal

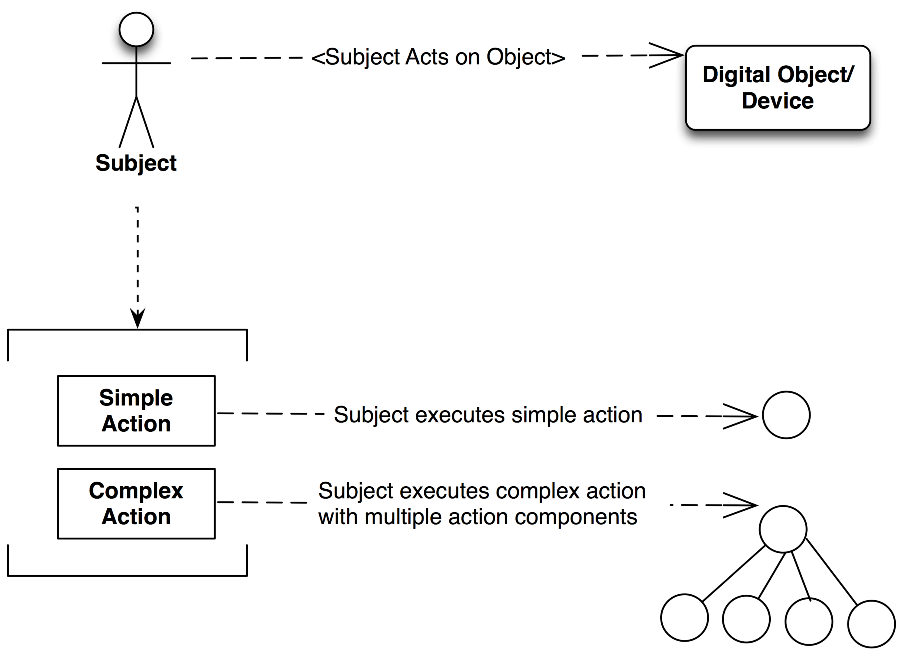


Figure 24: Implementation of simple actions versus complex actions while interacting with digital devices

Step 1: [Action]

Step 2.1: [Intention, operation]

Step 2.2: (Continue until all operations are covered),

Step 3.1: [Expression (equals to content of operation)]]

Step 3.2: (Continue until all operations are covered)

Figure 25: Pseudo code for identification of execution order of an action

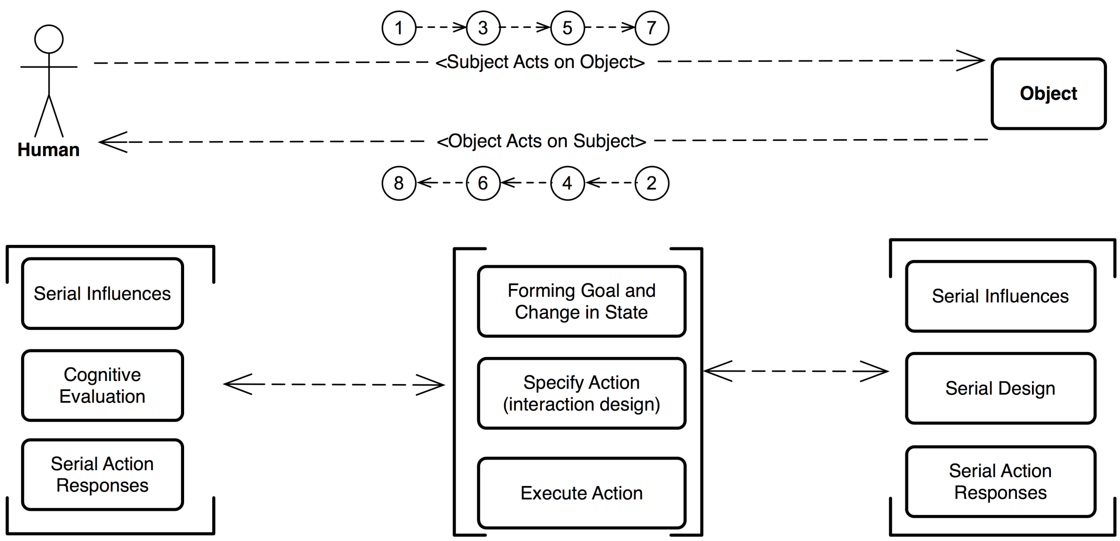


Figure 26: Steps of an Interaction: dependent actions, mutual actions, and mutual influences follow each other

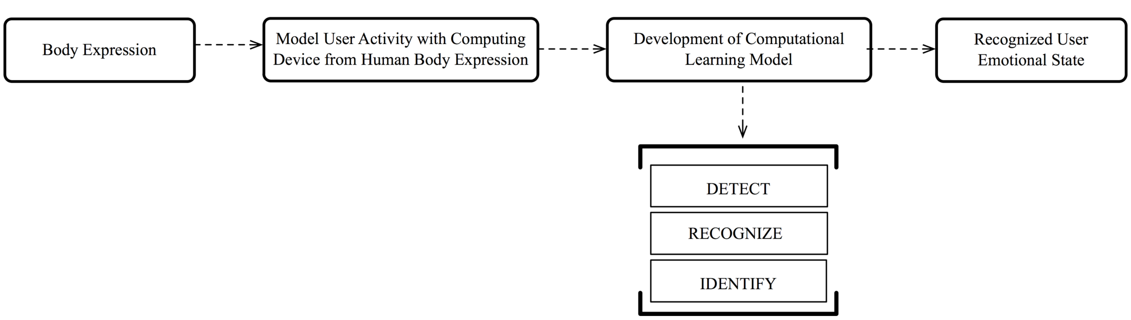


Figure 27: Step-by-step implementation of emotion recognition method

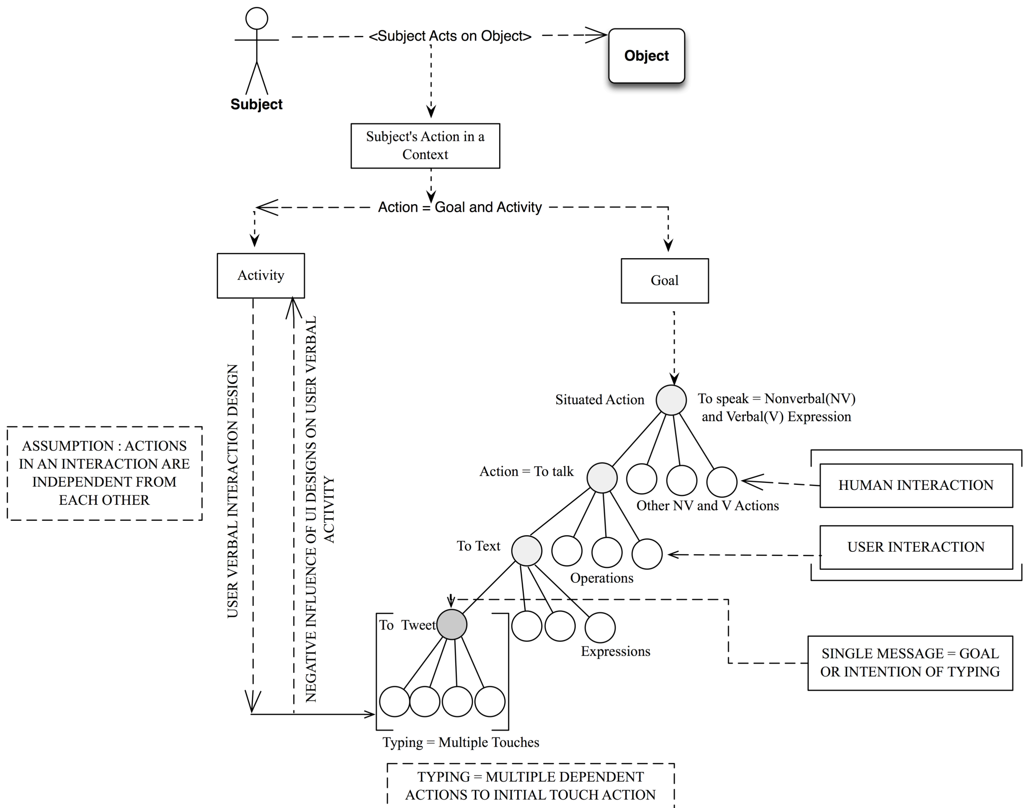


Figure 28: Steps of user verbal interaction design: how the previous UI design rules negatively influence development of user verbal activity structure

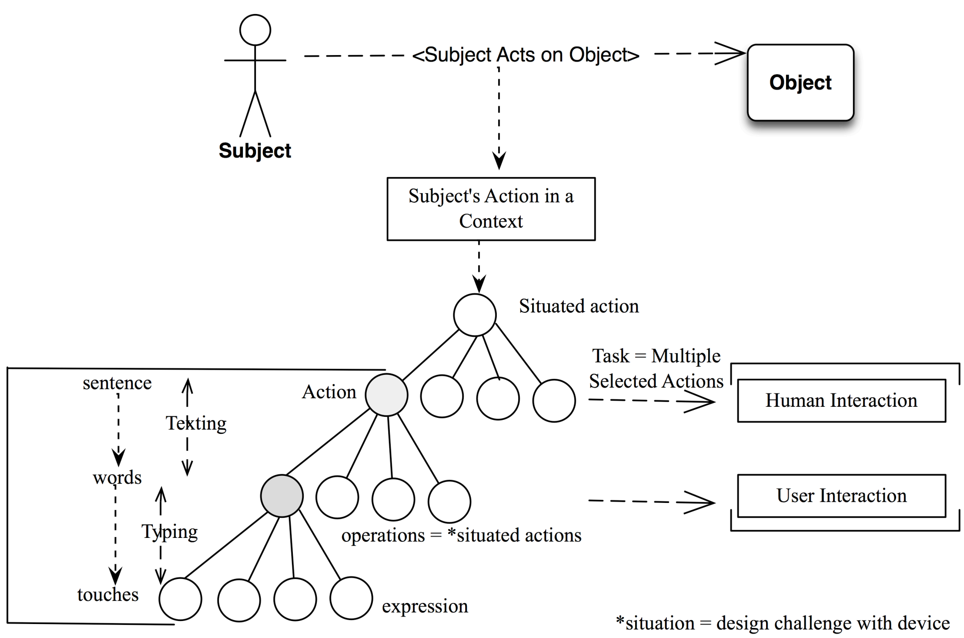


Figure 29: Basic steps of generation of user verbal responses with software keyboards

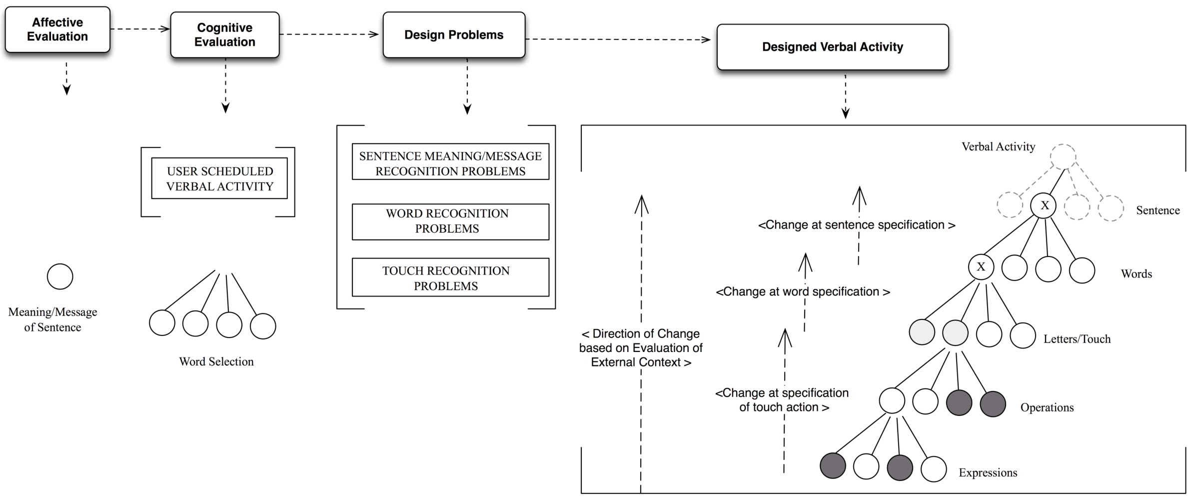


Figure 30: Users agree with the UI design rule for typing letters: The users would like to reduce the effect of the design on their verbal experiences

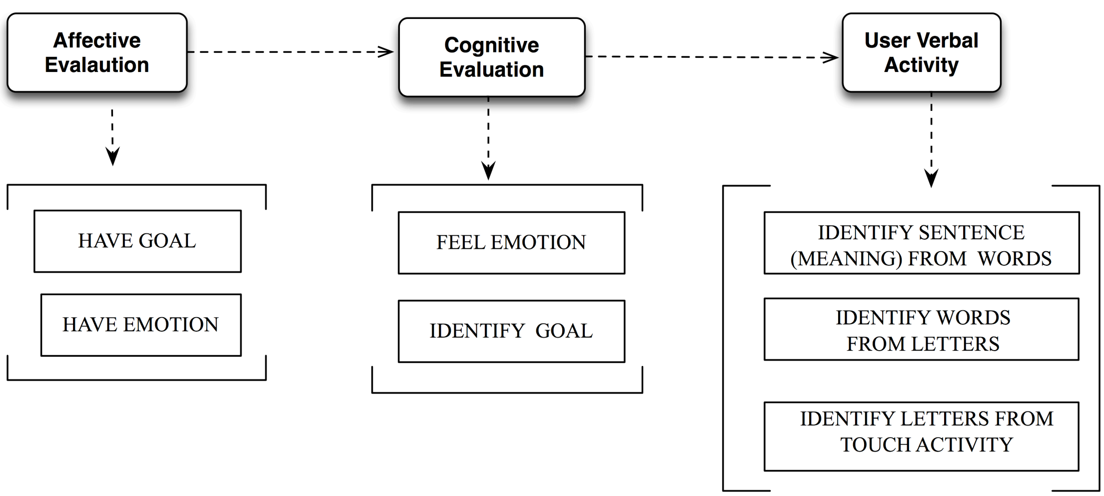
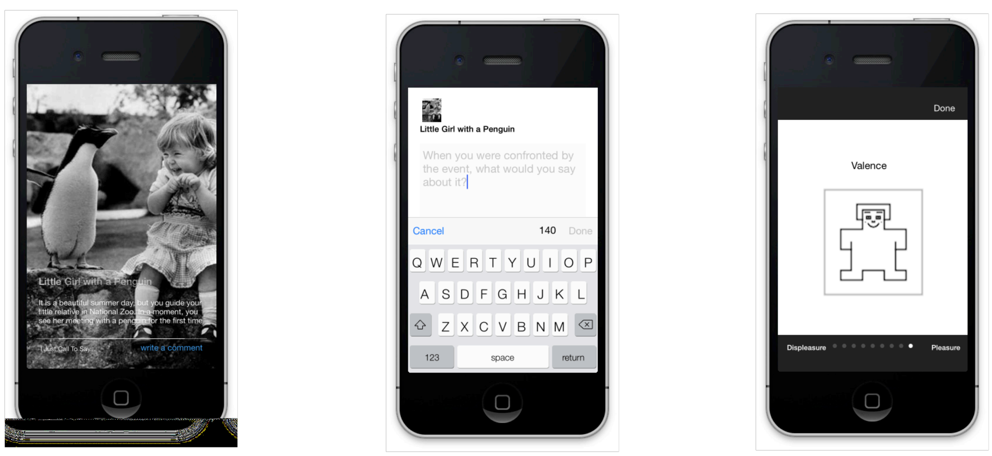


Figure 31: Some of the research problems within verbal UI design field

a) Typing tweets b) Press on “finished” button d) Press on send button to send tweet c) Emotion reporting interface

Figure 32: User interface designs of a mobile app: users express their views about TV contents



a) Interacting With Story b) Creating Textual Content c) Emotion reporting interface

Figure 33: User interface designs of a mobile app: users express their views about multimedia stories on mobile device screens

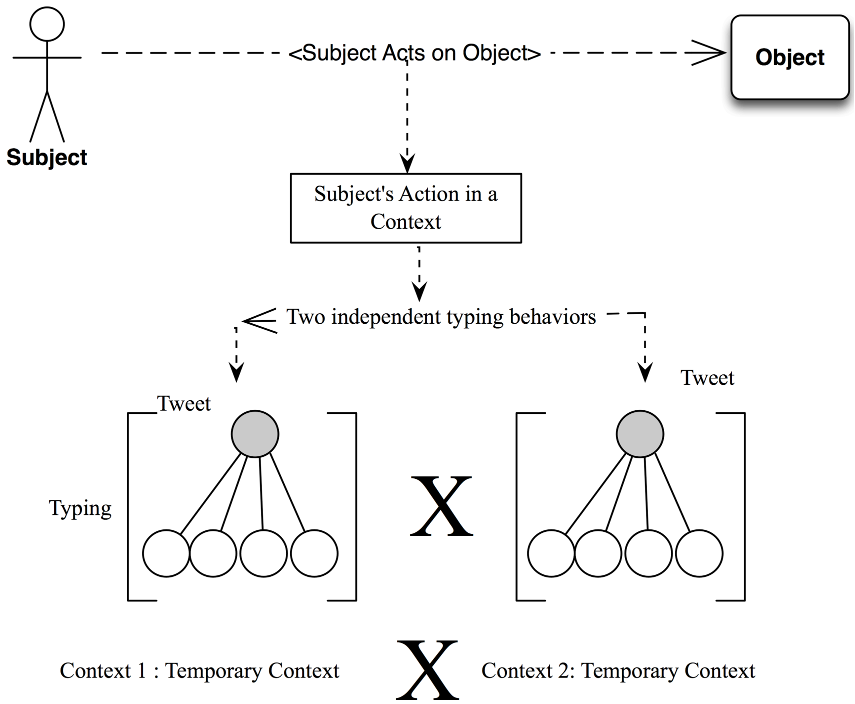


Figure 34: Development of 2 different temporary contexts to help users' typing activities

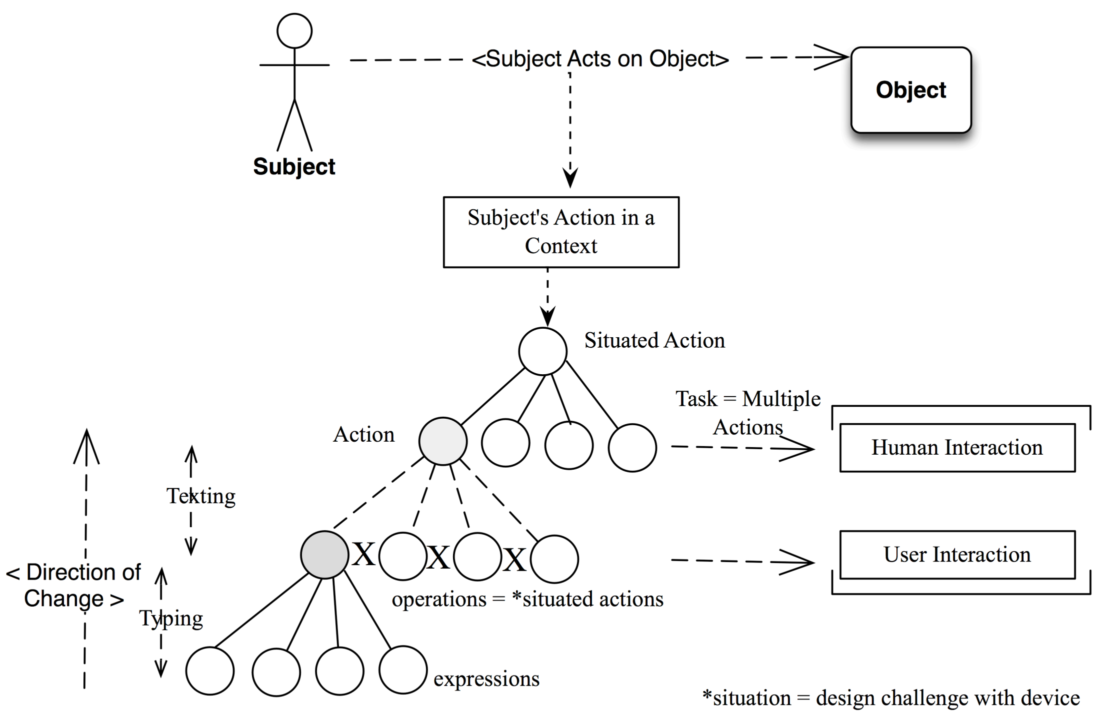


Figure 35: UI design rules individualize dependent actions of the previous context settings from each other

TABLES

Table 1: Identification of actions in the development of complex user activity of texting

Type of Action	**Description**
Identify action	Begin from starting point to end point of action
Identify intention	Begin from first touch starting point to next touch starting point
Identify touch gesture (content of touch action)	Begin from end point of first touch to end point of next touch

Table 2: Statistical features for description of user activity

Content of Activity Description			
Entropy/Automatic	**Fluidity**	**Energy**	**Power**
Entropy	Absolute gradient value	Energy	Number of peaks
Form of Activity Description			
Fast/Slow	**Smooth/Jerky**	**Even/Uneven**	**Large/Small**
Zero cross Mean cross	First order difference	Second order difference	Interquartile range

Table 3: Statistical features for definition of user activity

Content of Activity Definition			
Entropy/Automatic	**Fluidity**	**Energy**	**Power**
-	-	-	-
Form of Activity Definition			
Fast/Slow	**Smooth/Jerky**	**Even/Uneven**	**Large/Small**
- correlation between motion signal axes - Angle between acceleration and rotation signals - rate of change between the two signals and correlation of axes	- absolute value - minimum - maximum - mean - root means squared value	- standard deviation - skewness - kurtosis - higher order moment	- variance - number of local maximum and minimum values

Table 4: Statistical features for description of user goal

Content of Goal Description			
Entropy/Automatic	Fluidity	Energy	Power
entropy	Spectral flux	Energy	Power
Form of Goal Description			
Fast/Slow	**Smooth/Jerky**	**Even/Uneven**	**Large/Small**
- Fourier transform - Area under power signal	Flatness		- Interquartile range

Table 5: Statistical features for definition of user goal

Content of Goal Definition			
Entropy/Automatic	**Fluidity**	**Energy**	**Power**
Band Dynamics in entropy	-	- bandwidth of spectrum - band energy values - spectral roll-off frequency - spectral centroid	Band Dynamics in power spectrum
Form of Activity Definition			
Fast/Slow	Smooth/Jerky	Even/Uneven	Large/Small
- fft/band, - band area under power curve	- absolute value - minimum - maximum - mean - root means squared value	- standard deviation/fluctuation - skewness - kurtosis - higher order moment	- variance/spread - local maximum and minimum

Table 6: Affective TV content in user study 1

Emotional Meta Experience	Stimulus Film and Video Source	Duration	Median Value	Standard Deviation	Mean	Standard Deviation
Happiness	The Lottery Ticket	1’ 06’’	1’ 125’’	0’ 0919’’	1’ 289’’	0’ 3725’’
	Laughing Baby Ripping Paper	1’19’’				
Sadness	Titanic	1’ 56’’	2’02’’	0’ 0848’’		
	Requiem for a Dream	2’ 08’’				
Disgust	Ear Worm	0’ 54’’	0’37’’	0’ 2404’’		
	Manager of a Sport Team	0’ 20’’				
Anger	The Out of Towners	2’ 10’’	1’545’’	0’ 2193’’		
	Five Easy Pieces	1’ 39’’				
Fear	The Day After Tomorrow	2’ 08’’	2’ 075’’	0’ 7072’’		
	Aftershock: Earthquake in New York	2’ 07’’				
Surprise	Inception	1’ 50’’	1’ 125’’	0’ 5303’’		
	Wayne’s World 2	0’ 35’’				
Neutral	You’ve Got Mail	1’ 36’’	1’ 165’’	0’ 2757’’		
	The Terminal	0’ 57’’				

Table 7: Recognition results of user core affect in social TV viewing experiences: classifiers tested with 10-fold cross validation method

	TP	FP	Kappa	P	R	F
Valence	0.834	0.091	0.7459	0.834	0.834	0.833
Arousal	0.826	0.087	0.7395	0.829	0.826	0.826

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 8: Distribution of features used for valence recognition in TV interaction scenario

Total Feature Count	Action type	2 vs. 3 operations	Goal versus activity	Content versus form	Definition vs. description
	Touch letters: 14 Touch content: 16 Intention: 13 Action: 4	2 operations: 14 3 operations: 33	Goal: 27 Activity: 20	Content: 17 Form: 30	Definition: 40 Description: 7
47	47	47	47	47	47

Table 9: Distribution of features used for arousal recognition in TV interaction scenario

Total Feature Count	Action type	2 vs. 3 operations	Goal versus activity	Content versus form	Definition vs. description
	Touch letters: 15 Touch content: 13 Intention: 12 Action: 5	2 operations: 19 3 operations: 26	Goal: 26 Activity: 19	Content: 12 Form: 33	Definition: 40 Description: 5
45	45	45	45	45	45

Table 10: Recognition results of user core affect in social TV viewing experiences: classifiers tested with leave one-person-out method

	TP	FP	Kappa	P	R	F
Valence	0.796	0.108	0.6886	0.796	0.796	0.796
Arousal	0.789	0.106	0.6828	0.79	0.789	0.789

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 11: Online multimedia stories in user study 2

Vignette #	Stimulus Audio/Song Source Name	Duration of Song	Mean value	Standard Deviation
Vignette 1	"I Just Call To Say..."	0'50"		
Vignette 2	"Everything I do..."	0'53"		
Vignette 3	"Give Me One Reason…"	0'59"		
Vignette 4	"Sweat"	0'56"		
Vignette 5	"Ganstta's Paradise"	0' 54"	0'53"	0'04'
Vignette 6	"No Woman No Cry"	0'48"		
Vignette 7	"Lose Yourself"	0'56"		
Vignette 8	"Terrible Things"	0'44"		
Vignette 9	"She Bangs"	0'53"		

Table 12: Recognition results of user core affect in online multimedia story interaction: classifiers tested with 10-fold cross validation method

	TP	FP	Kappa	P	R	F
Valence	0.86	0.084	0.7798	0.86	0.86	0.859
Arousal	0.81	0.114	0.7021	0.812	0.81	0.809

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 13: Distribution of features used for valence recognition in story interaction scenario

Total Feature Count	Action type	2 versus 3 operations	Goal versus activity	Content versus form	Definition vs. description
	Touch letters: 25 Touch content: 7 Intention: 9 Action: 4	2 operations: 17 3 operations: 29	Goal: 27 Activity: 19	Content: 17 Form: 29	Definition: 36 Description: 10
46	46	46	46	46	46

Table 14: Distribution of features used for arousal recognition in story interaction scenario

Total Feature Count	**Action type**	**2 versus 3 operations**	**Goal versus activity**	**Content versus form**	**Definition vs. description**
	Touch letters: 23 Touch content: 12 Intention: 8 Action: 6	2 operations: 19 3 operations: 30	Goal: 33 Activity: 16	Content: 17 Form: 32	Definition: 42 Description: 7
49	49	49	49	49	49

Table 15: Recognition results of user core affect in online multimedia story interaction: classifiers tested with leave one-person out method

	TP	**FP**	**Kappa**	**P**	**R**	**F**
Valence	0.826	0.109	0.7264	0.827	0.826	0.826
Arousal	0.798	0.118	0.6831	0.797	0.798	0.796

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 16: Recognition results of user core affect in online multimedia story interaction, when machine learning model from TV interaction based study is used

	TP	**FP**	**Kappa**	**P**	**R**	**F**
Valence	0.298	0.347	-0.0516	0.326	0.298	0.303
Arousal	0.281	0.342	-0.0519	0.302	0.281	0.278

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 17: Detailed results of user valence recognition in online multimedia story interaction, when machine learning model from TV interaction based study is used

	TP	**FP**	**P**	**R**	**F**
Low	0.339	0.362	0.447	0.339	0.386
Med	0.356	0.443	0.206	0.356	0.261
High	0.183	0.246	0.236	0.183	0.206

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 18: Detailed results of user arousal recognition in online multimedia story interaction, when machine learning model from TV interaction based study is used

	TP	**FP**	**P**	**R**	**F**
Low	0.451	0.419	0.223	0.451	0.299
Med	0.26	0.342	0.333	0.26	0.292
High	0.211	0.299	0.313	0.211	0.252

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 19: Recognition results of user core affect in social TV interaction, when machine learning model from online multimedia story interaction based study is used

	TP	FP	Kappa	P	R	F
Valence	0.347	0.319	0.0257	0.371	0.347	0.302
Arousal	0.317	0.347	-0.0298	0.311	0.317	0.293

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 20: Detailed results of user valence recognition in social TV interaction, when machine learning model from online multimedia story interaction based study is used

	TP	FP	P	R	F
Low	0.736	0.691	0.342	0.736	0.467
Med	0.167	0.127	0.474	0.167	0.247
High	0.143	0.154	0.25	0.143	0.182

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)

Table 21: Detailed results of user arousal recognition in social TV interaction, when machine learning model from online multimedia story interaction based study is used

	TP	FP	P	R	F
Low	0.105	0.117	0.3	0.105	0.155
Med	0.341	0.424	0.286	0.341	0.311
High	0.495	0.489	0.346	0.495	0.407

(TP: True Positive, FP: False Positive, Kappa: Kappa Statistics, P: Precision, R: Recall, F: F measure)