DESIGNING ENGAGING INTERACTIONS WITH DIGITAL PRODUCTS

Proefschrift

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Marco Rozendaal
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# INTRODUCTION

To start this thesis, imagine the experience of cooking. Compare cooking that involves preparing a dinner from scratch to cooking that involves heating up a TV-dinner in the microwave. In the first situation, cooking involves cutting and washing the raw ingredients, spicing and cooking the food and serving it out on a plate. In the second situation, cooking involves placing the TV-dinner in the microwave, setting the timer and then waiting for a few seconds. Preparing a meal from scratch can be considered a richer experience compared to preparing a TV-diner since the cooking involves a considerable amount of choice, involves extensive physical action in manipulating the ingredients and involves increased sensorial stimulation.

Rich interaction, in the case of cooking from scratch, is considered engaging for various reasons. Firstly, an increased amount of choice allows freedom. A person can choose which ingredients are used, for how long they are cooked and how the food will be presented. Secondly, by manipulating the food directly, a person is more physically involved in the preparation of the food, such as cutting, pinching and stirring compared to pushing buttons on the microwave oven. Lastly, preparing a meal from scratch is considered engaging since the senses of a person are stimulated. Handling the vegetables results in a variety of tactile experiences, various flavors can arise during cooking and the heat of the stove may be felt.

In contrast, preparing a meal from scratch may be less engaging for a person who lacks the appropriate cooking skills. A person who has no knowledge about the flavors of the ingredients, does not know how to prepare the food and does not know how to light the stove might feel overwhelmed by the richness of the activity and may feel anxious about the outcome of his or her cooking. In this situation, heating up a TV-dinner may be less engaging but safer for the dinner guests. Even when a person has the appropriate skills, preparing food from scratch might not be engaging when a person wants to eat

Figure 0.1. Pictures showing the ingredients and tools that are needed to prepare a traditional Indian curry from scratch (top), preparing a semi-prepared dinner kit (middle) and heating up a TV-diner (bottom). Richness in cooking is considered to increase from bottom to top given that a person is allowed more choice, expressiveness and sensorial stimulation while cooking. Increasing richness is considered to increase engagement. However, the extent engagement can increase depends upon one's cooking skills and readiness to enjoy the experience or one's urge to eat as quickly as possible.

quickly without wanting to invest time and energy into the cooking. Here too, a TV-dinner may be less engaging but the end-result can be reached without much effort.

Although the TV-dinner-microwave combination makes it easy and efficient to prepare a meal due to restriction of choice and simplicity in action, the choice, physical action and sensorial stimulation in food preparation is lost. Semi-prepared dinners are examples of products that afford a certain degree of richness in food preparation without needing to invest too much time and energy. These kits include washed and pre-cut vegetables, a seasoning mix and clearly stated procedures. Here, the person is allowed some freedom in preparing food within a restrained amount of choice and within a clearly defined set of procedures (Figure 0.1).

The example of preparing a dinner illustrates nicely that interaction involves the interplay of a product, a person and a goal. Interaction can be considered engaging when it supports the process of self-actualization; the intrinsic enjoyment of experiencing one's functioning and growth. Experiences of richness and control are thought to be important in this respect. Richness captures the complexity of thoughts, actions and sensations that are evoked during interaction. Interactions that are experienced as rich provide possibilities for growth. As in the cooking example, the richness of preparing a meal from scratch provides these possibilities given that many things can be tried out, manual skills can be developed and new sensations can be experienced. Experienced control captures the effort that is experienced in the attainment of goals and relates to feelings of competence and confidence. Effort may be experienced in creating an understanding of the elements and procedures involved in interaction and can also be experienced during the performance of action that brings one closer to a goal. As the effort increases, experienced control decreases. A sense of control is needed in order to actualize the growth-potentials richly experienced interactions provide. In the cooking example, preparing a meal from scratch may not be engaging when skills and knowledge are lacking or when one aims to eat as quickly as possible.

This thesis aims to investigate how the experience of engagement in interaction can be explained by examining the experiences of richness and control and how these experiences are influenced by the features of a product, the expertise of a person and the type of task. This research is carried out within the domain of digital products. From the results of these investigations a conceptual framework will be created that is intended to assist interaction designers in the creation of engaging interactions and may also be used to guide the development of user-models for product intelligence.

In pursuing this goal, consideration is given to the relevance of research for interaction design practice. Following Archer (1981), design research focuses on generating design principles that can be generalized across various contexts. A research method that promotes the balance between practical application and general design knowledge is called *research through design*. This method involves the design of highly experiential prototypes that are driven by research questions and that are assessed by people in controlled as well as natural settings (Desmet et al 2001, Keller 2005, Frens 2006). Since the experiential prototypes are designed according to a set of hypotheses, neither a realistic product nor a highly controlled set of stimuli need to be the result. While a realistic product would result in the most practically applied design knowledge without the power to be generalized to other contexts, a highly controlled set of stimuli would result in general knowledge without the power of practical applicability. However, it is possible to design controlled variability in prototypes without loosing their realistic product character. Further, testing conceptual prototypes through *wizard of Oz* approaches, such as by conceptual walkthroughs (Carroll 2000) are not able to capture many of the sensorimotor experiences that highly experiential prototypes elicit. Thereby, many of the experiences of joy and frustration that are evoked on this level are not addressed. Lastly, *research through design* generates knowledge about the feasibility of the design solution. Solutions to the research questions are generated in the real world of design, showing the boundaries and possibilities of the underlying technology.

The thesis is set-up as follows: First, the introduction continues with a discussion about the particularities of digital products, the experience of engagement and the factors of interaction – product, person and task - based upon the literature. Hereafter, research questions are presented, including how they are addressed across four experimental studies by giving a short summary of each study. The studies themselves are presented in the second part of the thesis and can be read as independent articles. In the third part of the thesis, the proposed conceptual framework is presented, which is constructed by combining the results of the four studies. Hereafter, design recommendations are given that have been distilled from the framework. The thesis concludes with a discussion about the utility and limitations of the framework.

## Digital products

Digital products are products that incorporate information and communication technology. Common examples are desktop computers and mobile phones, alarm clocks and digital cameras. A characteristic of these type of products is that digital content and/or functionality is accessible via a designed mediation made available through sensor- and media-technologies (Bradshaw 1997). Rijsdijk (2006) describes digital products as intelligent products that can collect, process and produce information. A person is allowed to influence digital content via buttons, mice or via pen input while digital contents are communicated, for example, through screens and speakers. The digital contents may vary across the physical platforms, hereby making the relationship between platform and content an arbitrary one.

More specifically, the relations between digital functionality, manipulation and appearance of a product are arbitrary (Wensveen 2005). Product *function* refers to the digital mechanisms of the product that can either operate autonomously or operate because of user behavior. Product *manipulation* refers to the means by which a user can operate these digital product mechanisms. Product *appearance* refers to the form in which these functions are represented including their physical and virtual (digitally mediated) elements. Due to the nature of digital technology, the same digital function can be manipulated in different ways depending on the sensor technology that is used to transfer physical phenomena into digital information. Oppositely, the same digital function can appear differently according to the actuator and media technologies that are used to transfer digital information to physical phenomena.

Usability requirements for digital products have changed over time. Initially, information and communication technology was used in highly professional environments, such as in scientific and military ones. Here, usable products were products that are effective and efficient. These qualities were assessed by measures of performance like *success-rates* and *task-completion-times*. Later, information and communication technology was more broadly used to support work processes in a variety of domains. Besides objective performance, attention was given to the experienced satisfaction of using a product. Satisfaction was assessed through various subjective measures of which the experienced *ease-of-use* was most prominent (Nielsen and Levy 1994). More recently, digital products have expanded from professional environments into our everyday lives (Hallnäss and Redström 2002). Here, information and communication technologies support personal, social, and even spiritual activities.

Now, usable products should not only be effective, efficient and easy to use, but they should also provide compelling experiences (Pine and Gilmore 1998). What these experiences entail is still rather evasive (Lindgaard and Dudek 2002, Hornbæk 2006). However, Hassenzahl (2006) captured some key essence of these experiences by the hedonic qualities of products that appeal to the intrinsic need for stimulation and self-expression. Quesenbery (2005) used the term *engagement* to address these experiences.

## Engagement

To address the question of *how* one can create a sense of engagement in interaction with digital products, the initial question should be: *What* is engagement? The various descriptions of engagement that are found in the literature indicate that engagement is a multifaceted construct. For example, the concept of engagement is referred to as a *positive* interactive state, in which attention is willingly given and held. During engagement people experienced feelings of *curiosity*, *interest*, *confidence* and *surprise* (Jacques et al 1995). Others have described engagement as an intrinsically enjoyable experience that involves *focused attention*, *challenge* and *control* (Webster et al 1993, Chapman et al 1999). Further, engagement is described as a kind of *playfulness* in which things may be freely tried out (Laurel 1991, Webster and Martocchio 1992). Engagement is also referred to as an *optimal* experience called *flow* (Csikszentmihalyi 1990, Novak et al 2000) that is both *holistic* and *situation specific* (Finneran and Zhang 2003). All of these characteristics make engagement an evasive concept.

Common in these views on engagement is that engagement is *intrinsically enjoyable*. The activity is performed for the intrinsic rewards of the activity and is not performed for extrinsic rewards (Malone 1981). Deci and Ryan (2000) described intrinsically enjoyable experiences as driven by intrinsic motivation and defined it as the: "… the inherent tendency to seek out novelty and challenges, to exercise one's capacities, to explore and to learn." (pp 70). The distinction between intrinsic and extrinsically enjoyable activities can be illustrated by the distinction between work and play. While activities that are experienced as work tend to be experienced as something that *must* be done, activities that are experienced as play are experienced as something that one is *free* to do (Caillois 2000, Levy 1978, Matsumoto and Sanders 1988). Within humanistic psychology, this inherent tendency underlying intrinsic motivation is described as self-actualization; a constructively and directional force, aiming toward increasing differentiation and complexity and resulting in growth, development and fulfillment of potentialities (Maslow 1943, Rogers 1951). Thus, an interaction is considered engaging when growth-potentials are provided that can be actualized. Experiences of richness are considered to capture this growth-potential while experiences of control are considered to capture the extent that they can be actualized.

Experiences of richness are influenced via (a) external stimulation gathered by the sensory modalities, (b) internal stimulation gathered by the organs and muscles and (c) cortical stimulation via thought processes (Fiske and Maddi 1961). For example, an interaction may be experienced as rich because it involves extensive visual and auditory stimulation, involves the experience of varied behavior through the movement of muscles and joints and involves the experience of curiosity and ambiguity through a process of reflection. Due to the elaborateness of rich experiences, a person can be attentive to the various aspects of the experience and may investigate each aspect in relation to the whole. Thus, richly experienced interactions are complex ones. Experiences of control are influenced by the connection between actions and outcomes aligned to goals (Skinner 1996, Bandura 1988, Ajzen 2002). Experienced control is defined as the process of ac-

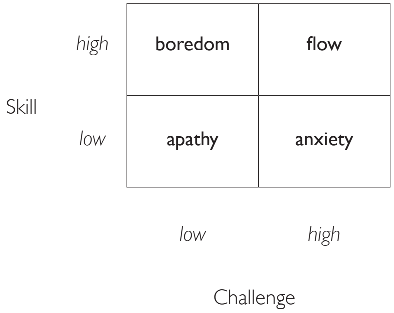



Figure 0.2. Representation of the flow-segmentation-model. Combinations of high and low levels of challenge and skill can give rise to experiences of flow, anxiety, boredom and apathy.

tion and action feedbacks in which "...an individual intentionally exerts effort towards a goal and can feel the energy of the effort transmitted into the environment to produce the outcome" (Skinner 1996, pp 551). The more effort is needed to reach the goal, the less control is experienced. Experiences of control are influenced by the combination of objective control conditions, skills and personal beliefs.

The relationship between the experiences of richness and control on experienced engagement can be explained via the flow segmentation-model[1] (Ellis et al 1994, Massimini and Carli 1988). As described earlier, flow is considered an optimal experience. Four zones can be identified that are characterized by having high and/or low levels of challenges and skills (Figure 0.2). In this model, activities lead to *flow* when high levels of both challenge and skills are experienced; the activity provides growth-potentials that can be actualized. Sub-optimal levels of flow are experienced when either high levels of challenge and low levels of skill or high levels of skill and low levels of challenge are experienced. Activities may lead to feelings of *anxiety* or *boredom* respectively: Growth-potentials cannot be actualized or growth-potentials are not available. When low levels of flow are experienced due to low levels of challenge and skills, interaction leads to feelings of *apathy*.

[1] Flow, challenge and skill are closely associated with the concepts of engagement, richness and control as used in this thesis. However, richness is viewed as a perceptually grounded experience leading to challenge (Fiske and Maddi 1961) while control is viewed as an experience influenced by skill (Novak et al 2000).

## Interaction

In understanding experience in interaction, characteristics of a *product*, a *person* and a *task* should all be taken into account simultaneously (Michaels and Carello 1981, Rijken en Mulder 1996, Shaw 2001, Finneran and Zhang 2003). These factors have been widely acknowledged within the domain of interaction design. In terms of

Figure 0.3. Increasing the amount of (digital) functions incorporated into a game or product may lead to increased levels of experienced richness in interaction through choice. In games for instance, a game of Chess allows more playing strategies compared to a game of Tic-tac-toe, and given the increased range of functions. Newer mobile phones allow an increased sense of discovery compared to older ones.

Increasing the range of human action that is needed to manipulate the digital functions may lead to increased levels of experienced richness in interaction through physical involvement. For example, full-body interfaces allow more diversity in action compared to joysticks. Similarly, more physical involvement is allowed by using a stylus or by using the mechanical parts of a device itself compared to using push buttons in order to manipulate functions of mobile phones.

products, aspects such as product behavior and appearance have been discussed in relation to usability and aesthetics (Djajadiningrat et al 2004). In terms of people, expertise (Rasmussen 1983), personality (Hummels and van der Helm 2004) and age (Freudenthal 1999) have been discussed. In terms of tasks, consideration has been given to goal characteristics and the physical and social contexts in which they take place (Suchman 1987, Preece et al 2002, Hedman and Sharafi 2004, Melles et al 2004).


Increasing the amount of modalities and their dimensionality in which digital functions are represented may lead to increased levels of experienced richness in interaction through sensorial stimulation. For example, sensorial stimulation is increased in videogames by using high-resolution audiovisual and haptic displays compared to using a monochrome visual display only. Similarly, mobile phones allow increased auditory stimulation by using polyphonic sounds as ring-tones instead of simple 'beep' sounds.

In order to create engaging interactions, digital products should be designed to evoke increased levels of experienced richness. Digital products can be made increasingly rich by increasing the amount of digital *functions* that can be *manipulated* in real-time (Chapman et al 1999, Webster and Ho 1997, Fortin and Dholakia 2005). In this way, a person is allowed increased influence over the digital contents and is allowed playful manipulative behavior in which things can be tried out (Laurel 1991). Richness can also be increased via the *appearance* aspects of a product, by increasing the amount of sensory modalities to be stimulated and the perceptual dimensions within a modality in which digital functions are represented (Steuer 1992). This has the potential of drawing people into interaction since the senses are stimulated (Malone 1981). Figure 0.3 provides an illustration of how, for mobile phones and videogames, these aspects may increase levels of experienced richness during interaction.

As the growth-potential in interaction is provided by the experienced richness that a product affords, the expertise of a person can determine if these potentials can be actualized or not. Expertise is captured by the completeness of the *cognitive schema* that a person has constructed of a product. In general, cognitive schemata are mental constructs that are used to recognize objects and to predict events within our environment (Neisser 1976, Matlin 2005). These schemata are useful since they provide a frame of reference that allows novel situations to be learned and allows familiar situations to be handled with routine. In interactive systems, cognitive schemata are discussed as *mental models* (Norman 1988,

Figure 0.4. Picture of the game of pool. The pen is used to manipulate the movements of virtual balls projected on the tabletop from underneath.

Figure 0.5. Picture of the game of flight. The game is presented in an audiovisual format on a desktop computer and the virtual aircraft-avatar can be manipulated via keys on the keyboard.

Rauterberg 1995). When a complete model of an interactive system is formed, human performance is characterized as smooth, integrated, automatic and guided without conscious attention (Rasmussen 1983, VanDeventer and White 2002). Thus, levels of experienced control are thought to increase when a person learns about the product functions and learns to operate them.

Engagement in interaction may also be determined by a goal a person has set. Tasks involve the manner in which goals are dealt with in interaction. Two types of tasks are considered in engagement. Experiential tasks are the ones in which goals emerge freely from the interaction itself (Hassenzahl et al 2002, Novak et al 2003). Here, a person can be characterized as having an aesthetic or process-oriented state of mind. He/she is attentive to all of the experiences that arise during interaction and behavior is playful, improvisational and explorative (Caillois 2001, Levy 1978). Tasks in which the focus is on attaining a set goal are called goal-directed tasks. Here, a person can be characterized as having a pragmatic or outcome-oriented state of mind. He/she narrows down the focus of attention to aspects that are relevant in attaining the set goal. The eye for detail, concerning goal irrelevant aspects, is lost and behavior is less explorative (Kahneman 1973, Wickens 1992).

Figure 0.6. Picture of the voice mail browser. Voice mail messages are stored within one of 16 voice mail slots along its ridge and can be accessed by performing gestures above the product. The middle slot serves as a base for the input device.

## Aims and overview

This thesis aims to investigate how the amount of product features, the expertise of a person and the type of task affect experienced engagement through the experiences of richness and control. Table 0.1 provides an overview of the studies. Note that those studies can be read as independent articles. Questionnaires were used to assess the subjective qualities of richness, control and engagement by means of 7-point or 10-point numerical category scales (de Ridder and Majoor 1990). These were filled in after interactions took place. Experiments were carried out within the department of Industrial Design. Participants included university students and people with various backgrounds living within the vicinity of the university. Gender was balanced and ages varied between 22 and 49. Below a summary is given for each study.

Study I investigated how the amount of product features across behavior and appearance aspects influenced experiences of richness during experiential tasks. A videogame was created that resembled a *game of pool*. Virtual balls projected from underneath upon a glass table could be directly manipulated by placing a pen upon the touch sensitive tabletop. Function and manipulation aspects were varied by increasing the ways the balls behaved and how their movements could be influenced by the pen. Appearance varied by changing the colorfulness and level of detail of the visual design of the game (Figure 0.4).

Study II examined how product behavior and appearance aspects that were experienced as increasingly rich influenced experiences of control and engagement during experiential and goal-directed tasks. The same *game of pool* as in Study II was used but for some minor changes (see Studies I and II for more detailed descriptions of these games). During experiential tasks, people were given plenty of time to freely explore the game and could stop at any given time. During goal-directed tasks, an imposed goal had to be attained within a limited amount of time (Figure 0.4).

Study III examined how the amount of game features and player expertise influenced engagement during gameplay. A *game of flight* was developed in which a virtual aircraft-avatar could interact within a virtual game world. The game was played on a desktop computer. Function aspects varied according to the amount of possibilities that were available to play the game. Manipulation aspects varied according to the amount of perceptual-motor coordination required to manipulate the virtual aircraft-avatar via keys on the physical keyboard. Appearance aspects varied according to the audiovisual stimulation that was provided by the game. Player expertise varied according to the amount of times games have been played (Figure 0.5).

Study IV examined how the amount of product features influenced the experienced richness, control and engagement of *voice mail browsing* during experiential and goal-directed tasks. A physical

Table 0.1. Overview of the manipulations of the amount of product features, expertise and task type across the four studies together with the assessed subjective experiences.

| | | STUDY I | STUDY II |
|---|---|---|---|
| Amount of product features | [function] | Amount of possibilities in which balls could behave within a virtual playing field. | |
| | [manipulation] | Pen-input was used to directly manipulate the virtual balls projected on a tabletop from underneath. | |
| | [appearance] | Use of color, form diversity and detail in the game representation. | |
| Expertise | | | |
| Task type | | | Experiential vs. goal-directed |
| Subjective measures | | Richness | Control & engagement |

product was designed in which voice mails could be accessed by performing gestures above the product. Function aspects varied according to the amount of accessible voice mail content. Manipulation and appearance aspects varied by increasing the amount of gestures that resulted in sound-feedback and by increasing the variety of sounds that could be heard (Figure 0.6). Tasks were manipulated in a similar fashion as in Study II i.e., experiential and goal-directed.

| STUDY III | STUDY IV |
|---|---|
| Amount of possibilities to interact within the game world via a virtual aircraft. | Amount of voice mails that could be accessed. |
| Key-inputs were used to manipulate a virtual aircraft through keyboard interaction. | Gestural inputs were used to browse through voice mails. |
| Use of color, amount of graphical objects and form diversity within the game representation. Use of classical background music mixed with wind sounds. Further extensive use of discrete sound feedbacks in the form of speech, materialistic and musical sounds that were given upon events. | Use of discrete sound feedbacks in the form of speech sounds and continuous feedback by volume differences of speech sounds and discrete sound feedbacks in the form of materialistic sounds. |
| Expertise | |
| | Experiential vs. goal-directed |
| Richness, control & engagement | Richness, control & engagement |

Study I is based upon the paper:
Rozendaal, M.C., Keyson, D.V., Ridder, H. de, 2007. Interactivity, vividness and richness in user interfaces. Int. Conf. on Soc. Intell. Design (SID2007). 269-278. Trento, Italy.

# STUDY 1

Richness in user interfaces is known to influence engagement. This study examines how the level of interactivity and vividness affect the experienced richness of a user interface. An experiment was conducted in which participants explored a game-like user interface under varying levels of interactivity and vividness. Twelve subjects with a background in industrial design participated in the experiment. Results showed that interactivity increased when the user interface allowed for multiple actions possibilities. Vividness increased when color and detail were employed more profoundly in the visual design. Raising the levels of both interactivity and vividness increased experienced richness. A stronger effect on experienced richness was found for interactivity as compared to vividness. Implications of these findings toward user interface design are discussed.

## Introduction

### Overview

In the consumer-electronics industry, user interfaces can be found in which the design focus is on creating a sense of engagement. For example, interacting with websites can be made more engaging through the addition of sound, animation and increased levels of interactivity. In the case of digital music players, the interface of the Apple iPod may be seen as engaging due to the rich action the rotation wheel offers to access soundtracks compared to the rather poor action of just pushing buttons. For voice mail services, browsing through a collection of voice mails may be enriched, and thus may become more engaging, by using gestures and musical sounds (Rozendaal and Keyson 2005).

Engagement, which may be seen as a playful state in which things can be tried out (Malone 1981, Laurel 1991) has been found to relate to feelings of curiosity, interest and confidence (Jacques et al. 1995). Richness is known to affect the levels of experienced engagement during interaction (Webster & Ho 1997, Chapman et al. 1999). Given these findings, having knowledge about how to enrich the user interface may be a valued design goal. In this study, an experiment was setup that investigated various ways of manipulating richness within a user interface.

## Richness

Richness in user interfaces can generally be conceptualized as the range of possibilities afforded by an interactive medium in terms of perception and action. In terms of gaining an understanding of richness in communication media, a classification system was defined by Daft and Lengel (1984). The criteria applied were (1) the capacity of the medium to transmit multiple cues, (2) language variety, (3) the personal focus of the medium and (4) the availability of instant feedback (D'Ambra et al. 1998). In considering these criteria, face-to-face communication was considered the richest one while numerical computer data output was considered the poorest one.

While Daft and Lengel analyzed media richness by taking the perceptual and behavioral aspects simultaneously, Steuer (1992) analyzed richness in terms of the perceptual and behavioral aspects in isolation (Steuer 1992, Klein 2003). The richness of the medium was composed of a behavioral aspect he named interactivity and a perceptual aspect he named vividness. Interactivity was described as "…the extent to which a person is able to influence and manipulate either the form or content of a mediated environment in real-time" (Steuer 1992 p. 14). Vividness was described as "…the representational richness of a mediated environment as defined by its formal features…" (Steuer 1992 p. 11). Using these dimensions, various media could be mapped. For example, a book may be seen as low in interactivity and low in vividness, while the fictional holodeck of the 'Star Trek' series may be high in both interactivity and vividness. In the following two sections, interactivity and vividness will be explained in further detail.

### *Interactivity*

Interactivity as defined by Steuer (1992) combines both the possibilities of the system and the human action that is needed to bring about these possibilities (Barfield et al 1994). With increased interactivity, users are free to switch between goals and means to attain goals (Manninen 2002), thereby allowing users to interact in an increasingly expressive and personal manner (Hummels and van der Helm 2004, Wensveen 2005).

In terms of system possibilities, a system can be made more interactive by increasing the amount of lower-level manipulations to reach higher-level goals (Kuutti 1996, van der Veer et al. 1996, Manninen 2002). When a user interface is designed top down, the lower-level manipulations are restrained by the higher-level goal. When the number of lower-level manipulations of the user interface is increased, users can vary strategies to reach the higher-level goal and may even vary between goals. Here, a drawback can be that due to the increased range of possibilities users might get lost because more planning and action is needed to reach a goal.

In terms of human action, a system can be made more interactive by allowing users to influence multiple parameters, in parallel, continuously and in real-time (Steuer 1992). While interaction with our physical natural environment is conducted in this manner, interaction with mediated user interfaces may be considered having limited parameters that are often have to be addressed serially in a discrete manner. By designing interaction inspired by human action, the kind of interaction is created that feels more direct. In this line of thinking user interfaces were developed, so-called direct manipulation interfaces (Schneiderman 1983), graspable (Fitzmaurice et al. 1995) and tangible user interfaces (Ullmer 2000, Djajadinigrat 2004, Bruns Alonso and Keyson 2005). With graspable user interfaces, physical objects, having a dedicated function, are used to influence mediated content. Often, the mediated content could be manipulated by using both hands simultaneously (Buxton and Meyers 1986). Physical elements may be used in combination with mediated content. For example, Fitzmaurice et al (1995) designed a system in which physical bricks could directly manipulate graphical objects on a screen by laying a block upon the projected graphical objects. These blocks could control the location and rotation of mediated graphical objects simultaneously by moving and rotating the brick. Using these bricks was found to encourage two-handed usage and allowed for more parallel input, thereby improving user's overall expressiveness.

### *Vividness*

Vividness as defined by Steuer (1992) involves the representational richness of a medium. Vivid user interfaces were found to increase the robustness of interaction (Oviatt 2003) and were found to increase the attractiveness of the user interface (Sutcliffe 2002). The robustness of interaction is increased with increased vividness because the messages that the interface transmits are easier to recognize and memorize (Wickens 1992, Pirhonen 1998, Sutcliffe 2002). The main reason is that in a vivid interface, messages contain multiple perceptual cues that can be used to contrast a message with other messages. Furthermore, messages may be remembered more easily because the rich perceptual cues allow one to build richer schemas and memory cues (Sutcliffe 2002). For example, color coding menu items within a graphical user interface increases the clarity of menu navigation. Using sound feedback in interaction gives users an increased sense of control, especially in situations where users are visually occupied.

Vividness can also influence the attractiveness of a user interface through experienced arousal as a mediating variable. There are indications that, in this way, an optimal level of vividness can be established. Firstly, increasing vividness by increasing the heterogeneity of elements, irregularity of shapes and asymmetry in the visual design may lead to increased levels of arousal experienced during perception. Secondly, the attractiveness of a visual design follows an inverted U-shape path with increasing levels of experienced arousal (Moles 1966, Berlyne 1971). Therefore, intermediate levels of vividness will be considered most attractive. In a similar way, the highest experienced quality of photographic images could be established by manipulating vividness through varying color saturation (de Ridder 1996).

## Aim of this study

The current study investigates how the experienced interactivity and vividness of user interfaces accumulate into experienced richness. First, experienced interactivity is expected to increase by increasing the action possibilities of the user interface while experienced vividness is expected to increase by increasing the use of color, detail and asymmetry in the visual design. Second, experienced richness is thought to increase with increasing levels of experienced interactivity and vividness. However, it is not clear how this accumulation will take place.

In the following sections of this study, the words 'interactivity' and 'vividness' are represented in plain text starting with a capital letter to refer to the physical manipulations of interactivity and vividness. Italics are used to refer to the subjective experience of interactivity and vividness. For example 'Interactivity' versus '*interactivity*'.

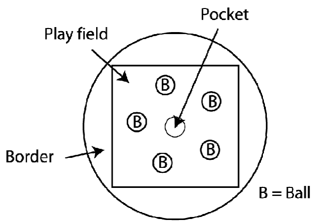



Figure 1.1. Schematic overview of the layout of the user interface.

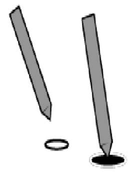
# Method

## Prototype

For the present study, a game-like user interface was developed. The user interface follows the so-called direct manipulation paradigm i.e., the user interface consists of virtual objects that can be manipulated via a physical input device. The user interface is designed such that the level of Interactivity and Vividness may be freely varied. Figure 1.1 gives an overview of the layout of the user interface. Five virtual balls and a virtual pocket are located in a virtual playfield area. The pocket is placed in the middle of the playfield and five balls are circularly distributed around it. The balls are not able to leave the playfield area. To exemplify this to the player, a border element has been added. Balls are removed from the game by dropping them into the pocket. The game is played on a glass table with a physical pen-like input device. A beamer projects the game on the table surface from underneath (Figure 1.2). On the table, a Mimio pen input system is placed to make the tabletop touch sensitive. The combination of the projection and the Mimio system creates a situation in which projected objects (in this case the balls) can be directly manipulated by means of the pen.

Figure 1.2. Picture of layout of the experimental setup. The interactive table is placed within a living room. The pen is used to manipulate the virtual objects projected on the tabletop.

Table 1.1. Descriptions of the three interactive versions. Descriptions are given at the level of the possibilities of the system and the human action that is needed to bring about these possibilities.



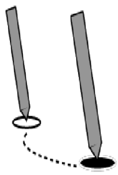
| | | |
|---|---|---|
| System possibilities | [general] | Balls are not moveable and give feedback by means of a visual highlight effect. |
| | [ball potting] | Pocket area must be clicked after a ball has been clicked. |
| Human action | | Position input device and press and release the input device upon the tabletop surface. |

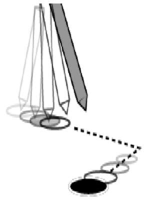
*Interactivity*

With increased levels of Interactivity, the variety of ball behavior and ball control, via the pen, increased. In total, three versions were designed that were named I1, I2 and I3. These versions are described in more detail below (see also Table 1.1 for a schematic overview).

In the case of I1, the balls are not moveable. A ball can be selected by means of pressing the pen upon the tabletop in the area where the ball is projected. When the ball is selected, the ball is highlighted by means of a visual effect. The type of visual effect that is applied depends upon the visual design. Balls can be potted by selecting a ball and selecting the pocket subsequently. At the moment the pocket is selected, the previously selected ball disappears.

In the case of I2, balls can be selected and potted in the same way as in behavior I1. Additionally, balls can be moved around through the playfield. This can be done by first selecting a ball and then moving the pen, while keeping pressure upon the table. The ball that is being moved can push the other balls and a ball can be potted by placing it above the pocket area.





| | |
|---|---|
| Balls are moveable, give feedback by means of a visual highlight effect, and push other balls. | Balls are moveable, give feedback by means of a visual highlight effect, push other balls, can be thrown and bounces off against borders. |
| Pocket area may be clicked after a ball has been clicked or a ball may be dragged or pushed above the pocket. | Pocket area may be clicked after ball has been clicked or a ball may be dragged, pushed or thrown above the pocket. |
| Position input device, press input device upon the tabletop surface. The input device may be moved while keeping pressure upon the tabletop surface. | Position input device, press input device upon the tabletop surface. The input device may be moved while keeping pressure upon the tabletop surface. When the input device is lifted from the tabletop surface, the ball continues to move in the given direction and with a certain speed both specified by the input device. |

In the case of I3, balls can be selected and moved around in the same way as in behavior I1 and I2. Additionally, the balls can also be thrown. A ball can be thrown by moving the ball with the pen, and then by lifting the pen from the tabletop. The ball continues to move in the initiated direction and speed specified by the pen action. Furthermore, the balls bounce off the borders. Besides clicking, dragging and pushing balls into the pocket as in behavior I2, balls can also be potted by performing the throwing action into the direction of the pocket area.

### *Vividness*

With increased levels of Vividness, the use of color, detail and asymmetry of the visual design increased. In total, three versions were designed that were named V1, V2 and V3 (Figure 1.3). These versions are described in more detail below.

The design of V1 can be characterized as a symmetrical geometrical figure, without any color or detail. Differences between the balls and the pocket are communicated by means of the line-thickness of the circles, in that the pocket line is a bit thinner than the lines of the balls. When a ball is selected, visual feedback is given by increasing the line thickness of that ball.

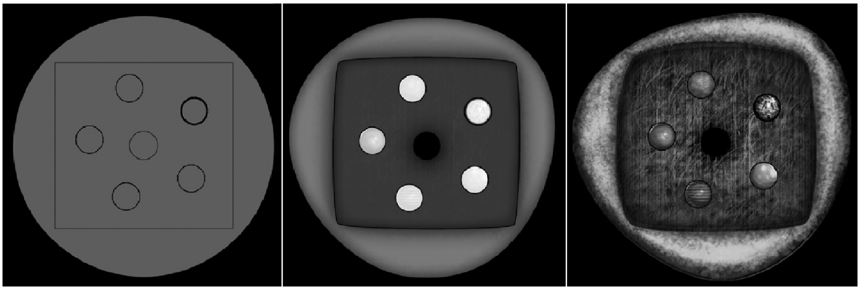


Figure 1.3. Impressions of the three visual versions. Vividness increases from left to right.

The design of V2 can be characterized as being smooth and tinted. The circular form of the game border is slightly asymmetrical and the four corners of the playfield are rounder compared to the appearance of V1. In terms of color, low saturated colors have been added. The game border is presented in a shade of blue, the playfield is purple shaded, the balls are in an ivory color, and the pothole is black. When a ball is selected, visual feedback is given by increasing the ball's line thickness and by increasing the ball's color saturation and level of textural detail.

The design of V3 can be characterized as being bright and detailed. The asymmetry of the game's border and the smoothness of the playfield have been further increased. Colors appear more dominant due to the increased saturation levels. The game objects appear to have materialistic properties due to increased level of detail. This look is supported by the increased shading effect that besides smoothening the lines, creates a sense of depth. When a ball is selected, the same effect is applied as in V2.

## Experimental design

The experimental design was a three by three full factorial design consisting of three levels of Interactivity (I1, I2 and I3) and three levels of Vividness (V1, V2 and V3). Each participant experienced all nine experimental conditions. In each condition, participants were asked to judge the level of *interactivity*, *vividness* and *richness*. Each person was presented with a different random order of conditions.

## Participants

Twelve subjects participated in the experiment. The participants were six masters students, two PhD students and four employees of the faculty of Industrial Design Engineering. Of this sample group, nine were men and three were women. Their age varied between 22 and 43 years, with an average age of 29 years and a standard deviation of 7 years.

## Procedure

Participants were seated behind the interaction-table. Then the participants were told that the goal of the experiment was to judge nine different user interfaces in terms of several perceptual dimensions. The working of the interaction platform was briefly explained to the participants. They were explained that the user interface, which was projected on the interaction-table from underneath, could be manipulated by means of pressing the pen upon the table surface. Hereafter, the participants were presented with all nine experimental conditions. In each condition, the participants were given all the time they needed to create an understanding of the interface. After each condition, a questionnaire had to be filled in.

This questionnaire consisted of three multi-items scales measuring *interactivity* (Steuer 1992, Manninen 2002, Wensveen 2005), *vividness* (Berlyne 1971, Moles 1966, de Ridder 1996) and *richness* (D'Ambra 1998, Chapman 1999). Judgments had to be be given on a seven-point scale (Table 1.2). The experiment was concluded with a short interview and debriefing.

Table 1.2. List of items assessing *interactivity*, *vividness* and *richness*.

| | | | | | |
|---|---|---|---|---|---|
| Interactivity | Direct feedback | Vividness | Colorful | Richness | Complex |
| | Freedom in action | | Level of detail | | Intense |
| | Interactivity | | Symmetry | | Varied |
| | Level of influence | | Form diversity | | Rich |
| | Possibilities | | | | |

# Results

A reliability analysis was performed upon the three multi-item scales measuring *interactivity*, *vividness* and *richness* to assess the internal consistency of each scale. All three scales were above the critical Cronbach's alpha threshold of .70 (Carmines and Zeller 1979). For

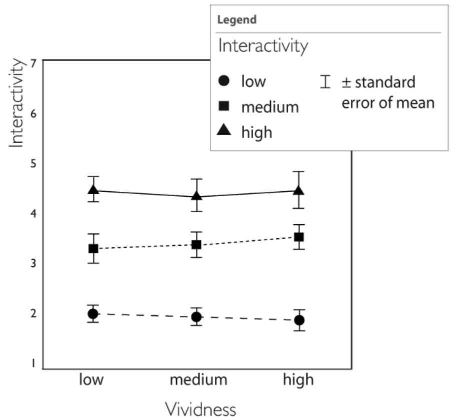



Figure 1.4. Mean scores of *interactivity* as a function of Interactivity and Vividness. Vertical bars represent twice the standard error of the mean.

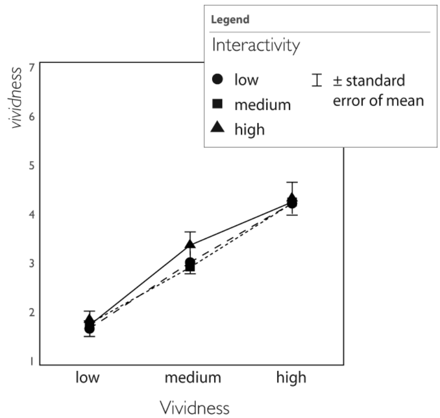



Figure 1.5. Mean scores of *vividness* as a function of Interactivity and Vividness. Vertical bars represent twice the standard error of the mean.

*interactivity* the value of Cronbach's alpha was 0.91 (N=108, 4 items). The item assessing *direct feedback* was not included since it decreased alpha to 0.87. This makes sense since the Interactivity manipulations were confined to the range of possibilities without taking into account the amount of time between user action and system feedback. For *vividness* the value of Cronbach's alpha was 0.80 (N=108, 3 items). The item assessing *symmetry* was not included since it decreased the value of alpha to 0.77. This is due to the fact that the layout of the user interface was varied to a small extent compared to that of the use of color and detail. For *richness* the value of Cronbach's alpha was 0.90 (N=108, 4 items). For further data analysis, the ratings of the remaining items were averaged per participant for *interactivity*, *vividness* and *richness* respectively.

A multivariate repeated measures analysis of variance was performed upon the averaged scales. *Interactivity* was found to be affected by the number of Interactivity manipulations but not by Vividness (Table 1.3). The reverse holds for *vividness*. *Richness* appears to be influenced by Interactivity as well as Vividness. For none of the three dependend variables a significant interaction effect could be measured. The conclusions of the MANOVA are complemented by the plots in Figures 1.4 - 1.6 denoting, as a function of Interactivity and Vividness, the averaged scores across participants, for *interactivity*, *vividness* and *richness* respectively. These data show that by increasing the level of Interactivity only the level of experienced *interactivity*

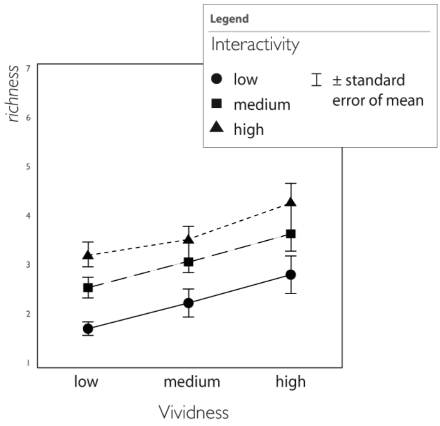



Figure 1.6. Mean scores of *richness* as a function of Interactivity and Vividness. Vertical bars represent twice the standard error of the mean.

increased and that by increasing the level of Vividness only the level of experienced *vividness* increased. By increasing the levels of both Interactivity and Vividness the level of experienced *richness* increased.

## Discussion

The main conclusion from this study is that user interfaces, which are perceived as increasingly interactive and vivid, are also perceived as increasingly rich. This finding is similar to the results from investigations in media richness and virtual reality systems. There, it has frequently been observed that the richness of the media technology is based upon both behavioral and perceptual dimensions (Daft and Lengel 1983, Steuer 1993). No interaction effect was found between Interactivity and Vividness on richness. According to Anderson's information integration theory, this indicates that interactive and visual attributes accumulate linearly or by averaging into richness judgments (Anderson 1990). Interestingly, Interactivity had a stronger effect on richness than Viv-

Table 1.3. Effects of Interactivity and Vividness on experienced *interactivity*, *vividness* and *richness*.

| | *interactivity* | | *vividness* | | *richness* | |
|---|---|---|---|---|---|---|
| Interactivity | $F_{(2,22)} = 107.465$ | p<.000** | $F_{(2,22)} = 2.234$ | p<.131 | $F_{(2,22)} = 31.015$ | p<.000** |
| Vividness | $F_{(2,22)} = 0.112$ | p<.895 | $F_{(2,22)} = 66.223$ | p<.000** | $F_{(2,22)} = 16.784$ | p<.000** |
| Interactivity x Vividness | $F_{(4,44)} = 0.498$ | p<.737 | $F_{(4,44)} = 0.578$ | p<.680 | $F_{(4,44)} = 0.195$ | p<.940 |

** p<..0001

idness. The interactive aspects may have been more influential since Interactivity affects the user behaviorally while Vividness only affects the user perceptually. However, this effect might also be attributed to the range of Vividness manipulations that may have been smaller compared to the range of the Interactivity manipulations.

Increased levels of interactivity were found to increase exploratory behavior. Participants varied strategies to pot the balls and discovered possibilities such as placing balls on top of each other, making patterns and exploring the bouncing action. These observations are in line with Manninen's notion of rich interaction, in that increasing the range of low-level manipulations tends to increase the variety in goals and strategies to attain them (Manninen 2002). Furthermore, the increased range of manipulations allowed participants to interact in a personal manner. For example, one participant furiously explored the throwing and bouncing action, while another participant using the same user interface tried to place the balls into the hole with minute precision. This may support the proposition by Wensveen (2005) that rich interaction allows for more personal and affective expressions.

The prototype has also been used in a number of informal demonstrations to groups of visitors. This lead to a number of interesting ideas about the social impact of the prototype based upon observing peoples reactions to it. The physical platform of the prototype i.e., round tabletop with video projection from underneath, facilitated a co-experience; multiple people could easily group around the table. This would have been more difficult to attain when the user interfaces were presented on a desktop computer. Further it was observed that the group became livelier as the user interfaces increased in richness; group members showed more physical movement, laughter and conversation as the variety of experiences that the user interfaces elicited increased. Given these observations, the impact of the prototype, in terms of its platform and richness manipulations, may have an impact beyond an individual level.

## Implications for design

In terms of user interface design, designers may design towards specific richness levels by manipulating either the interactive or the perceptual aspects of the design. In applying richness, consideration will have to be given to the ease of implementation and to technological restrictions. Increasing richness via perceptual features may be easier to implement compared to interactive ones. While perceptual features may be skin deep, changing interactive features usually affect the interface structurally and thus involves programming new code. Implementing interactive features could therefore be more time consuming and error-prone than implementing perceptual ones. However, increasing richness through interactive features may put less demands on memory and processing power compared to perceptual ones. Adding interactive features merely increases the programming, while the addition of perceptual features may increase the number of large media files, like sound and video for instance.

## Future studies

Given the results of this experiment, an appropriate next step would be to examine how interactivity and vividness relate to engagement through richness. Based upon the results of a study conducted by Chapman (1999) described earlier it seems that richly experienced user interfaces may also be experienced as engaging during interaction. Increasingly interactive user interfaces were experienced for longer periods and were perceived as fun, while the less rich user interfaces were quickly abandoned. Upcoming studies will focus on the effect that richly experienced user interfaces may have on engagement.

## Acknowledgments

This study was carried out as part of the research program of the ICT-Delft Research Centre. Thanks to: Rick Schifferstein and Caroline Hummels for their input and inspiration. Rosalind Boschloo, Peter Craig and Anneke Nipius for their help in developing the concept of richness and for their help in gaining knowledge about the application of richness into design.

Study II is based upon the paper:
Rozendaal, M.C., Keyson, D.V., Ridder, H. de, 2007. Product behavior and appearance effects on experienced engagement during experiential and goal-directed tasks. Int. Conf. on Designing Pleasurable Products and Interfaces (DPPI2007). 181-194. Helsinki, Finland.

# STUDY II

The aim of this study is to examine how digital products can be designed towards increased levels of experienced engagement. To this end, an experiment was conducted in which 24 participants were asked to interact with a videogame that varied in behavioral and appearance aspects while performing experiential and goal-directed tasks. Behavioral aspects were manipulated by varying the amount of possibilities in the game affecting the complexity in human action. Appearance aspects were manipulated by varying the colorfulness, detail and asymmetry within the visual design. During experiential tasks participants were free to explore the game while during goal-directed tasks participants were given a goal that had to be completed as efficiently as possible. Results indicate that experienced engagement is based upon the extent the game provides rich experiences as well as by the extent the game provides a sense of control. Based on these results, recommendations for designing engaging interactions with digital products are discussed.

## Introduction

In recent years, there is a growing interest in engagement within the field of human computer interaction. In games, engagement is often examined as an evaluator of game playability (Chen et al 1999, Douglas and Hargadon 2001, Lindley 2004). In interaction design engagement is often examined in relation to the usability of digital products (Hassenzahl 2004, Monk 2002, Chung and Tan 2004, Jorgensen 2004). Yet, engagement is still an evasive concept given the multiplicity of meanings that are attributed to it (Lindgaard and Dudek 2003, Hornbæk 2006).

Engagement has been discussed in relation to product features such as interactivity, vividness, media, input devices and narrative (Jacques et al 1995, Mallon and Webb 2000, Fortin and Dholakia

2003, Desurvire et al 2004). In addition, task effects on engagement have been investigated such as experiential and goal-directed tasks (Novak et al 2000, Hassenzahl et al 2002, Finneran and Zhang 2003). However, not many studies can be found in which these product and task factors have been systematically varied within a single study.

The current study investigates how, by systematically varying the behavioral and appearance aspects of a digital product, engagement is affected during experiential and goal-directed tasks. By including both experiential and goal-directed tasks, it can be assessed to what extent digital products are considered engaging when a person is exploring a product or is using a product towards a specific goal.

## Engagement

In the literature on interactive systems, engagement is described in various ways (Hornbæk 2006). For example, engagement is described as an exciting and enjoyable state of mind in which attention is willingly given and held (Malone 1981, Laurel 1991, Jacques et al 1995, Webster and Ho 1997, Chapman et al 1999). In everyday activities, engagement has also been described as an optimal state of mind, called *flow*, in which people report loosing the sense of self and time and report experiencing an effortlessness in the development of skills (Csikszentmihalyi 1990, Ellis et al 1994, Novak et al 2000, Garris et al 2002). Common in these varied views on engagement is that engaging activities are intrinsically enjoyable i.e., the activity is performed for intrinsic rewards and is not performed for extrinsic rewards such as money or status (Deci and Ryan 2000).

By taking an intrinsic enjoyment perspective on engagement, engagement was found to be influenced by the behavior and appearance of a product being both sources of hedonic stimulation and mediators of goals (Hassenzahl et al 2000, van Reekum et al 2004). In this study, the term *richness* is introduced to capture the extent the behavioral and appearance aspects of the product provide hedonic stimulation by assessing the levels of experienced variety and complexity (Fiske and Maddi 1961, Moles 1966, Berlyne 1971). Similarly, the term *control* is introduced to capture the extent the behavioral and appearance aspects of the product mediate goals by assessing the level of experienced ease and efficiency (Skinner 1996, Ajzen 2002). Now, the question becomes: How is engagement influenced by a product's behavioral and appearance aspects, mediated by the experiences of richness and control?

## Product behavior and appearance

Product behavior and product appearance are known to influence richness as shown in the Study I but they are also assumed to affect the feeling of control. Generally speaking, product behavior captures the responsiveness of a product to the actions of a user and combines the possibilities of the product with the means by which they are manipulated (Barfield et al 1994, Laurel 1991, Welch 1996). Product appearance captures the means by which a digital product is presented including its digital and physical aspects (Steuer 1992, Sutcliffe 2002). The behavioral aspects of a product have been found to raise the levels of richness by increasing the amount of possibilities and by the extent these possibilities could be manipulated simultaneously and in real-time (Steuer 1992, Welch 1996, Manninen 2002). Behavioral richness may be coined *expressiveness* since the product allows increased levels of physical involvement in interaction (Fortin and Dholakia 2003, Hummels and van der Helm 2004).

In a similar vein, the appearance aspects of a product have been found to raise the levels of richness by increasing the range of sensory modalities involved as well as the resolution within these sensory modalities (Steuer 1992). Richness in appearance may be coined *vividness* since the product allows increased levels of sensorial involvement in interaction (Malone 1981, Fortin and Dholakia 2003).

The effect of the behavioral and appearance aspects of a product on the levels of control should be discussed in relation to goals (Skinner 1996). When a goal is set, product behavior can be viewed as providing *pathways* to goals and product appearance can be viewed as providing *information* about goals. Control is increased when a product allows goals to be attained easily.

## Experiential and goal-directed tasks

Assuming that experienced control is affected by product behavior and appearance when attaining goals, experiential and goal-directed tasks must be considered a possible third influence on engagement. In user-product interaction, two types of tasks can be distinguished, namely, experiential and goal-directed tasks (Hassenzahl et al 2002, Novak et al 2003, Finneran and Zhang 2003). Experiential tasks involve the exploration of goals as they emerge from an activity. In this context, a person can be described as creative and improvisational. Goals are always attained since goals emerge based upon the features of the product. In contrast, goal-directed tasks involve the pursuit of goals that are imposed upon an activity. Here, a person can be described as focused and persevering. However, by having set goals, goals do not necessarily have to be attained.

## Assumptions

From the previous discussion, it follows that both experienced richness and control must be assumed to contribute to the experienced engagement (Table 2.1). The impact of richness as well as control however, may depend on the kind of task to be performed. During experiential tasks, products are assumed to differentiate on experienced engagement predominantly by the extent the products provide rich experiences. Increasing levels of *expressiveness* and *vividness* made available by the behavioral and appearance aspects of the product allow for further exploration of goals. Since goals emerge during experiential tasks, the levels of control may be considered to remain at relatively high constant levels.

During goal-directed tasks, it is assumed that products predominantly differentiate on experienced engagement by the extent the products provide a sense of control. Since the goal that is set needs to be attained as efficiently as possible, the main focus is on the goal-related *pathways* and *information* made available by the behavioral and appearance aspects of the product. Since goals are pursued during goal-directed tasks, the levels of control are thought to vary with the extent effort is experienced in the attainment of goals. In this context, the impact of richness is less clear and has to be determined experimentally.

To investigate these assumptions a videogame was developed that was designed towards increased levels of richness and decreased levels of control in three intermediate steps. The videogame is described in the following section.

Table 2.1. Matrix showing a characterization of the behavioral and appearance aspects in relation to richness and control as possible factors of engagement.

| | | Richness | Control |
|---|---|---|---|
| Product aspect | Behavior | **Expressiveness** | **Pathways to goals** |
| | Appearance | **Vividness** | **Information about goals** |

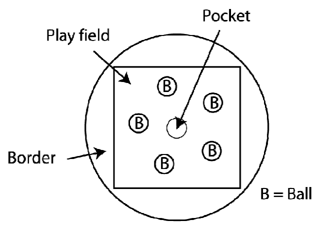



Figure 2.1. Schematic overview of the layout of the videogame

# Method

## Prototype

The videogame that was developed followed the so-called direct manipulation paradigm i.e., the game consists of virtual objects that are manipulated via a physical input device similar to Study I (Schneiderman 1983). Figure 2.1 gives an overview of the layout of the videogame. Five virtual balls and a virtual pocket are located in a virtual playfield area. The pocket is placed in the middle of the play field and five balls are circularly distributed around it. The balls cannot leave the play field area. To exemplify this to a player, a border element has been added. Balls are removed from the game by dropping them into the pocket.

The game is played on a glass table with a physical pen-like input device. A beamer projects the game on the table surface from underneath (Figure 2.2). On the table, a Mimio pen input system (Mimio tracking system; http://www.mimio.com) is placed to make the tabletop touch sensitive. The combination of the projection and the Mimio system creates a situation in which projected objects (in this case, the balls) can be directly manipulated by means of the pen.

Figure 2.2. Picture of layout of the experimental setup. The interactive table is placed within a living room. The pen is used to manipulate the virtual balls projected on the tabletop.

### *Behavior*

Game behavior was designed towards increasing levels of richness by increasing the variety in ball behavior and manipulation by means of the pen. At the same time, game behavior was designed towards

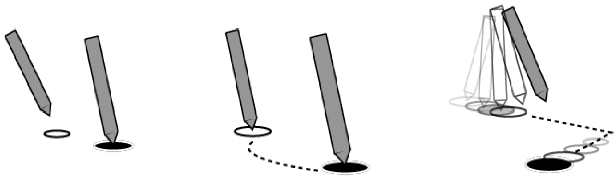


Figure 2.3. Schematic impressions of the three behavioral versions b1 (left), b2 (middle) and b3 (right). From left to right, behavioral richness increases since the game allows more expressivity in action. Behavioral control decreases from left to right since increasingly complex hand-eye coordination is needed to pot the balls.

decreasing levels of control by increasing the complexity of the hand-eye coordination needed to pot the balls. In total, three versions were designed that were named b1, b2 and b3 (Figure 2.3). These versions are described in more detail below.

Version b1: Balls are not moveable. A ball can be selected by means of pressing the pen upon the tabletop in the area where the ball is projected. When the ball is selected, the ball is highlighted by means of a visual effect. The type of visual effect that is applied depends upon the visual design. Balls can be potted by selecting a ball and selecting the pocket subsequently. At the moment the pocket is selected, the previously selected ball disappears.

Version b2: Balls can be selected in the same way as in version b1. Additionally, balls can be moved around through the playfield. This can be done by first selecting a ball and then moving the pen, while keeping pressure upon the table. The ball that is being moved can push the other balls. A ball can be potted by placing it above the pocket area. This way of potting a ball requires a more elaborate hand-eye coordination compared to the previous version since a ball must be placed above the pocket with some precision.

Version b3: Balls can be selected and moved around in the same way as in versions b1 and b2. Additionally, the balls can also be thrown. A ball can be thrown by moving the ball with the pen, and then by lifting the pen from the tabletop. The ball continues to move in the initiated direction and speed specified by the pen action. Furthermore, the balls bounce off the borders. Balls can be potted by throwing a ball into the direction of the pocket. This way of potting a ball requires even more elaborate hand-eye coordination compared to the two previous versions, since the trajectory of the ball, in terms of direction and speed have to be estimated before the action is performed.

Figure 2.4. Impressions of the three visual versions: a1, a2 and a3. From left to right visual richness increases since color, detail and asymmetry is used more extensively in the visual design of the game. Control is considered to decrease from left to right since redundant visual information is added. reducing the ease of identifying the objects

### *Appearance*

Game appearance was designed towards increasing levels of richness by increasing the use of color, detail and asymmetry in the visual design. At the same time, game appearance was designed towards decreasing levels of control by the addition of redundant visual information as described above. In this way, it was expected to decrease the ease of identifying the balls and pocket. In total, three versions were designed that were named a1, a2 and a3 (Figure 2.4). These versions are described in more detail below.

The design of a1 can be characterized as a symmetrical geometrical figure, without any color or detail. Differences between the balls and the pocket are communicated by means of the line-thickness of the circles, in that the pocket line is a bit thinner than the lines of the balls. When a ball is selected, visual feedback is given by increasing the line thickness of that ball.

The design of a2 can be characterized as being smooth and tinted. The circular form of the game border is slightly asymmetrical and the four corners of the playfield are rounder compared to the appearance of a1. In terms of color, low saturated colors have been added. The game border is presented in a shade of blue, the playfield is purple shaded, the balls are in an ivory color, and the pothole is black. When a ball is selected, visual feedback is given by increasing the ball's line thickness and by increasing the ball's color saturation and level of textural detail.

The design of a3 can be characterized as being bright and detailed. The asymmetry of the game's border and the smoothness of the playfield have been further increased. Colors appear more dominant due to the increased saturation levels. The game objects appear to have materialistic properties due to increased level of detail. This look is supported by the increased shading effect that besides smoothening the lines creates a sense of depth. When a ball is selected, the same effect is applied as in a2.

## Experimental design

The experiment was setup according to a 5 by 2 full factorial design consisting of 5 videogames varying in behavior and appearance combined with two types of tasks, namely experiential and goal-directed tasks. The five games were selected from nine videogames that were employed in a previously conducted pilot study similar to Study I, on the basis of the mean richness ratings. The five games were selected such that they could be clearly ranked by means of these ratings. Table 2.2 shows the resulting combinations of behavioral and appearance levels belonging to the five selected videogames. In that study, it was found that both the behavior and appearance manipulations increased the levels of experienced *richness* but with a stronger behavioral effect. The corresponding levels of experienced *control* will be derived from the results of the present study. Each participant experienced all ten experimental conditions. Half of the participants started with experiential tasks while the other half started with goal-directed tasks. The order in which the games were presented was randomized across participants.

## Participants

Twenty-four subjects participated in the experiment. The participants were selected from a consumer evaluation panel database consisting of a diverse range of people living within the vicinity of the Delft University of Technology. They received seven euros for their participation. One important selection criterion was that the participants had some prior computer experience in either work or leisure domain. Otherwise, they were selected randomly. Their ages ranged between 26 and 36 years, with an average age of 32 years and a standard deviation of 2.5 years. Of this sample group, ten were men and 14 were women.

Table 2.2. Table showing the selection of the videogames that were used in the experiment based upon the richness rankings that were assessed in an earlier conducted pilot study with ten participants, similar to Study I.

| Behavior | a1 | a2 | a3 |
|---|---|---|---|
| b3 | 4 | | 5 |
| b2 | | 3 | |
| b1 | 1 | | 2 |

Appearance

## Procedure

Participants were positioned behind the glass table on which the videogame was projected. Participants were asked to interact with ten games divided into two sessions. After each game they had to fill in a questionnaire.

Table 2.3. Selection of items considered to assess the various aspects of engagement. Items are listed in an alphabetical order.

| | |
|---|---|
| Challenge | Excitement |
| Control | Motivation |
| Ease | New possibilities |
| Efficiency | Playability |
| Engagement | Self-confidence |
| Enjoyment | Skill development |

Beforehand, instructions were given on how to fill in the questionnaire. In the experiential tasks condition, participants were asked to explore the games without external demands or time limits. In the goal-directed tasks condition, participants were given a clearly described task that had to be completed as efficiently as possible. The task involved removing all five virtual balls as fast as possible from the visual playing field by 'potting' them. This had to be done twenty times within a fixed timeframe. To create realistic time limits for each game, limits were based on measurements from earlier pilot studies. Behavioral versions b1 and b2 received a maximum playing time of three minutes. Behavioral version b3 received a maximum playing time of six minutes. For each game that was played during the goal-directed tasks conditions, the experimenter notified participants twice: once when they were halfway through the tasks and once when they had three tasks left to go. When the time limit was exceeded the game stopped automatically without notification from the experimental leader.

To assess engagement a questionnaire was developed that not only included items assessing aspects like enjoyment, challenge, control and learning (Chen et al 1999, Garris et al 2002) but also included items on playability and efficiency. Ten-point numerical scales were used ranging from 1 (low value) to 10 (high value). The items are presented in an alphabetical order in Table 2.3.

# Results

## Principal components analysis

A principal components analysis was conducted to determine the dimensions underlying the set of questionnaire items. To this end, the data from the experiential and goal-directed task conditions were taken together (seperate analyses resulted in about the same outcomes). The analysis resulted in the extraction of two components with an eigenvalue higher than one, together explaining about 73 percent of the total variance (Table 2.4). The first component, which is labeled *engagement*, included the item directly assessing engagement plus

Table 2.4. Results of the principal components analysis with varimax rotation on the selection of items shown in table 2.3.

| | 1 | 2 |
|---|---|---|
| Motivation | .918 | |
| Challenge | .914 | |
| Excitement | .903 | |
| Enjoyment | .901 | |
| Engagement | .883 | |
| Skill-development | .845 | |
| New possibilities | .737 | |
| Control | | .885 |
| Ease | | .837 |
| Self confidence | | .835 |
| Efficiency | | .703 |
| Playability | .494 | .569 |
| Eigenvalue | 5.63 | 3.08 |
| %Variance explained | 46.91% | 25.70% |

N=240 (24 participants x 2 task types x 5 games). Factor loadings < .3 are omitted

items that assessed experiences of challenge, enjoyment and skill development. The second component, which is labeled *control*, included the item directly assessing control plus items assessing ease, efficiency and self-confidence. The item assessing playability loaded almost equally on both components. This may be attributed to a possible ambiguity in the term 'playability' referring to the joy of playing as well as the ability to play. Due to this ambiguity, the item was removed from further analysis.

For each component, a scale was constructed based on the group of individual items. A reliability analysis was performed upon the two multi-item scales measuring *engagement* and *control* to assess the internal consistency of each scale. Both scales were above the critical alpha threshold of .70 (Carmines and Zeller 1979). For *engagement* Cronbach's alpha was 0.95 (N=240, 7 items) and for *control* Cronbach's alpha was 0.85 (N=240, 4 items). For further analyses, the scores on the items were combined per component and participant.

## MANOVA

A full factorial multivariate repeated measures analysis of variance was performed upon the engagement and control ratings to examine to what extent richness of a game and task type affected these experiences. Figure 2.5 and 2.6 denote the corresponding mean judgments for engagement and control respectively. The results indicate that as Richness rank increased the levels of *engagement* increased ($F(4,88) = 29.463$, $p < .000$) but the levels of *control* decreased ($F(4,88) = 14.713$, $p < .000$). *Engagement* was higher for Goal-directed tasks compared to Experiential tasks ($F(1,22) = 5.607$, $p < .027$). No significant effect of

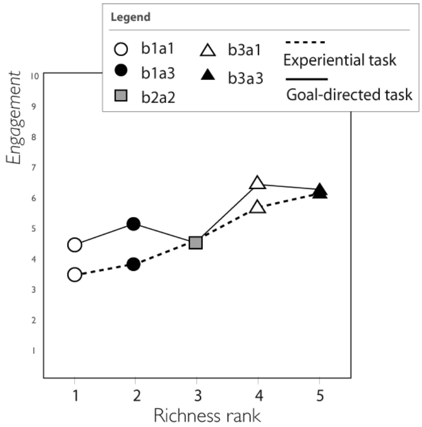



Figure 2.5. Experienced engagement as a function of Richness rank during Experiential and goal-directed tasks.

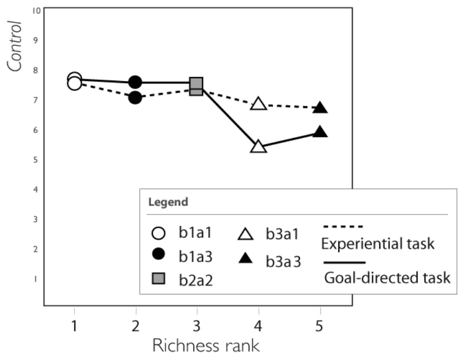



Figure 2.6. Experienced control as a function of Richness rank during Experiential and goal-directed tasks.

Task type on *control* was found ($F(1,22) = 1.454$, $p < .241$). Finally, interaction effects of Richness ranking and Task Type were found for *engagement* ($F(4,88) = 3.949$, $p < .005$) and *control* ($F(4,88) = 4.684$, $p < .002$): During Experiential tasks *engagement* increased as Richness increased. However, during Goal-directed tasks *engagement* decreased for Richness ranks 3 and 5. *Control* decreased slightly for Experiential tasks while *control* seems to split into a highly experienced control cluster (Richness ranks 1-2-3) and a less highly experienced control cluster (Richness ranks 4-5) for Goal-directed tasks. For the three games within the highly experienced control cluster most of the participants could complete the task within the time that was provided. However, for the other two games within the low experienced control cluster only half of the participants could complete the tasks within the available time.

## Summary

The results seem to support the assumption that the games differentiated on engagement during experiential tasks and that this differentiation depended more upon the richness of the game and less upon the extent the game provided a sense of control. During goal-directed tasks engagement seems to depend about equally on richness and control. During experiential tasks, engagement gradually increased with increasing levels of richness while the levels of control remained high. Apparently, control was influenced only to a small extent by game behavior and appearance aspects. This suggests that engagement varied according to the extent game behavior and appearance aspects provided expressiveness and vividness, while the ease of attaining goals remained at high levels.

During goal-directed tasks, engagement did not gradually increase with increasing levels of richness but rather followed a similar - almost inverted - trend as observed for control. In other words, engagement increases as a function of richness and decreases as a function of control. Engagement was hypothesized to vary according to the extent game behavior and appearance mediated the goal that was set via pathways and information respectively. It seems that only the two richest games caused difficulty in goal attainment but that despite this difficulty the richness of these games still led to increased levels of engagement. Apparently, players still felt confident enough to pursue the challenges.

## Conclusion

This study leads to the tentative conclusion that engaging interactions with digital products can be obtained by enriching the behavioral and appearance aspects of a digital product. Behavioral richness was increased by increasing the various ways in which a product can behave and respond to users actions. Richness in appearance was increased by increasing the variety of formal elements such as color and form within the visual design.

In terms of tasks, engagement was found to be higher for games played in a goal-directed manner relative to those played in a experiential context. In particular for the less rich games, merely experiencing these games was considered quite boring by many of the participants and the time pressure that was put on them during the goal-directed tasks led to higher levels of engagement. However, it is interesting to note that during these goal-directed tasks, the richer game versions gained less engagement compared to the poorer ones. This may be attributed to the decreased levels of control resulting from the difficulty to attain goals within the available time. This suggests that as time pressure is increased further, control will continue to decrease hereby decreasing engagement. As a result, the poorer game versions are predicted to be more engaging than the richer ones.

Additional studies are needed to determine the generalizability of this conclusion. The richness, control and engagement constructs can be strengthened by applying the questionnaires in other studies. Additionally, results can become more convincing if the richness range is increased by extending the amount of possibilities and the degrees of freedom in action, and by including multiple sensory modalities within the product appearance. Lastly, results may be easier to generalize beyond a game context when the pragmatic use of digital products is emphasized; goal-directed tasks may be setup as sub tasks within a task hierarchy.

## Acknowledgments

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Study III is based upon the article:
Rozendaal, M.C., Craig P., Keyson, D.V., Ridder, H. de: Game features and expertise effects on experienced richness, control and engagement in gameplay. *Submitted.*

# STUDY III

The extent in which gameplay is experienced as engaging is an important criterion for the playability of videogames. This paper presents two experiments that led to the creation of a conceptual framework called the 'Richness, Control and Engagement framework (RC&E)' meant to support game designers in the creation of engaging games. The framework identifies the experiences of richness and control as two factors of experienced engagement, which are shaped by the features of the game and the expertise of a player. Experienced richness captures the degree a videogame is experienced as varied and complex while experienced control captures the extent players experience effort in the attainment of goals. In the first experiment was investigated how the levels of experienced richness were influenced by varying the amount of features in the game. In the second experiment it was investigated how the levels of experienced control and engagement were influenced by varying the amount of features in the game dynamically over a three-day period. The overall results show that the levels of experienced engagement can be predicted based upon the levels of experienced richness and control. The results further show that the levels of experienced richness are influenced by the amount of game features and that the levels of experienced control are influenced by (1) the levels of experienced richness of the game, (2) the extent goals could be attained effectively and efficiently based upon the physical characteristics of the game and (3) the expertise of the player. Based upon these findings, the RC&E-framework was developed. Implications of the framework for game design are discussed.

## Introduction

Knowledge about engagement as a key element in gaming is of increasing interest since "…Over the last three decades, gaming has gradually become one of the main entertainment media, comparable in revenue, customers and employees to the film and music industries; the industry generates some $20 billion annually." (Kirriemuir 2002). One of the interpretations of engagement is that it captures the extent to which gameplay is experienced as intrinsically enjoyable (Laurel 1991, Jacques et al 1995, Webster and Ho 1997, Chapman et al 1999, Chen et al 1999). It is therefore seen as a good evaluator of game playability (Douglas and Hargadon 2001, Järvinen et al 2002, Lindley 2004). To support the design of engaging videogames more knowledge is needed on the constituents of the experience of engagement and on the game features that promote it.

The development and use of formal models in the design and evaluation of videogames are considered important in the field of game studies (Grünvogel 2005, Klabbers 2006). Models are able to make explicit the success factors across a variety of games as well as players' subjective experiences that are of importance in play. Models may be useful within game design practice since general guidelines can be developed supporting game design and game design education. Further, models can be used as user models embedded within game intelligence (Bradshaw 1997). Based upon such models, games may autonomously transform themselves in order to maintain optimal levels of gameplay. With this in mind, the present study was setup to develop a framework for "Richness, Control and Engagement (RC&E)" making explicit the experience of engagement and the factors that influence it.

Engagement is a widely used concept that is difficult to grasp given the multitude of meanings attributed to it (Hornbæk 2006). In the literature on interaction design, engagement is described as an exciting and enjoyable state of mind in which attention is willingly given and held (Malone 1981, Laurel 1991, Webster et al 1993, Jacques et al 1995, Chapman et al 1999) and also was specifically discussed in relation to web applications and interactive training simulations (Novak et al 2000, Garris et al 2002). In studies on well-being, engagement has also been described as an optimal state of mind, called *flow*, in which people report experiencing a sense of enjoyment, loosing the sense of self and time and experiencing effortlessness in the development of skills (Csikszentmihalyi 1990, Ellis et al 1994). Common in these views on engagement is that engaging activities are intrinsically enjoyable i.e., the activity is performed for the intrinsic rewards of the activity and is not performed for extrinsic rewards such as money or status (Malone 1981, Deci and Ryan 2000).

Currently, various strategies are used to create a sense of engagement in gameplay. The features of a game should support at least one of the specific motivations that appear to drive play. Caillois (2001) classified four varieties of play, each reflecting the specific motivation it addresses: Games of competition, games of chance, games of fantasy and games of stimulation. Each category places different requirements upon the features of a game. For example, goal related feedback is important for competition games, while the extent to which the senses are excited is important in stimulation games (Malone 1981). Specifically in videogames, games are designed towards engagement by creating optimal difficulty curves by balancing players' skills and challenges within a game (Crawford 1982), by facilitating social interaction by creating competition and/or cooperation in a game (Klastrup 2003) or by creating an unfolding narrative that integrates events that occur within a game (Laurel 1991).

In the present study, the focus is on creating engagement in games by taking into account the experienced richness of the game and the extent players feel in control of the game (van Reekum et al 2004). Experienced richness refers to the extent in which a game is experienced as intrinsically stimulating. Richness was found to be engaging since stimuli that are experienced as rich are experienced as challenging and exciting (Fiske and Maddi 1961, Moles 1966, Berlyne 1971, Webster et al 1993). In contrast, low levels of experienced richness may lead to sensory deprivation and boredom (Ellis et al 1994). Experienced control refers to the amount of effort a player feels he/she needs to invest to attain his/her goals. The more effort is believed to be required, the lower the level of experienced control (Skinner 1996, Ajzen 2002). Control was found to be engaging since people intrinsically enjoyed feelings of mastery, competence and confidence (White 1959, Hedman and Sharafi 2004). Low levels of experienced control may lower the levels of engagement since a lack of experienced control will lead to feelings of helplessness (Seligman 1975).

The features of a game in combination with the expertise of the player are expected to determine the level of experienced richness and control. For game designers it is crucial to understand the impact game features will have on players in order to create engaging games. Game features cover many aspects of a game (Barfield et al 1994, Fabricatore et al 2002) ranging from functional aspects of a game, the so-called game mechanics (Manninen 2002, Björk et al 2003), to aspects of a game related to its manipulation (Ullmer and Ishii 2000, Djajadiningrat et al 2004) and to aspects related to its appearance (Steuer 1992, Pirhonen 1998, Sutcliffe 2002). Increasing the amount of game features across these aspects can be expected to increase the levels of experienced richness since a game affords choice, expressiveness and sensorial stimulation (Fiske and Maddi 1961). Similarly, it can be expected that by increasing the amount of features in a game the sense of control will decrease since more effort is needed in identifying and attaining goals via available pathways, and the pick-up of goal related information (Skinner 1996).

Players' expertise is thought to interact with game features affecting the levels of experienced richness and control. Expertise is seen as the knowledge a person has about a particular domain and the extent a person can act within this domain in a skillful manner (Dreyfus et al 1986). VanDeventer and White (2002) addressed some of the differences between expert and novice players. Expert players are described as knowing all objects and actions that are available in a game. They group these objects and actions into large meaningful patterns and characterize their behavior as fast and accurate. The increased expertise of a player may, however, decrease the levels of experienced richness since the objects and actions of the game are grouped into larger patterns, hereby decreasing the levels of experienced variety and complexity. At the same time, the levels of experienced control may increase since goals can be attained with ease due to the players' ability to attune to the relevant information and automatically elicit appropriate behavioral responses (Rasmussen 1983).

Assuming experienced engagement to be at its maximum when both the levels of experienced richness and control are optimal and assuming that increased expertise of a player leads to decreasing levels of experienced richness as well as increasing levels of experienced control, the features of a game should vary in order to maintain high levels of experienced engagement over time. Currently in videogames, this is done by adding novel features over time. Game features can be added explicitly via clear boundaries through game levels. Game features can also be added more subtle in time via increasing capabilities: new game features arise based upon players' current capabilities and progresses through the game depend upon previously made choices. On a more cosmetic level, the design of the game may vary by changing the audio-visual setting in which the game is played. The game may vary contextually by setting time limits to reach goals.

Study III presents the results of two experiments. The main aim of the research is to develop a conceptual framework relating experienced engagement to experienced richness and control. This framework is abbreviated to the "RC&E-framework". In the first experiment it was investigated how the levels of experienced richness are influenced by increasing the amount of game features. A videogame was developed that was configurable in terms of its functional, manipulative and appearance aspects. In the second experiment it was examined how videogames varying in levels of experienced richness affect experienced control and engagement over time. By varying the games over time, the influence of the players' expertise on the levels of experienced control and engagement could be assessed.

# Experiment 1

The goal of this experiment is to assess to what extent the amount of game features leads to experiences of richness.

## Method

### *Prototype*

A videogame called "game of flight" was developed in which the amount of features could be systematically varied. The game resembled a classic arcade game that could be played on a desktop computer. A virtual aircraft-avatar could interact within a virtual game world and points could be earned by performing a variety of actions such as shooting objects and collecting items. As discussed above, game features can involve game functions, game manipulation and/or game appearance aspects (Fabricatore et al 2002). Specific functions were chosen based upon the results of a focus group session held with students at Delft University of Technology where participants were asked about what interested them in games. Some expressed that they liked playing games for being challenged either physically or mentally. Some stated that they like playing games to win in competition. Other participants were less oriented towards competition and just liked playing games for the social experiences it creates. These resulting categories matched with the categories that are described in game literature noted earlier. Based upon the expressions given by the participants, four groups of game functions were designed that were named: (1) *Aircraft control*, which connected to the need for a physical challenge. (2) *Tile coloring*, which connected to the need for a mental challenge. (3) *Item collecting*, which connected to the need for chance and power and (4) *Multiplay*, which connected to the need for a social experience. See Table 3.1 for more detailed descriptions of these functions. The videogame was designed in such a way that the various groups could be freely combined. In addition, the amount of functions within a group could vary from one to three functions. In the case of aircraft control, the amount of maneuvers that the aircraft could perform was variable. Similarly with multiplay, the amount of players could vary. In this way, a wide assortment of games was created that ranges from having one function (Figure 3.1) towards games having a maximum of twelve functions (Figure 3.2) consequently affecting the manipulation and/or the appearance of the game. Below, each game-function-group is explained in more detail.

*Aircraft control* involves the possibility to manipulate an aircraft appearing as a red or blue figure. The aircraft maneuvers can be influenced by the player via the keys on a physical keyboard. The amount of maneuvers that the aircraft can perform is variable (Figure 3.3). Sound feedbacks are given upon the performed maneuvers in the form of mechanical sounds.

Table 3.1. Overview of the four groups of functions and the effect of each function-group on the manipulation and appearance aspects of the game.

| Game feature | Aircraft control | Tile coloring |
|---|---|---|
| Function | Involves the possibility to control the aircraft. The amount of aircraft maneuvers is variable. | Involves the possibility to color tiles by performing spatial patterns above the tiles in the playing field with the aircraft. The amount of patterns that can be made is variable. |
| Manipulation | The maneuvers of the aircraft can be influenced via keys on the computer keyboard. | No effect |
| Appearance [visual aspects] | Aircraft figure with the addition of bullets when the shooting ability is added. | Tiles that appear in a 10 x 10 grid. Visual feedback is given on aircraft movement by highlighting the tiles via increased color saturation. Tiles remain colored when a pattern is made. The tiles are colored in red and blue when two parties are involved. |
| Appearance [auditory aspects] | Mechanical sounds are heard when aircraft maneuvers are performed. | Musical sounds are heard when a pattern is made. |

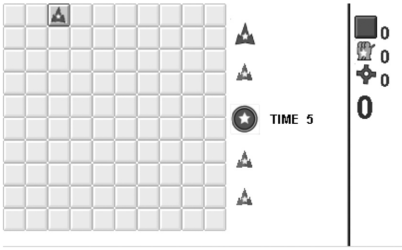



Figure 3.1. Image of a videogame having only one function; the aircraft could autonomously change it's position in the playing field. As a result, the game cannot be manipulated by the player and the appearance of the game provides little audiovisual stimulation.

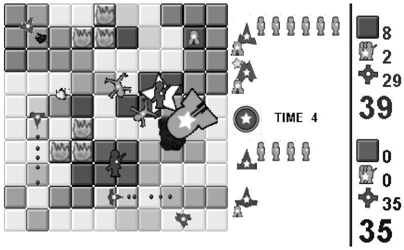



Figure 3.2. Image of a videogame having the maximum of twelve functions. As a result, manipulating these functions requires continuous and parallel input by the player. The appearance of the game provides extensive audiovisual stimulation.

| Item collecting | Multiplayer |
|---|---|
| Involves the possibility to collect items into sets that appeared in the game by placing the aircraft above them. The amount of different collectible items is variable. | Involves the possibility to play the game with others who are physically present. The number of players is variable. |
| No effect | No effect |
| Item appears as floating objects traveling through the gaming field. Items appear in the color green. Variety of item forms increases with increasing amount of collectable items. Strategic advantages are presented by other objects. | Depending upon the amount of players, one to four aircraft-avatars can appear simultaneously in the game. Each aircraft-avatar has a different form. The colors red and blue are used to distinguish between (teams of) aircrafts affecting the colors of the tiles as well. |
| Voice feedbacks are heard on the collection of an item and the creation of a set. | No effect |

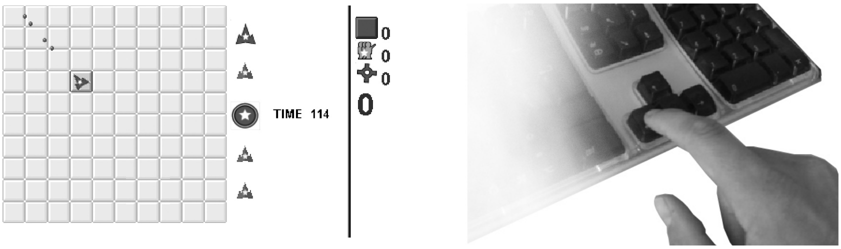



Figure 3.3. Image of aircraft control. Aircraft control relies on a visual representation of an aircraft (left) that can be manipulated via the keys on the keyboard (right).

*Tile coloring* involves the possibility to color tiles by moving the aircraft above them in specific flight patterns. When the aircraft moves over a tile, the amount of color saturation of that tile is set towards its maximum level after which it gently fades once the aircraft has passed. The color of the tile could be either red or blue depending upon the amount of players involved. When a pattern is made correctly, the color saturation of the tiles in the pattern remain fixed to their maximum levels (Figure 3.4). The amount of different patterns that can be made vary in complexity. Sound feedbacks are given upon the creation of a pattern in the form of musical sounds.

*Item collecting* involves the possibility to collect items that appear within the game by placing the aircraft above them. The amount of different items can vary. Sets of items create new strategic possibilities within the game. The collectable items appear as green colored objects that move through the playing field. Sound feedbacks in the form of speech sounds are given when an item is collected or when a set is created (Figure 3.5).

*Multiplay* involves the possibility to play the game together with other players. The amount of players can vary, resulting in a changing amount of physical players as well as in a changing amount of aircraft-avatars (Figure 3.6). When the game is played alone the color red is used in the representation of the aircraft and within the coloring of the tiles. When multiple players are involved, the colors red and blue are used.

Table 3.2. Matrix showing the total amount of functions in the game across the experimental conditions.

| Amount of functions within each group \ Amount of combined groups | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 4 |
| 2 | 2 | 4 | 6 | 8 |
| 3 | 3 | 6 | 9 | 12 |

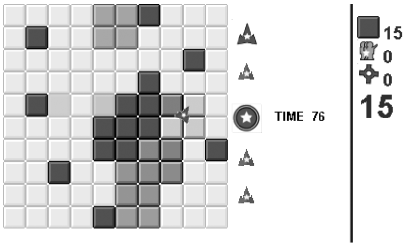



Figure 3.4. Image of tile coloring. By passing over tiles within the grid initially highlights the tiles after which the color fades. When a flying pattern is performed successfully, the colored tiles keep their color.

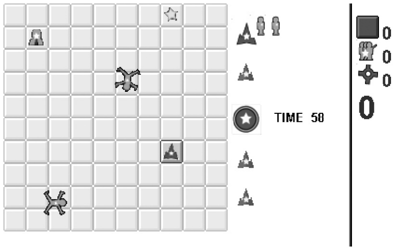



Figure 3.5. Image of item collecting. Items appear as green figures floating within the playing field. An item is collected when the aircraft is placed above it.


Figure 3.6. Image of multiplayer. The aircrafts appear in multiple forms in two colors (left). Red is used in a single player game. Red and blue are used in a two and four player game. On the right is shown the physical situation of multiplayer. Two participants are playing the game via the desktop computer on the right. The experimenter on the left plays with two of the aircrafts against the two participants.

## *Experimental design*

The experiment was set-up as a full factorial - within subjects – design, in which the total amount of game functions varied; according to (1) the amount of groups that were combined in the game and (2) the amount of functions that were available within each group (Table 3.2). Thus, the total amount of functions in the game was calculated by multiplying the amount of groups with the amount of functions within each group. Whenever multiple groups were involved, the number of functions within each group was kept the same. This resulted in twelve instances of the game as illustrated in Table 3.2. The specific groups that were part of a group-combination varied randomly across participants. For example, a game in which two groups were combined could consist of a combination of *Aircraft control* and *Item collecting*, *Multiplay* and *Tile coloring* or any other possible combination.

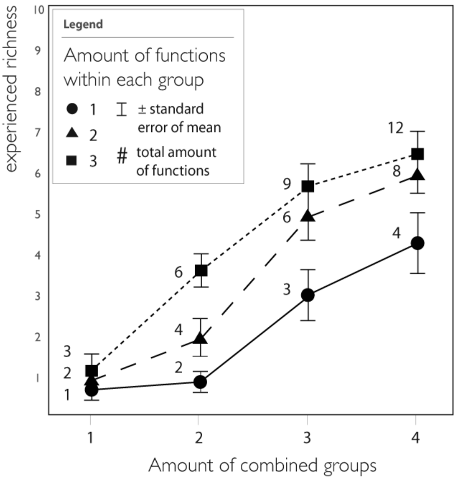



Figure 3.7. Mean scores of experienced richness as a function of the amount of combined groups and the amount of functions within each group. Numbers next to the symbols denote the total amount of functions per game determined by multiplying the Amount of combined groups with the Amount of functions within each group.

### *Participants*

Ten subjects participated in the experiment. They were either students or employees of the faculty of Industrial Design Engineering. Their ages ranged between 24 and 28 years with an average age of 26 years and a standard deviation of 1.3 years. Six participants were male and four were female.

### *Procedure*

The participants were asked to play twelve games for a maximum of two minutes per game. The games were played in a room where a desktop computer was placed on a table. A maximum of three people could sit behind the monitor. During the experiment, the experimenter was present and was positioned in such a way that he remained out of sight of the participants. The experimenter only appeared in situations in where he was needed as a player in the specific instance of *Multiplay* where two participants team up against the experimenter (who played with two aircraft-avatars simultaneously). Participants could stop a playing session at will by pressing the restart button on the screen with a mouse click. Before the experiment started, participants played two demonstration games for thirty seconds. One of these games involved a game set-up in which only one function was available. The other game involved a game set-up in which all twelve functions were available. Hereafter, participants played a series of twelve games in a randomized order. After each game, participants were asked to judge the levels of experienced *richness*, *variety* and *complexity* on a ten-point scale via a pen-and-paper format.

## Results and discussion

Increasing the amount of functions in the game appeared to increase experienced richness. Cronbach's alpha was calculated for the three items on the questionnaire i.e., richness, variety and complexity,

Table 3.3. ANOVA results of Amount of combined groups and Amount of functions within each group effects on the levels of experienced richness.

| | experienced richness | |
|---|---|---|
| Amount of combined groups | $F_{(3,27)} = 56.637$ | p<.000** |
| Amount of functions within each group | $F_{(2,18)} = 18.390$ | p<.000** |
| Amount of combined groups x Amount of functions within each group | $F_{(6,54)} = 2.429$ | p<.038 |

** p<.0001

as a measure of internal consistency. Alpha measured .928 (N=120, 3 items) indicating that the three items measured the same construct and that they could be grouped (Carmine and Zeller 1979). Figure 3.7 denotes the resulting experienced richness scores, averaged across the participants, as a function of the Amount of combined groups and the Amount of functions within each group. An ANOVA-repeated-measures-analysis was performed upon the grouped item ratings (Table 3.3). The significant main effects of the Amount of combined groups and the Amount of function within each group on experienced richness confirm that by increasing the amount of functions in the game the levels of experienced richness indeed increases. The significant interaction effect between the Amount of combined groups and the Amount of functions within each group can be mainly attributed to the little variety in richness scores when only one function is involved.

# Experiment 2

The goal of this experiment is to examine the influence of both experienced richness of a game and players expertise on experienced control and engagement in gameplay.

## Method

### *Stimuli*

Eight videogames varying in level of experienced richness were selected out of the pool of twelve games employed in the previous experiment. The experienced richness levels of these videogames were distributed about equally over the richness scale. On a scale from one to ten, the averaged experienced richness scores varied between 1.6 and 6.7, with a mean experienced richness score of 4.6 and a standard deviation of 2.5 (Table 3.4). Objectively, game features varied

Table 3.4. Ranking of the 8 games employed in experiment 2 on the basis of their average richness ratings in experiment 1.

| Richness Rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Richness score** | **1.6** | **2.5** | **3.5** | **4.7** | **5.3** | **5.9** | **6.2** | **6.7** |

in the amount of functions that were available in the game, which affected the manipulation and/or appearance aspects of the game as a consequence.

## *Experimental design*

The experiment was set-up as a between subjects design having four conditions as the basis of how the various games were presented over time. These conditions were named: High richness, Low richness, Increasing richness and Decreasing richness. In the High and Low richness conditions, participants repeatedly played with identical games having the experienced richness rank 1 and 8 respectively. In the Increasing and Decreasing richness conditions, participants played a series of ten games that either increased in richness from rank 1 to 8 in ten intermediate steps or decreased in richness rank from 8 to 1 in ten intermediate steps after each successive playing session (richness ranks 4 and 6 were played twice). In this way, the effect of experienced richness and the effect of expertise of the player on the levels of experienced control and engagement could be evaluated.

## *Participants*

Twenty-five subjects, fifteen male and ten female, participated in the experiment. The participants were either students or employees at the Faculty of Industrial Design Engineering. Their ages ranged between 19 and 33 years, with a mean age of 24 years and a standard deviation of 3 years. Four subjects participated in the Low richness condition, seven subjects participated in the High richness, seven subjects in the Increasing richness condition and seven subjects in the Decreasing richness condition.

## *Procedure and measures*

The participants were told that the experiment was about evaluating the playability of several videogames. The games were played in ten sessions over a three-day period. Five sessions were scheduled on the first day and five sessions were scheduled on the third day. Within each playing session, the game had to be played within a time-period of ten minutes but participants were free to stop earlier. After each playing session, the participants had to evaluate gameplay by means of rating twelve items taken from several studies assessing experiences of control and engagement. Each item had to be assessed on a 10 point numerical scale ranging from 1 (left) to 10 (right). The list included items assessing *self-confidence*, *ease* and *efficiency* (White 1959, Bandura 1982, Skinner 1996, Ajzen 2002, Hedman and Sharafi 2002) and included items assessing the experience of *pleasure*, *motivation*, *challenge*, *excitement*, *experiencing skill development* and *discovering new possibilities* (Malone 1981, Csikszentmihalyi 1990, Webster et al 1993, Jacques et al 1995, Laurel 1996, Chapman et al 1999, Garris 2002). *Playing time* was taken as a possible behavioral measure of the quality of gameplay.

## Results and discussion

### *Behavior*

The first step in the analysis was to investigate playing times across the experimental conditions. Figure 3.8 shows *playing time* as a function of Playing session for all four experimental conditions. Results show that for the High richness and Low richness conditions *playing time* decreased as Playing session increased. Two of the four participants in the Low richness condition stopped playing after the third session and the other two participants stopped playing after the sixth session. In the High richness condition, four of the seven participants stopped playing after the third playing session. The other three participants continued playing till the last playing session. Participants who stopped playing gave as the main reason that they disliked the game.

For the Increasing richness condition, *playing time* increased as Playing session increased while for the Decreasing richness condition *playing time* remained stable during the playing sessions on day 1 but decreased during playing sessions on day 3. In both of these conditions, all seven participants continued playing throughout all sessions. These participants were eager to find out what type of game awaited them in the next playing session.

### *Principal Component Analysis*

As the second step in the investigation a principal component analysis was conducted to determine the components underlying the assessments of the assortment of questionnaire items. The analysis resulted in the extraction of two components each with an eigenvalue higher than one together explaining about 81 percent of the total variance (Table 3.6). The two components that were extracted grouped the items almost identically as occurred in Study II. Following that

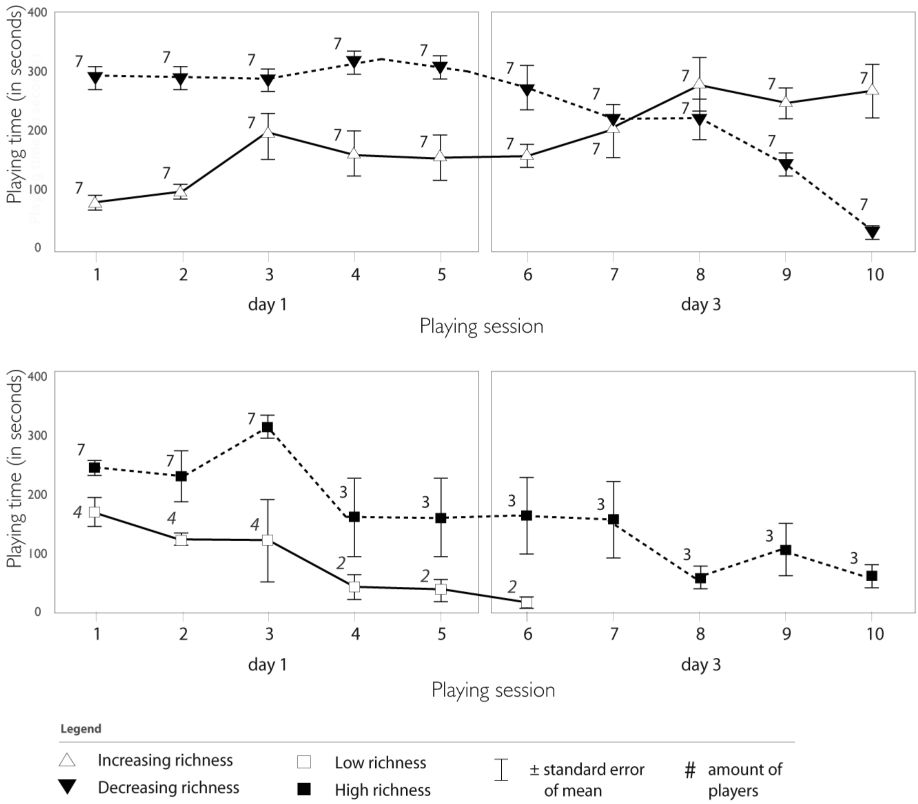



Figure 3.8. Figure showing the amount of playing time and the amount of players per playing session across all experimental conditions. Playing time is depicted in the top row and the amount of players is depicted in the bottom row. Playing time decreased after each playing session for the High, Low and Decreasing richness conditions while playing time increased for the Increasing richness condition. Four participants discontinued playing in both the High and Low richness conditions.

study, the two components will be labeled *engagement* and *control*. For each component a sum scale was developed by averaging the individual items. For the two multi-items scales, Cronbach's alpha was calculated to assess their internal consistency. For the first component, assessing *engagement*, alpha measured 0.97 (N=200, 7 items). For the second component, assessing *control*, alpha measured 0.91 (N=200, 5 items). For both components alpha measured above the critical threshold of .70 (Carmine and Zeller 1979) indicating that the items reliably assessed one component, namely experienced engagement and control respectively.

Table 3.6. Results of the principal component analysis with varimax rotation on the items measuring control and engagement.

| | 1 | 2 |
|---|---|---|
| Challenge | .932 | |
| Excitement | .911 | |
| Engagement | .891 | .350 |
| Motivation | .861 | .401 |
| Pleasure | .850 | .354 |
| New possibilities | .733 | .355 |
| Skill-development | .718 | .504 |
| Control | | .858 |
| Ease | | .840 |
| Efficiency | .477 | .773 |
| Self confidence | .397 | .749 |
| Playability | .492 | .719 |
| Eigenvalue | 8.27 | 1.5 |
| %Variance explained | 68.90% | 12.08% |

N=200. Factor loadings < .3 are omitted

### *Experimental effects on control and engagement*

As a third step, it was investigated to what extent the experimental conditions affected the levels of experienced *control* and *engagement*. In the Increasing and Decreasing richness conditions, the judgments for games with richness rank 4 and 6 - that were played twice in a row – were grouped together by taking the mean score of the two succeeding playing sessions.

Figure 3.9 shows the relation between experienced *control* and *engagement* as a function of Increasing richness and Decreasing richness. In general, the scores on experienced control and engagement did not vary much between the Increasing and Decreasing richness conditions except that for two games having high levels of richness (Rank 6 and 8) these games were experienced both higher on the levels of experienced control and engagement for the Increasing richness condition compared to the Decreasing richness condition.

Games that were experienced as increasingly rich were initially found to increase the levels of experienced control and engagement. Subsequently, the levels of experienced control decreased while experienced engagement still grows. Finally, both control and engagement decrease with increased richness. It has already been noted that playing some of the games with high richness levels as the last ones led to higher levels of experienced control and engagement compared to playing these games first.

Figure 3.10 shows the relation between experienced control and engagement for the High richness and Low richness conditions. Looking at the High richness condition, it appears that when the number of playing sessions increased the levels of experienced *control* initially increased after which it decreased. At the same time, the levels of experienced *engagement* initially fluctuated at intermediate levels but

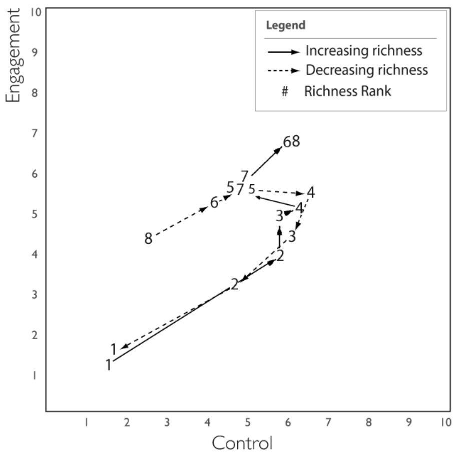



Figure 3.9. Levels of experienced control and engagement for the Increasing and Decreasing richness conditions. Games with varying richness levels are plotted in a two-dimensional space with experienced control depicted on the x-axis and experienced engagement plotted on the y-axis. Numbers represent Richness Rank. The arrows point towards games that were played further in time.

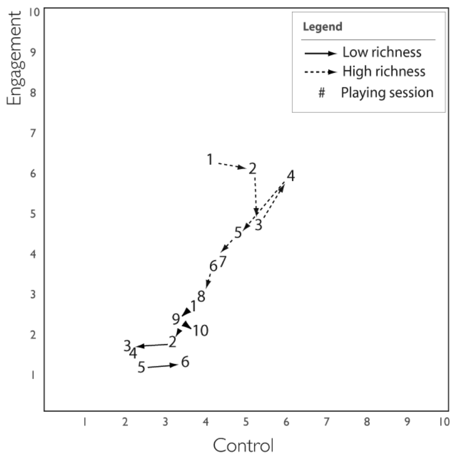



Figure 3.10. Levels of experienced control and engagement for the High and Low richness conditions. Games having richness rank 8 in the High richness condition and richness rank 1 in the Low richness condition are plotted in a two-dimensional space with experienced control depicted on the x-axis and experienced engagement plotted on the y-axis. Numbers represent Playing session. The arrows point towards games that were played further in time.

then also decreased. Looking at the Low richness condition, the levels of experienced *control* and *engagement* always remained at low levels during all playing sessions.

## *Regression Analysis*

The final step involved an analysis of the relationship between experienced *richness*, *control* and *engagement*. Given the observations that (1) engagement is high when richness and control are high (2) that engagement is low when richness and control are low and (3) engagement is low when richness is high and control is low, experiences of richness and control are thought to accumulate into experiences of engagement via a multiplication rule. When the product of richness and control is normalized to a scale from 1 to 10, the following formula evolved: $E = R^{0.5} C^{0.5}$. When this formula was used to correlate the predicted levels of experienced engagement with the actual mean scores of experienced engagement for the Increasing richness and Decreasing richness conditions, this formula led to a correlation value of .977 ($N=16$, $p < .000$).

## General discussion

Based upon the experimental results a conceptual framework is proposed that links engagement to richness and control. Taking also into account the influence of product features and user expertise. Figure 3.11 shows a graphical representation of the framework. The framework identifies the experiences of richness and control as two factors of experienced engagement, which in turn are shaped by the features of the game and the expertise of a player. Experienced richness captures the degree in which the videogame is experienced as varied and complex while experienced control captures the extent players experience effort in the attainment of goals. More specific, the framework assumes that engagement (E) can be calculated by taking the square root of the product of experienced richness (R) and control (C): $E = R^{0.5} C^{0.5}$. Thus, the level of the experienced engagement is raised when either the level of experienced richness or control is raised or both.

In terms of the properties of the game, results showed that by increasing the amount of game features the levels of experienced richness increased which may be attributed to the increased amount of choice, expressiveness and/or sensorial stimulation that the game provided. Results also showed that increasing the amount of features of the game first increased but then decreased the levels of experienced control. The levels of experienced control could decrease when the game was experienced as increasingly rich; more effort was needed in identifying possible playing strategies and in performing them. But, the levels of experienced control could also decrease because goal attainment was constrained by the physical characteristics of the game; some playing strategies were more effective or efficient than others.

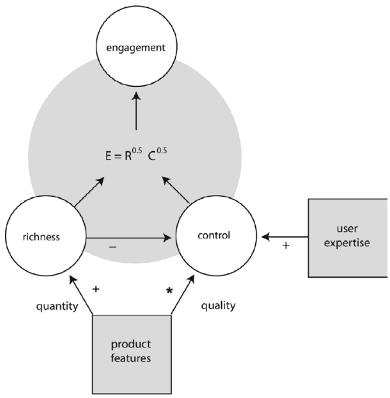


Figure 3.11. Figure showing the conceptual framework for engagement representing the amount of game features and expertise as influences on experienced engagement via experienced richness and control.

This double effect of game features on experienced control may explain the observed curvilinear effect that the manipulation of game features had on the levels of experienced control: Experienced control initially increased due to the addition of playing strategies that were objectively more effective or

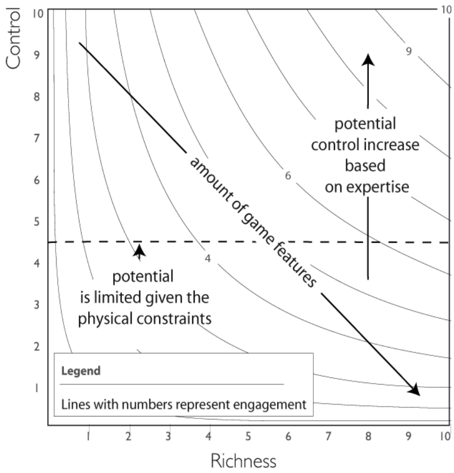



Figure 3.12. Visualization of the levels of experienced engagement (curved lines) as a function of the levels of experienced richness (x-axis) and experienced control (y-axis) according to the formula: $E = R^{0.5} C^{0.5}$. Most control can be potentially gained with many product features and few physical constraints. As the maximum amount of control is reached through learning, control decreases in time due to feelings of apathy.

efficient compared to pre-existing strategies e.g., earning points or having an advantage otherwise. As the amount of game features increased further, the levels of control decreased based upon the increasing levels of experienced richness. This nonlinear, inverted U-shape function is represented in Figure 3.11 by the '*' between product features and control combined with the '-' between richness and control

In terms of the player, results showed that increased expertise increased the levels of experienced control after it decreased (Figure 3.10). The extent in which the levels of experienced control may increase in time is considered to depend upon the levels of experienced richness and upon the physical constraints of the game as described above. The richer the game is experienced and the lower the physical constraints, the more the levels of experienced control can increase in time due to increased expertise and hence the longer high levels of engagement can be maintained (Figure 3.12). Counter intuitively, experienced control was also found to decrease over time. This may be the result of feelings of apathy that arise when a person experiences a lack of control potential i.e., he/she experiences that the maximum amount of control has been attained that is physically possible.

## Conclusions

This study presented a proposal for a conceptual framework of 'Richness, Control and Engagement' that aims to support game designers in the creation of engaging games. The RC&E-framework was developed based upon experiments that were conducted in this study and in two previously conducted studies (this thesis Study I, this thesis Study II). It was found to provide predictions of the levels of experienced engagement based upon the levels of experienced richness and the levels of experienced control. Due to these empirical results, the model may be used as design knowledge in the creation of videogames.

Further, the systematic effects of the amount of game features and the players expertise on the levels of experienced richness and control seems promising in identifying objective factors that can be used in the prediction of the levels of experienced engagement. However, these factors should be defined more precisely before they can be useful in user models. For instance, a larger set of physical product descriptors and human behavior parameters should be used to predict the levels of experienced engagement directly without the need to assess the levels of experienced richness and control as intermediate steps. Upcoming studies will further develop the framework on each of these levels.

## Acknowledgements

This study was carried out as part of the research program of the ICT-Delft Research Centre. Thanks to: Peter Craig for developing the prototype and for carrying out the experiments; Anneke Nipius and Rosalind Boschloo for their help in developing the concept of richness and for their help in gaining knowledge about the application of richness into design. Finally, the authors would like to thank the other members of the ID-Studiolab for their input and inspiration.

Study IV is based upon the article:
Rozendaal, M.C., Keyson, D.V., Ridder, H. de: Product features and task effects on experienced richness, control and engagement in voice mail browsing. *Submitted.*

# STUDY IV

A recent focus in developing innovative products is on creating engaging user experiences with digital products and services such as voicemail. This study aims to design towards increased levels of engagement in voicemail browsing by using the ‘Richness, Control and Engagement framework (RC&E)’. This framework explains the levels of engagement via the levels of richness and control that are shaped by the features of a product and user’s expertise. A product was developed that utilized gestures and sound to access digital voicemail contents. An experiment was conducted in which 28 participants interacted with the product while varying (1) the amount of features of the user interface, (2) the amount of voicemail content and (3) the type of task. Results showed that the levels of engagement could be predicted according to levels of experienced richness and control when a task-term was added to the framework. Implications of the refined RC&E-framework for interaction design practice are discussed.

## Introduction

Within the design of new digital products and services, increased attention is given to experience of engagement. In the terminology of Quesenbery, engagement is defined as: “…the degree to which the tone and style of the interface makes the product pleasant or satisfying to use” (Quesenbery 2005, p. 86). Product attributes such as *tone* and *style* can be seen as hedonic attributes relating to the intrinsic stimulation of a product that are seen as distinct from pragmatic attributes relating to the proper functioning of a product (Hassenzahl 2004). These style aspects have become increasingly important since digital products are moving from professional environments into our everyday lives (Hallnäs and Redström 2002, Norman 2004). However, engagement remains an evasive concept given the multitude of terms that are used to describe it (Lindgaard and Dudek 2003, Hornbæk 2006).

A framework of 'Richness, Control and Engagement (RC&E)' was developed in order to assess the qualities of the experience of engagement to identify the factors that influence it (this thesis: Study III). The preliminary experiences of the framework were positive: The framework was found helpful in designing towards engagement in a videogame due to its predictive power and due to its openness to allow freedom in the creation of design solutions. However, given that the RC&E-framework was found to be useful during experiential tasks (free play) it might not be useful during goal-directed tasks (use). In this study, the RC&E-framework is applied in the domain of voicemail browsing as a means to (1) design digital products towards increased levels of experienced engagement and (2) to examine if the RC&E-framework holds its predictive power during goal-directed tasks.

In short, the RC&E-framework explains the levels of experienced engagement via the levels of experienced richness and control, which are shaped by the features of a product and the expertise of a person. Engagement assesses the extent an activity is intrinsically enjoyable and arises when the activity supports the *functioning* and *growth* of an individual (Rogers 1951, Maslow 1970, Deci and Ryan 2000). During engagement, a range of positive emotions can be experienced such as feelings of excitement, freedom and enjoyment, and time and energy is willingly invested (Malone 1981, Laurel 1991, Jacques et al 1995, Webster and Ho 1997, Chapman et al 1999, Chen et al 1999, Csikszentmihalyi 1990, Ellis et al 1994). Richness captures the growth-potential of an activity by assessing the variety and complexity of *thoughts*, *actions* and *perceptions* as they are evoked during the activity (Fiske and Maddi 1961, Moles 1966, Berlyne 1971, Varela et al 1991, Rozendaal et al 2007:1, Study III). The higher the levels of experienced variety and complexity, the higher the levels of experienced richness. Control captures the extent a person is able to actualize these growth-potentials by assessing the effort that is experienced in the selection and attainment of goals (Skinner 1996, Ajzen 2002). The more effort is experienced, the lower the levels of experienced control. An activity is considered optimally engaging when the activity affords high levels of experienced richness and control i.e., the activity affords growth-potentials that can be actualized. More specifically, the levels of engagement could be predicted by taking the square root of the product of experienced richness and control (Figure 4.1).

Experiences of richness and control are shaped by the features of a product and the expertise of a person (Douglas and Hargadon 2001, Lindley 2004, this thesis: Study III). In the current study, the focus is on the influence of product features on the levels of experienced richness and control. Product features can include *functional* aspects i.e., the possibilities of the digital product, *manipulation* aspects i.e., the responsiveness of the product to the actions of a person, and *appearance* aspects i.e., the presentation of the product (Barfield et al 1994, Fabricatore et al 2002). Function, manipulation and appearance aspects can vary independently in digital products due to digital mediation (Wensveen 2005).

Varying product features on the functional, manipulation and appearance aspects influences the levels of experienced richness across mental, behavioral and sensorial levels respectively. For example, the game of Chess is considered a mentally richer game compared to the game of Tic-Tac-Toe since the game of Chess allows more *choice* (Manninen 2000, Schwartz 2000). Playing Chess by moving physical pieces across a three dimensional space is considered behaviorally richer compared to playing Chess by typing in the coordinates via push buttons since the game allows more *expressiveness* in physical action (Djajadiningrat et al 2000, Ullmer and Ishii 2000). Playing Chess with chess pieces that are visually presented in high level of detail are considered sensorially richer compared to chess pieces that are represented in a minimal abstract form since the game allows more *sensorial stimulation* (Steuer 1992, Pirhonen 1998, Sutcliffe 2002). A previously conducted study showed that the experienced behavioral and sensorial richness could be integrated into overall richness judgments via an additive rule (Anderson 1990, Rozendaal et al 2007:1).

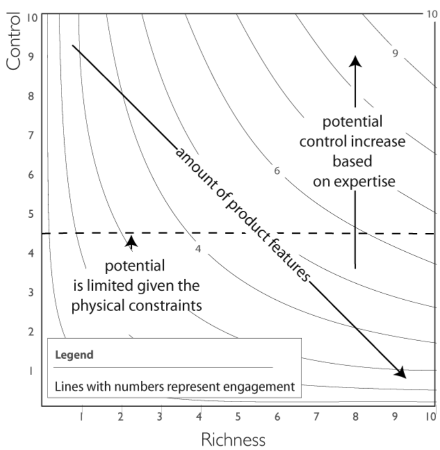


Figure 4.1. Visualization of the levels of experienced engagement (curved lines) as a function of the levels of experienced richness (x-axis), experienced control (y-axis) according to the formula: $E = R^{0.5} C^{0.5}$. The levels of experienced engagement increased when the levels of experienced richness and/or the levels of experienced control increased. Increasing the amount of product features led to increased levels of experienced richness and to decreased levels of control. Further, levels of control could decrease according to the extent the product physically constrained goal-attainment. The levels of control could increase in time as users' expertise increased.

Similarly, varying product features on functional, manipulation and appearance aspects influences the levels of experienced control across mental, behavioral and sensorial levels. Product functions provide *goals*, product manipulation provides *pathways* to goals and product appearance provides *information* about goals (Skinner 1996). A previously conducted study showed that the levels of experienced control decreased in two different ways i.e., an objective and subjective manner (this thesis: Study III). One, experienced control could decrease when the product physically constrained interaction i.e., product features did not have the required functions, pathways and/or information to attain a goal or to attain a goal in an efficient manner. Two, experienced control could decrease when a person lacked expertise to attain goals with the product. He/she then had trouble in understanding the product functions, performing actions that are needed in product manipulation and attuning to the appropriate product information. Increased expertise resulted in increased levels of experienced control given that this increase was possible given the product's physical constraints.

The RC&E-framework was developed for games during experiential tasks. During these tasks a person could pursue goals freely as they emerge from the features of the product and a person was free to start or stop playing at will (Levy 1972, Caillois 2001). During goal-directed tasks however, goals are bound by the goal for which the product is used and these goals should be met within a certain time frame. In this situation, the levels of experienced control may be more influential in the levels of experienced engagement compared to the levels of experienced richness. Further, the relationship between the amount of product features and the levels of experienced richness and control may be affected due to changes in goals (Skinner 1996), focus of attention (Wickens 1992, Kahneman 1973) and behavior (Berlyne 1971).

When engagement is discussed within the domain of voicemail browsing both types of tasks should be included since people may experience products as things in themselves i.e., *toys*, or as things for something else i.e., *tools* (Hassenzahl et al 2002, Monk 2002, Novak et al 2003). Further, consideration should be given to the effects the user interface and the content of the product have on the levels of experienced engagement. Both the user interface and the content interact in terms of the overall product features since both transform each other (Ishizaki 2003). For example, a website of an on-line store might be considered engaging since sound and animation is used to represent the virtual products. However, as the amount of products within the virtual store increase, the levels of engagement may decrease since the total amount of sounds and animations become overwhelming. In this case, a user interface that represents virtual products by a visual image only may lead to high levels of engagement.

To examine to what extent the user interface and the content of a digital product affect the levels of experienced richness, control and engagement during experiential tasks vs. goal-directed tasks, a prototype of a voicemail application was developed. Following the framework, voicemail browsing can be designed towards high levels of experienced engagement in play by designing products towards increased levels of experienced richness and control. However, it is not yet clear if the levels of engagement are increased similarly during goal-directed tasks compared to experiential tasks and how the user interface and content in combination affect the levels of experienced richness and control across both types of tasks.

# Method

## Prototype

A novel voicemail machine was developed that uses gestures and sound to access voicemails. Previous studies showed that various types of information could be represented in sound (Kramer 1994, Brewster et al 1993). Further, gestures combined with sound feedbacks can be effectively used to access digital information such as music (Pirhonen 2002, Bruns Alonso and Keyson 2005, Rekimoto 2001). A previously conducted study identified the three most relevant voicemail properties for voicemail browsing (Rozendaal and Keyson 2006). These were; (1) the sender of the voicemail message, (2) the time the voicemail message was sent and (3) the level of urgency of the voicemail message. These properties were used to drive the design of the sounds in the current study. In terms of the sender property, three senders were defined: *Henk*, *John* and *Anna*, in terms of the reception date, three date/time categories were defined: *Yesterday*, *today*, and *most recent*, in terms of the urgency of the message, three levels were defined: *Chitchat*, *informative* and *urgent*. These voicemail properties formed the basis for distinguishing voicemails from each other.

The voicemail machine consists of a physical product that serves as the basis upon which gestures and sound are added (Figure 4.2). The physical product has a circular form that is 230 mm. in diameter and 70 mm. in height and has 16 slots along the ridge and 1 slot within the products centre. Voicemail messages can be stored virtually above the spaces of the physical slots along the ridge. Messages can be accessed by performing gestures with an input device above the slots.

Figure 4.2. Picture of the physical product within its physical context. The physical product has a circular form, with 16 slots along the ridge and one slot within the products centre. Voice mail messages may be stored within one of the 16 voice mail slots and can be accessed by performing gestures above the product. The middle slot serves as a base for the input device.

The input device has a rod-like form that is 40 mm. in diameter and is 55 mm. in height. The slot in the middle of the product serves as a base for the input device.

Three versions were designed that varied in the way voicemail properties were represented in sound and how gestures influenced these sounds. Sound-feedbacks were used to inform the user about the before mentioned voicemail properties during browsing and to inform the user about the locations of the physical slots in which voicemails are stored within the physical product. In this sense, the gestures (manipulation) and sound (appearance) can be seen as the *user interface* embodying the voicemail *content* (function). The three versions are described in more detail below (Table 4.1).

With user interface I, spoken voice mail messages are heard when the input device is placed closely above the physical slots where the voice mails are stored. When this is the case, the voice mail message starts playing at the beginning of the message and stops playing when the input device is removed above the physical slot. Voice mail properties such as sender, reception date and urgency are communicated directly through the spoken message via the voice of the sender and the subject of the message intonation of the speaker. In terms of sender, the voice mails were recorded using two male and one female voice. In terms of reception date, a second female voice states the time the message was received before the message starts and in terms of urgency the actors carefully choose content and applied intonation to fit the message into three categories of urgency. This user interface can be characterized as a discrete selection tool given that one voice mail may be heard at a time.

With user interface II, additional sounds can be heard that complement the spoken voice mail messages. These sounds involve material impact sounds, which are elicited when the input device enters virtual rod-like regions that extends upwards from the physical slots. Voice mail properties (sender, time, and urgency) are translated into timbre, volume, and pitch, respectively. In terms of the sender, a bell-like, wood-like and water-like impact sound was used. In terms of reception date, volume differences were used. The volume levels for older voice mails were lower than for the more recently received ones. Urgency was communicated by pitch differences. This user in-

Table 4.1. Overview of user interfaces I-III. With each successive user interface, gestures and sound feedbacks are added.

User Interface I [a]

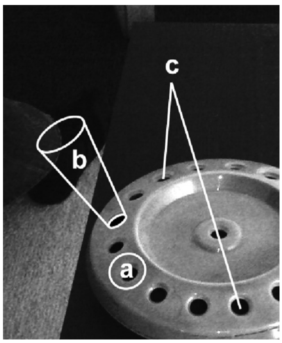
Gestures result in discrete onsets of spoken voice mail messages when the input device is directly placed above the physical slots where the voice mails are stored.

User Interface II [a + b]

Additionally to user interface I, gestures result in discrete onsets of materialistic sounds when the input device is placed within virtual rod-like regions that extend upward from the physical slots.

User Interface III [a + b + c]

Additionally to user interface II, gestures result in volume changes of multiple and continuous sounding spoken voice mail messages. The volume level of an individual voice mail message increases when the input device approaches the physical slot where it is stored.



terface can be characterized as a discrete selection tool combined with a musical instrument given that a variety of sounds can be created by gesturing above the product.

With user interface III, multiple sounding voices are given additionally to the previous sound-feedbacks described above. Voice mail properties such as sender, reception date and urgency are communicated directly through the spoken message. The volume levels of the voice mail samples are mapped to the distance between the input device and the physical slots. Thus, at a given location of the input device above the physical product, multiple spoken voice mail messages can be heard simultaneously having different volume levels. By moving the input device closer to a physical slot, the volume-level of the voice mail stored at that location increases accordingly. This user interface can be characterized as a discrete selection tool and a musical instrument combined with a chattering box given that multiple people can be heard chatting.

## Experimental design

The experiment was set-up as a full factorial design having three levels of User interface, three levels of Content and two types of Tasks. User interface and Content varied *within* participants and Task type varied *between* participants. User interface was manipulated by varying the amount of gestures that resulted in sound feedback and by varying the amount of sounds in which the voice mails appeared simultaneously. Content was manipulated by varying the amount of voice mails that were stored within the product and ranged from one and six to twelve voice mails. Task type was manipulated by asking half of the participants to play freely with the product and by asking the other half to use the product in a search task. The nine experimental conditions were presented to the participants in a random order.

## Participants

Twenty-eight subjects participated in the experiment. The participants were told the experiment was about evaluating a voice mail machine. The participants were randomly selected from a consumer evaluation panel database consisting of a diverse range of people living within the vicinity of the Delft University of Technology and received seven euros for their participation. Participants' ages ranged between 24 and 49 years, with an average age of 41 years and a standard deviation of seven years. Of the participants, 12 were women and 16 were men.

## Procedure

Participants were told that the goal of the experiment was to evaluate a novel voice mail machine. Before the experiment started the participants were explained that voice mails could be accessed by performing gestures above the tangible product that resulted in sound feedback. The participants were explained the voice mail properties i.e., sender, reception date and urgency, and their representation in the spoken voice mails and in the material sounds. Hereafter, participants were asked to interact with the voice mail machine in nine different sessions without prior training. In each experimental condition, the voice mails were randomly distributed around the tangible product. During experiential tasks, participants were free to play with the product and could stop playing at will. During goal-directed tasks, participants were given the task to locate a specific voice mail as efficiently as possible within 30 seconds. For instance, the experimenter could ask a participant to locate a voice mail message that Anna sent yesterday or to locate John's most urgent voice mail message. After each session, participants were asked to fill in a questionnaire and the experiment was concluded with a five-minute interview.

## Measures

In the current study, both behavioral and experiential measures were taken. In terms of behavior, *playing-time* was measured during experiential tasks as an indicator of intrinsic interest. Playing time was defined as the time between the start of the session until the moment the participant willingly ended the session. Participants could play for a maximum of three minutes. *Search time* and the *percentage of errors* were measured during goal-directed tasks as indicators of performance. Search time is defined as the time between the beginning of the task and the moment the participants identified target voice mails. Participants were given a maximum of 30 seconds per search task. An error was defined as the identification of an erroneous voice mail and its percentage was calculated across participants.
In terms of experience, a questionnaire and a structured interview were used. The questionnaire was used to assess the levels of experienced *richness*, *control* and *engagement* via 17 items on a ten-point scale. Richness included items assessing the extent *variety* and *possibilities* are experienced (Berlyne 1971, D'Ambra 1998, Chapman et al 1999). Control included items assessing *clarity*, *ease* and *self-confidence* (Bandura 1988, Ajzen 2002, Skinner 1996, Hedman and Sharafi 2004, White 1961). Engagement included items assessing *excitement*, *challenge*, *enervation*, *stimulation*, *enjoyment*, *fun*, *motivation*, *free-*

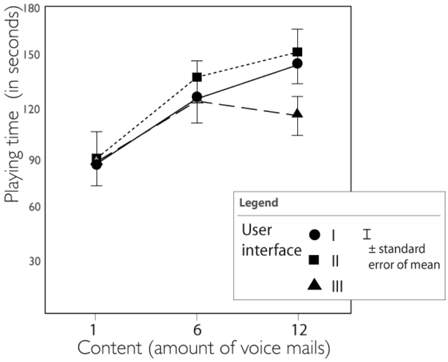



Figure 4.3. Mean scores of playing time across the User interface and voice mail Content conditions during Experiential tasks.

*dom* and *personal style* (Laurel 1996, Jacques et al 1995, Webster et al 1993, Chapman et al 1999, Garris et al 2002, Csikszentmihalyi 1990, Malone 1981). After each experimental condition, the questionnaire was filled in. The experiment was concluded with a structured five-minute interview in which participants could elaborate on their experiences.

# Results

## Behavior

Two separate analyses of variance were conducted to examine to what extent the User interface and the Content manipulations affected playing time during Experiential tasks and to what extent search time and percentage of errors were affected during Goal-directed tasks. During experiential tasks, increased amounts of voice mail Content led to increased amounts of *playing time* (Figure 4.3). No effect of the User interface on playing time was found. However, User interface version III decreased playing time when Content increased from 6 to 12 voice mails (Figure 4.3) but this effect was not significant (Table 4.2). During goal-directed tasks, increased amounts of voice mail Content led to increased *search time* (Figure 4.4) and led to an increased *percentage of errors* (Figure 4.5). These effects were at significant levels (Table 4.3) and indicate that search behavior becomes increasingly less effective and efficient as voice mail Content increases.

## Principal component analysis

To investigate participants' experience of the experimental conditions, a principle component analysis was performed to find the components underlying the assortment of questionnaire items. Three components were extracted that explained about 72 percent of the variance (Table 4.4). The first component was interpreted as a component related to

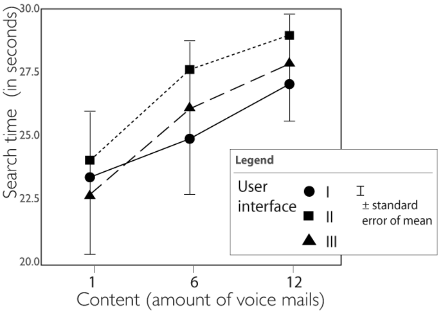



Figure 4.4. Mean scores of search time across the User interface and voice mail Content conditions during goal-directed tasks.

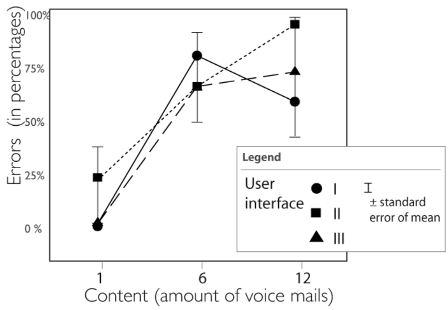



Figure 4.5. Mean percentage of the amount of errors across the User interface and voice mail Content conditions during goal-directed tasks.

*engagement*. The engagement component captured groups of items assessing enjoyment, excitement and freedom. The second component was interpreted as a component related to *richness*. The richness component captured variety, possibilities and enervation. The third component is interpreted as a component related to *control* and captured self-confidence, ease and clarity. The group of enjoyment and excitement items loaded on both the engagement and richness component. The items assessing freedom and personal style loaded on both the engagement and control component.

For experienced *richness*, *control* and *engagement*, sum scales were developed by grouping the individual items according to their highest loadings. For each sum scale, Cronbach's alpha was calculated as a measure of internal consistency. For the component assessing

Table 4.2. Effects of User interface and Content during Play on playing time.

| | *Playing time* | |
|---|---|---|
| User interface | $F_{(2,26)} = 1.944$ | $p<.163$ |
| Content | $F_{(2,26)} = 30.996$ | $p<.000$* |
| User interface x Content | $F_{(4,52)} = 1.448$ | $p<.232$ |

Table 4.3. Effects of User interface and Content during Use on search time and the amount of errors.

| | *Search time* | | *Errors* | |
|---|---|---|---|---|
| User interface | $F_{(2,26)} = 1.438$ | $p<.256$ | $F_{(2,26)} = 1.099$ | $p<.348$ |
| Content | $F_{(2,26)} = 6.222$ | $p<.006$* | $F_{(2,26)} = 19.580$ | $p<.000$* |
| User interface x Content | $F_{(1,13)} = 0.138$ | $p<.968$ | $F_{(1.13)} = 1.057$ | $p<.387$ |

* p<..05

Table 4.4. Results of Principle components analysis with Varimax rotation given the items measuring richness, control and engagement.

| | 1 | 2 | 3 |
|---|---|---|---|
| Engagement | .792 | | |
| Fun | .756 | .361 | |
| Motivation | .750 | .426 | |
| Enjoyment | .722 | .459 | |
| Challenge | .702 | .526 | |
| Excitement | .690 | .540 | |
| Freedom | .632 | | .429 |
| Stimulating | .608 | .595 | |
| Personal style | .554 | | .547 |
| Enervating | .474 | .680 | |
| Possibilities | | .803 | |
| Variety | | .796 | |
| Richness | | .735 | |
| Control | | | .865 |
| Self confidence | | | .856 |
| Ease | | | .829 |
| Clarity | | | .825 |
| Eigenvalue | 8.16 | 3.01 | 1.09 |
| %Variance explained | 48.00% | 17.75% | 6.41% |

N=252 (14 participants × 3 Browsing styles × 3 Amount of voice mails × 2 types of Interaction). Factor loadings < .3 are omitted.

*richness* alpha measured 0.83 (N=252, 4 items), for the component assessing *control* alpha measured 0.90 (N=252, 4 items) and for the component assessing *engagement* alpha measured 0.93 (N=252, 9 items). For all components alpha measured above the critical threshold of .70 indicating that each group of items measured a similar construct and that they could be grouped (Carmine and Zeller 1979).

## MANOVA

A multivariate analysis was conducted to examine to what extent User interface, Content and Task type influenced the levels of experienced richness, control and engagement. Results showed that by increasing the amount of voice mail Content, the levels of experienced *richness* increased and the levels of experienced *control* decreased (Figures 4.6 and 4.7). No significant differences were found for the Content manipulations on *engagement* (Figure 4.8). Further, Using the product led to lower levels of experienced *control* compared to Playing with the product (Figure 4.7). Additionally, Task type and Content were found to affect the levels of experienced *richness* in combination. While increasing the amount of voice mail Content during play, the levels of experienced richness increased. However, increasing the amount of voice mail Content during use did not increase the levels of experienced richness (Figure 4.7). All of these effects were at significant levels (Table 4.5). No significant effects were found for the User interface manipulations on any of the experiential measures: The user interfaces may not have varied much given that the user interfaces relied to a large extent on voicemail content given the gestures and sounds.

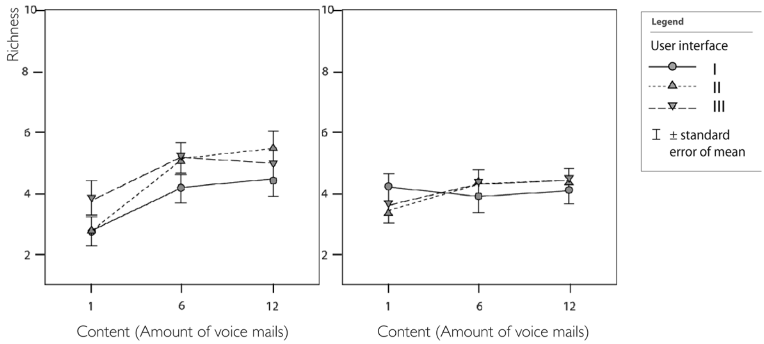



Figure 4.6. Figures showing the levels of experienced richness as a function of Content, User interface and Task type. Experiential tasks (left) and Goal-directed tasks (right).

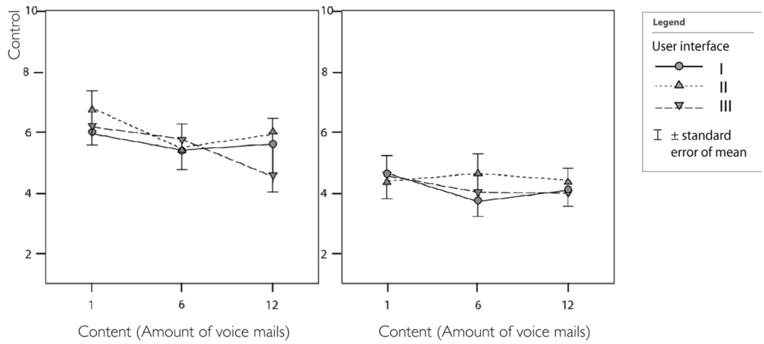



Figure 4.7. Figures showing the levels of experienced control as a function of Content, User interface and Task type. Experiential tasks (left) and Goal-directed tasks (right).

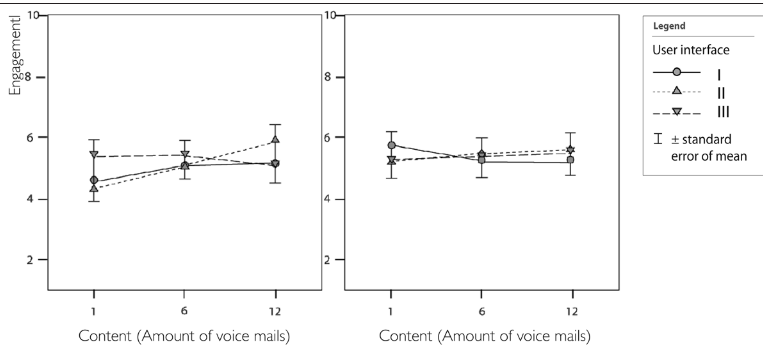



Figure 4.8. Figures showing the levels of experienced engagement as a function of Content, User interface and Task type. Experiential tasks (left) and Goal-directed tasks (right).

## Correlation

Figure 4.9 depicts the levels of experienced engagement (curved lines) as a function of the levels of experienced richness (x-axis) and experienced control (y-axis) according to the formula: $E = R^{0.5} C^{0.5}$. Mean scores of all 18 experimental conditions are plotted in this space. When the RC&E-framework is applied on the scores it appears that the levels of engagement could not be predicted according to this formula ($r=.237$, $p < .343$). However, a closer examination revealed that when regression lines are drawn between the actual levels of experienced engagement and the predicted levels of experienced engagement for experiential and goal-directed tasks separately the resulting regression lines were nearly parallel (Figure 4.10). This indicates that the levels of experienced engagement could be predicted by the addi-

Table 4.5. Effects of User interface, Content and Task type on experienced richness, control and engagement.

| | *richness* | | *control* | | *engagement* | |
|---|---|---|---|---|---|---|
| User interface | $F_{(2,52)} = 1.738$ | p<.178 | $F_{(2,52)} = 2.523$ | p<.090 | $F_{(2,52)} = 0.486$ | p<.618 |
| User interface × Task type | $F_{(2,52)} = 1.585$ | p<.215 | $F_{(2,52)} = 0.206$ | p<.814 | $F_{(2,52)} = 0.514$ | p<.585 |
| Content | $F_{(2,52)} = 13.729$ | p<.000* | $F_{(2,52)} = 4.962$ | p<.011* | $F_{(2,52)} = 2.311$ | p<.109 |
| Content × Task type | $F_{(2,52)} = 4.272$ | p<.019* | $F_{(2,52)} = 0.592$ | p<.557 | $F_{(2,52)} = 1.919$ | p<.157 |
| User interface × Content | $F_{(4,52)} = 2.178$ | p<.077 | $F_{(4,52} = 1.818$ | p<.324 | $F_{(4,52)} = 1.904$ | p<.115 |
| User interface × Content × Task Type | $F_{(4,104)} = 1.075$ | p<.373 | $F_{(4,104)} = 1.823$ | p<.130 | $F_{(4,104)} = 1.475$ | p<.215 |
| Task type | $F_{(1,26)} = 0.248$ | p<.623 | $F_{(1,26)} = 7.176$ | p<.013* | $F_{(1,26)} = 0.325$ | p<.574 |

* p<.05

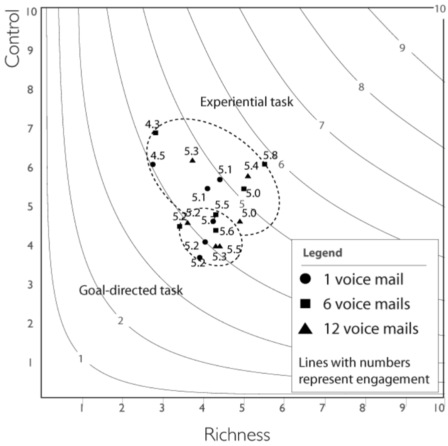



Figure 4.9. Figure showing the levels of experienced engagement (curved lines) as a function of the levels of experienced richness (x-axis) and experienced control (y-axis) according to the formula: $E = R^{0.5}\ C^{0.5}$. Mean scores of all 18 experimental conditions (User interface × Content × Task type) are plotted in this space. The numbers at the plots represents the assessed levels of engagement not the predicted ones based upon the before mentioned formula.

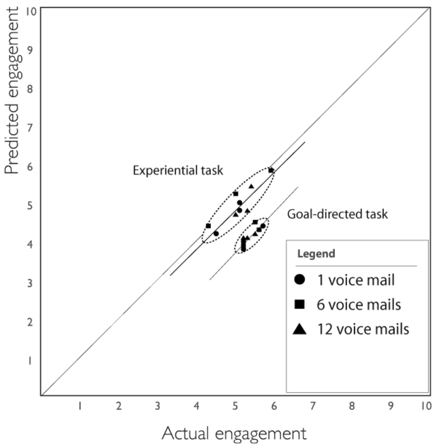



Figure 4.10. Figure showing the scores of User interface, Content and Task type on the actual levels of experienced engagement (x-axis) and on the predicted levels of experienced engagement (y-axis). For both types of tasks, regression lines are calculated. From the figure it can be seen that the regression lines appear to be parallel suggesting that the effect of Task type on the model is an additive one.

tion of a constant factor to the formula. This factor was calculated for Experiential tasks at .10 and for Goal-directed tasks at 1.42. When the factor was included in the formula, almost 80 percent of the total variance could be explained ($r = .886$, $r2 = .785$, $p < .000$).

# Discussion

The results showed that the 'Richness, Control and Engagement framework (RC&E)' was able to predict the levels of experienced engagement in voice mail browsing based upon the levels of experienced richness and control and based upon the addition of a task factor. According to the framework, the levels of experienced engagement increased with increased levels of experienced richness and increased levels of experienced control. Further, with increased amount of product features, the levels of experienced richness were found to increase and the levels of experienced control were found to decrease.

During goal-directed tasks, the predicted levels of experienced engagement following the formula: $E = R^{0.5} C^{0.5}$ were found to be systematically lower than the actual levels of experienced engagement indicating the task may have a level of engagement in itself that should be added to the formula: $E = R^{0.5} C^{0.5} + task$. The value of this task factor might depend upon the levels of experienced control, which decreased due to the addition of external demands. Decreased levels of experienced control based upon the difficulty of meeting goals, should hypothetically result in higher levels of experienced engagement. However, it can be expected that engagement may not increase and may even decrease when the levels of control are lowered further given that products having less voice mail content seemed to increase in levels of engagement during goal-directed tasks while products having more voice mail content did not increase.

Further, the task was found to influence the levels of experienced richness based upon the amount of product features. Participants may have been more sensitive to the variety of product features during experiential tasks compared to goal-directed tasks since the focus of attention was broader and behavior more explorative. Some support was found for this explanation since some participants who browsed voicemails during goal-directed tasks expressed during the interview that they were unaware of the material sounds. Either they did not explore these sound feedbacks resulting in a lower elicitation of these sounds or did not notice them during goal-pursuit.

Besides the influence of the amount of product features on the levels of experienced richness and control, the *randomness* of the product and the *playfulness* of the participants should be taken into account. Distributing voice mails randomly over the physical voice mail slots caused confusion since participants searched for a systematic ordering. Further, minor system fluctuations in the tracking technology resulted in that spatial locations in which sound feedbacks were given were not always directly aligned with the spatial location of the corresponding physical slots. Since sound was the only source of information in the identification of a location of a voice mail, both forms of randomness were experienced as very confusing. The levels of experienced control might considerably increase when these two manifestations of randomness are cancelled out. Lastly, individuals' playfulness was found to influence the levels of experienced engagement. Since it was observed that some participants were very performance oriented during experiential tasks, others remained relaxed. The opposite was found during goal-directed tasks. It seems that people are able to vary how they respond to the given context indicating that people's behavior may still be playful during highly demanding tasks (Chung and Chan 2004).

## Conclusions

This study showed that the RC&E-framework could be applied to design engagement in voice mail browsing by taking into account the levels of experienced richness and control that are based upon product features and the type of task. Product features may lead to experiences of engagement in voice mail browsing by providing rich and varied experiences and by providing means to find voice mails with ease. Voice mail browsing can lead to higher levels of experienced engagement when a clear goal has been set. This may explain why games that are experienced as not very engaging based upon its product features during experiential tasks may be engaging when these games are played in competition with oneself or with others.

The results seem difficult to generalize to real-world product use in which the outcome of the activity can have serious consequences, such as products that are used in surgery or money transactions. It does not seem plausible that in this case engagement increases when the level of experienced control decreases. A more suitable explanation could be that the task factor affects the relative weights that richness and control have towards engagement. The relative weight of control may increases when increased importance is given to meeting goals. Future studies should be conducted to develop the framework further by including all three relevant factors i.e. the amount of product features, the person's expertise and type of task in a study simultaneously. In this way, the interactions between these factors on the levels of richness, control and engagement can be investigated. Further, the framework should be investigated within a naturalistic setting to capture the actual concerns people have when a product is used towards a specific goal and to examine when people in fact play with the product. Longitudinal studies are needed to investigate the effect of a person's expertise in more detail. In this way, the RC&E-framework will increase in its usefulness for interaction design practice.

## Acknowledgements

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# RESULTS

In this concluding chapter, the main results of the four studies forming the basis of this thesis are combined into a conceptual framework. The conceptual framework, which has been named the 'Richness, Control and Engagement framework (RC&E)' aims to assist designers in creating engaging user-product interactions. The framework is meant to serve as a basis upon which future research can be built. This chapter is set-up as follows: First, the framework is presented step-by-step according to the results of the four conducted studies. Second, design recommendations are presented, which are distilled out of the framework. Third, the value of the framework for interaction design is discussed by highlighting its utility and limitation.

## The 'RC&E-framework'

In short, the RC&E-framework explains the levels of experienced engagement in interaction via the levels of experienced richness and control, which are shaped by the interplay of a product, a person and a task. More specifically, the framework includes *features* as a factor of a product. It further includes *level of expertise* as a factor of a person, and includes having an *experiential* and *goal-directed* orientation on interaction as a factor of a task. First, the essence of the experiences of engagement, richness and control will be explained in more detail. Second, it will be described how experiences of richness and control relate to the experience of engagement. Third, the various effects that a product, person and task can have on experienced richness and control will be discussed.

### Richness, control and engagement

Results across the four studies showed that experiences of richness, control and engagement can be viewed as three different experiential qualities. Subjective experience was assessed via questionnaires consisting of seven- or ten-point semantic categorical scales. Questionnaires were filled in after an interaction took place. As a consequence, the moments at which subjective experiences aroused during interaction could not be assessed. A total of 32 items were run through several principal component analyses in various combinations across the four studies. The analyses conducted were made across participants and prototypes, across varying levels of user expertise and across experiential and goal-directed tasks[2]. When these results are investigated, richness, control and engagement emerged as three components (Table 5.1) and will be discussed in more detail below.

A large multifaceted component emerging from of Studies II, III and IV, is labeled as *engagement*. Engagement is considered to assess the extent interaction was experienced as self-reinforcing: Interaction was evaluated as being self-determined and personally relevant given the inclusion of the items assessing *freedom* and *personal style*. Interaction was considered self-constructive; spurring on the development of skills and knowledge given the inclusion of the items assessing *stimulation*, *excitement*, *challenge*, *skill development* and *new possibilities*. These processes were positively experienced given the inclusion of the items assessing *enjoyment*, *fun* and *motivation*. This definition of engagement is compatible with theories of intrinsic motivation that view motivating and enjoyable experiences as arising out of situations that support human functioning and growth.

A second, smaller component emerging from of Studies I, III and IV, is labeled *richness*. Richness is considered to assess the experienced elaborateness of the behavioral and sensorial aspects of interaction given the inclusion of the items assessing *possibilities* and *interactivity* and the items assessing *colorfulness* and *level of detail*. Richness further assesses a general perception of this elaborateness across these aspects given the inclusion of the items assessing *variety* and *complexity*. Further, this elaborateness relates to feelings of excitement given the inclusion of the items assessing *intensity* and *enervation* and given the results of Study IV that showed factor loadings above .5 of the items assessing *stimulation*, *excitement* and *challenge* on both the engagement and richness component. Thus, from an intrinsic motivation perspective, richness can be viewed as providing the potentials for personal growth.

[2] Experiential tasks were manipulated by asking participants to experience or explore the products/games without time constraints. Goal-directed tasks were manipulated by asking participants to attain a specific goal. In Study III, this goal (earning points) could be freely pursued in time while in studies II and IV this goal (pot balls or find voicemails) had to be attained within a limited amount of time.

Table 5.1. Table showing the grouping of items across the three components combined from Studies I-IV represented within alphabetical order.

| Engagement | Richness | | Control |
|---|---|---|---|
| Challenge | Complexity | | Clarity |
| Engagement | Enervating | | Control |
| Enjoyment | Intensity | | Ease |
| Excitement | Richness | | Efficiency |
| Freedom | Variety | | Playability |
| Fun | | | Self confidence |
| Motivation | Freedom in action | Colorfulness | |
| New possibilities | Interactivity | Form diversity | |
| Personal style | Level of influence | Level of detail | |
| Skill development | Possibilities | | |
| Stimulation | | | |

A third component emerging from Studies II, III and IV, is labeled *control*. Control is considered an element to assess the effort with which goals can be attained during interaction and is based upon the connection between an agent and physical features mediated by goals. Experiences of control are considered to decrease when increased effort is experienced in attaining goals. Control is considered to assess the effort between an agent and his/her goals given the inclusion of the items assessing *ease* and *clarity*. Further, control is considered to assess the effort based upon physical features and goals given the inclusion of the items assessing *efficiency* and *playability*. Experiences that correspond with experiences of control are assessed by the inclusion of the item assessing *self-confidence* and given the results of studies III and IV that showed factor loadings above .4 of the items assessing *skill development*, *freedom* and *personal style* on both the engagement and control component. Thus, from an intrinsic motivation perspective, control influences engagement by assessing the extent the potentials that richly experienced interactions provide can be actualized.

Given the observation that during *playful* interactions in which people were free in time to experience, explore and pursue goals without time constraints, (1) engagement is high when richness and control are high (2) that engagement is low when richness and control are low and (3) engagement is low when richness is high and control is low, experiences of richness and control are thought to accumulate

Table 5.2. Table showing the results of regression analysis of Studies II, III and IV.

| | N | r | $r^2$ | Adj. $r^2$ | Std. error | p< |
|---|---|---|---|---|---|---|
| Study II (game of pool) [3] | 5 | .979 | .985 | .944 | .355 | .004 |
| Study III (game of flight) [4] | 12 | .977 | .955 | .955 | .352 | .000 |
| Study II (voicemail browser) [5] | 9 | .868 | .754 | .754 | .239 | .002 |

into experiences of engagement via a multiplication rule. More specifically, results of studies I/II, III and IV showed that levels of experienced engagement (E) could be predicted reasonably well by taking the square root of the multiplication of richness[6] (R) and control (C): $E = R^{0.5}\ C^{0.5}$ (Figure 5.1 and Table 5.2).

## Product features

Results across the four studies showed that product features affected experienced engagement through experienced richness and control based upon the quantity and quality of its features. Features could vary across product's function, manipulation and appearance aspects. Product *function* referred to the digital mechanisms of a product that could either operate autonomously or operate because of user behavior. Product *manipulation* referred to the means by which a user could operate digital product mechanisms. Similar functions could be manipulated in different ways depending upon the used sensor-technology. Product *appearance*

[3] Mean scores of Study II [$E = 1.23\ (R^{0.5}\ C^{0.5}) - 0.28$] were estimated on 5 prototypes across 9 participants for the richness-scores (N=90), and across 24 participants for the control- and engagement-scores (N=120).

[4] Mean scores of Study III [$E = 0.84\ (R^{0.5}\ C^{0.5}) + 0.70$] were estimated on 12 prototypes across 10 participants for the richness-scores (N=120), and 14 participants for the control- and engagement-scores (N=112).

[5] Mean scores of study IV [$E = 1.00\ (R^{0.5}\ C^{0.5}) - 0.10$] were estimated on 9 prototypes across 14 participants for the richness-, control- and engagement-scores (N=126).

[6] Experienced richness was not assessed simultaneously with experiences of control and engagement in studies II and III. Further, experienced richness was assessed on a 7-point scale in Study II and was transformed into a 10-point scale before being used in the regression analysis.

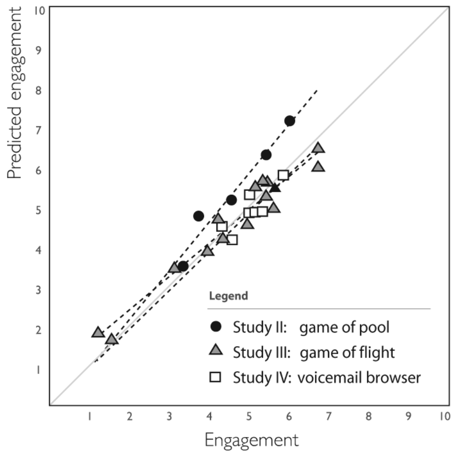



Figure 5.1. Figure showing the mean scores of the prototypes used in Studies II-IV on the assessed levels of experienced engagement (x-axis) and on the predicted levels of experienced engagement (y-axis) following the formula: $E = R^{0.5} C^{0.5}$ during play. Regression lines are calculated for all three studies and appear to approximate the line (x=y) indicating that the predicted engagement scores match well with the actual ones.

referred to the form in which functions were represented including tangible and virtual (digitally mediated) elements and could vary according to the used actuator- and media-technologies.

Results of Studies I, III and IV showed that by increasing the amount of product features the levels of experienced richness increased (Figure 5.2 and Table 5.3). By increasing the amount of functions of a product that could be directly manipulated, richness increased due to the increased amount of *choice* and *expressiveness* that was allowed in interaction. A person could discover the various product mechanisms in a direct physical manner. By increasing the amount of modalities within the appearance of the product, richness in interaction increased due to the increased amount of *sensorial stimulation*. A product could elicit sensory experiences by using color, detailed visual elements and sound within the representation of digital functions.

Results of Studies II-IV showed that with increased amount of product features the levels of experienced control slightly decreased since a product was increasingly difficult to understand (Figure 5.2 and Table 5.3). With increased amount of functions, experienced control decreased due to the increased amount of *goals* that could be pursued and could create difficulties in product understanding and navigation. With increased amount of modalities within the product appearance, experienced control may decrease due to the increased effort that is needed in attuning to the *information* that is provided within the total amount of sensorial stimulation.

Experienced control was also found to vary across and within prototype versions besides the amount of product features. The source of this variance has been related to connections between product features rather than the amount of features. In Study IV the *random* distribution of voicemail messages across the product caused difficulty

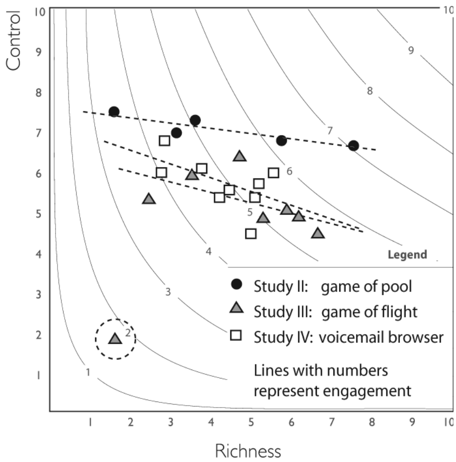



Figure 5.2. Figure showing the levels of experienced engagement (curved lines) as a function of the levels of experienced richness (x-axis) and experienced control (y-axis) according to the formula: $E = R^{0.5} C^{0.5}$. Mean scores of the prototypes that were assessed during play for studies II-IV are plotted in this space. For each study regression lines are drawn. Scores for the game of flight were calculated by averaging the scores of the same prototypes across Increasing and Decreasing richness conditions. For the game of pool, richness scores may be overestimated as a result of the scaling richness scores from a 7-point towards a 10-point scale hereby leading to higher predicted engagement scores. With increased amount of product features levels of experienced richness were found to increase and levels of experienced control were only found to decrease to a small extent. One prototype of study III that is circled was not included within the regression analysis given that contrary to the other prototypes, product functions could not be manipulated.

in product understanding and the minor *fluctuations* within the tracking technology that connected gestures with sound created difficulties within the localization of voicemails. In both cases, a structure was sought for within an inherently unpredictable system. Further, voicemail browsers that allowed multiple voicemails to be heard *simultaneously* decreased levels of control since it was difficult to focus on individual voicemail messages and became more critical as the amount of voicemails increased. In terms of the connection between product features and goals, control could vary according to the extent manipulations could *effectively* or *efficiently* bring about functional ones. In Study III for instance, levels of experienced control varied according to the extent points could be earned in the game.

Given the above discussion, high levels of engagement can be attained during play by creating richly experienced products. Richly experienced products allow choice, expressiveness and sensorial stimulation in interaction by increasing the amount of functions that can be directly manipulated and by increasing the amount of perceptual dimensions within the appearance of the product. During play, increasing the amount of product features slightly decreases control since the product become more difficult to understand but remain at higher levels since goals can be freely explored or pursued. Decreased levels of control were not found to decrease levels of engagement but lowered the rate in which engagement increased though richness. To compen-

Table 5.3. Product features effects on levels of experienced richness and control for studies II-IV during play.

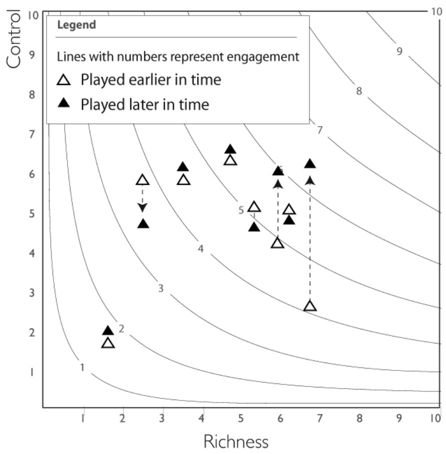
| | *richness* | | *control* | |
|---|---|---|---|---|
| Study I: Game of pool (Behavior) | $F_{(2,22)} = 31.015$ | p<.000* | | |
| Study I: Game of pool (Appearance) | $F_{(2,22)} = 16.784$ | p<.000* | | |
| Study II: Game of pool (Behavior and appearance combined) | | | $F_{(4, 92)} = 2.004$ | p<.101 |
| Study III: Game of Flight (Amount of combined groups) | $F_{(3,27)} = 56.637$ | p<.000* | | |
| Study III: Game of Flight (Amount of functions within groups) | $F_{(2,18)} = 18.390$ | p<.000* | | |
| Study III: Game of Flight (across functions and groups) | | | $F_{(6,78)} = 4,025$ | p<.002* |
| Study IV: Voicemail browser (Amount of voicemail content) | $F_{(2,26)} = 14.276$ | p<.000* | $F_{(2,26)} = 4.222$ | p<.026 |
| Study IV: Voicemail browser (User interface) | $F_{(2,26)} = 2.296$ | p<.121 | $F_{(2,26)} = 1.644$ | p<.213 |

* p<.05

sate for this lowered rate, connections between product features in terms of system behavior and in terms of actions-feedbacks should be systematic. Further, care should be given that the appearance of a product is designed in such a way that individual sensations remain distinguishable.

## Expertise

Results of Study III suggest that user expertise affected the levels of experienced richness and control. User expertise is considered to increase in time. With increased expertise, a mental model of a product is formed that incorporates details of a product in terms of its function, manipulation and appearance aspects. Increased levels of



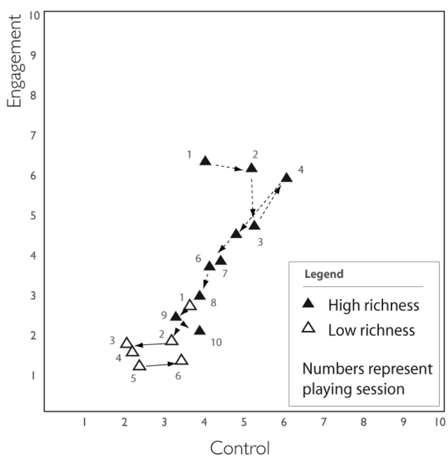




Figure 5.3. Figure showing the prototypes of the Increasing and Decreasing richness conditions of Study III. For two of the richly experienced games the levels of experienced control were raised significantly as players' knowledge of the game increased. Oppositely, for one of the poorly experienced games, having increased knowledge of the game seemed to have decrease the levels of experienced control.

Figure 5.4. Figure showing the levels of experienced control and engagement for the High and Low richness conditions of Study III. Games having richness rank 8 (score 6.7) in the High richness condition and richness rank 1 (score 1.6) in the Low richness condition are plotted in a two-dimensional space with experienced control depicted on the x-axis and experienced engagement plotted on the y-axis. The arrows point towards games that were played further in time. From the figure, a curvilinear path can be seen that initially moves towards higher levels of experienced control after which both the levels of experienced control and engagement decreased as gameplay continued.

Table 5.4. Table showing the results of regression analysis of Studies IV for High richness and Low richness conditions.

| | N | r | $r^2$ | Adj. $r^2$ | Std. error | p< |
|---|---|---|---|---|---|---|
| High richness [7] | 10 | .728 | .529 | .470 | .372 | .017 |
| Low richness [8] | 6 | .473 | .224 | .224 | .264 | .343 |

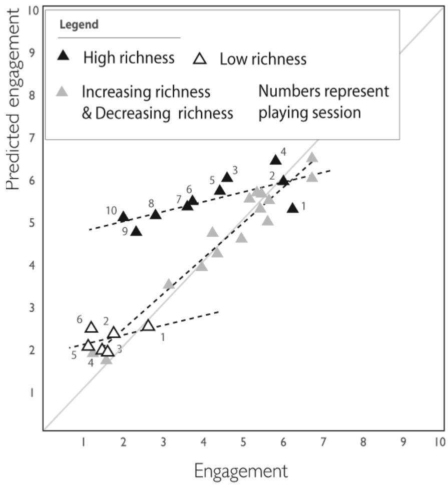



Figure 5.5. Figure showing the actual and predicted levels of engagement of games played during the High, Low, Increasing and Decreasing richness conditions of Study III. Actual levels of experienced engagement are projected on the x-axis and predicted levels of experienced engagement are projected on the y-axis. Games could be repeatedly played in ten sessions distributed over a three-day period. The regression lines show a similar slope for the High and Low richness conditions. For games within the High richness condition the levels of predicted engagement increasingly deviated from the actual levels of experienced engagement as playing time increased. This suggests that the levels of experienced richness may decrease in time.

control can be experienced in product navigation when a person knows about the functions of a product and understands how they are organized within the product. Further, levels of experienced control can increase when actions that are needed to bring about these functions are performed fluently and accurately as gestures move from sets of separate muscle activations into unified wholes. Further, experienced control can increase when people learn to (automatically) distinguish action/goal-relevant information from the overall sensorial stimulation that is elicited by the product appearance.

Results of an experiment in which various games varying in richness were repeatedly played in time showed that user expertise interacted with the amount of product features in terms of the levels of experienced control (Figure 5.3). When a variety of games were played varying in richness in an increasing or decreasing order, results showed that two of the richly experienced games led to increased levels of experienced control when these games were played later in time (Richness-score 6.7: $t=2.708$, $df=6.6$, $p<.032$, two-tailed. Richness-score 5.9: $t=2.126$, $df=18.8$, $p<.044$, two-tailed. Equalities of variance were not assumed) and further suggests that this led to lower levels of experienced control for one of the poorly experienced games,

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[7] [$E = 0.24 (R^{0.5} C^{0.5}) + 4.41$] Mean control- and engagement scores of games within the 'High richness condition' were estimated across 7 participants of which 4 discontinued playing after the third playing session (N=42).

[8] [$E = 0.24 (R^{0.5} C^{0.5}) + 1.70$] Mean control- and engagement scores of games within the 'Low richness condition' were estimated across 4 participants of which 2 discontinued playing after the third playing session and these 2 participants discontinued playing after the sixth playing session (N=18).

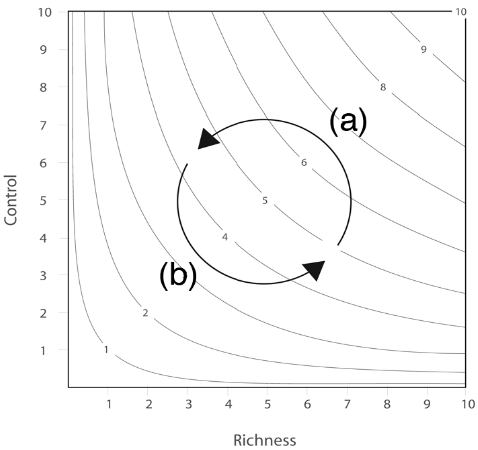


Figure 5.6. Visualization showing the dynamics of the levels of richness and levels of control affected by product features and user expertise. (a) Given user expertise richness is considered to decrease in time, control is considered to increases in time until the highest levels of experienced control have been attained. Subsequently, control will also decrease and engagement is decreased as a result. (b) The levels of experienced engagement can be restored when product features are changed or added. In this way experienced richness is increased and - when product features are manipulated on a functional level – experienced control can increase in time once more.

although this was not significant (Richness-score 2.5: t=1.085, df=10, p<.304, two-tailed). Further repeatedly playing with a richly experienced game initially increased the levels of experienced control in time after which they decreased. Repeatedly playing with a poorly experienced game decreased the levels of experienced control from the start (Figure 5.4). Apparently, it takes some time to feel in control of richly experienced games. For the poorly experienced games the levels of experienced control may decrease in time due to feelings of apathy. These feelings may arise when gameplay is prolonged when maximum levels of experienced control have been attained.

Results suggest that with increased user expertise the levels of experienced richness decreased. Levels of engagement could not be accurately predicted for the high richness and low richness conditions based upon the formula: $E = R^{0.5} C^{0.5}$. In these conditions, a richly and poorly experienced game could be repeatedly played in ten sessions over a three-day period. A closer examination revealed that for the high richness condition the engagement scores and predicted engagement scores were initially similar but increasingly deviated as the game was played repeatedly (Figure 5.5 and Table 5.4). Experienced complexity (and the related items assessing intensity and enervation) might have decreased as user expertise increased. Adjusting the levels of experienced richness based on this temporal effect can increase the accuracy of the prediction. However, this effect can also be based upon experiencing a lack of *novelty* and novelty might not be part of the richness construct.

These findings nicely illustrate the dynamic relationship between user expertise and engagement; user expertise affects experienced engagement through experiences of richness and control and while being engaged, skills and knowledge are developed. Thus, experienced engagement can initially be characterized by richness; the excitement and challenge that product features can provide. Hereafter, experienced engagement can be increasingly characterized by control; the extent person allows freedom by being able to utilize product features. Engagement decreases in time when the excitement and challenge via richness decreases and when a person experiences high levels of control since he/she has mastered the product. In preventing engagement to decrease in time the levels of experienced richness should be increased. On a superficial level experienced richness can be increased by changing product appearance. On a deeper level experienced richness can be increased by changing product functions and hereby allowing experienced control to increase in time once more (Figure 5.6).

## Task

Studies II and IV showed that *using* the prototypes in order to attain an externally imposed goal within a limited amount of time compared to freely *playing* with the prototypes affected engagement directly and interacted with product features in terms of experienced richness and control. Study II showed a significant effect of task type on experienced engagement ($F(1,22)=5.607$, $p<.013$). Also, an effect of task type on experienced engagement could be deduced for Study IV by comparing the actual engagement scores with the predicted ones. Results showed that the levels of predicted engagement across prototypes were systematically lower during these - time constrained - goal-directed tasks compared to playful ones (Figure 5.7 and Table 5.5). Compensating for these underestimated levels of engagement by including a task-term to the formula raised the accuracy of the model prediction ($N=18$, $r=.886$, $r2=.785$, $p<.000$). These results suggest that levels of engagement are increased when interaction is structured around a clearly defined goal. This may promote the ability to feel challenged and develop skills and knowledge since one's faculties can be directed purposefully and goal-progression can be precisely monitored in time.

Table 5.5. Table showing the results of regression analysis of Studies IV during play and use.

| | N | r | $r^2$ | Adj. $r^2$ | Std. error | p< |
|---|---|---|---|---|---|---|
| Study IV (Voicem. play) [9] | 9 | .868 | .754 | .719 | .239 | .002 |
| Study IV (Voicem. use) [10] | 9 | .845 | .714 | .671 | .114 | .004 |

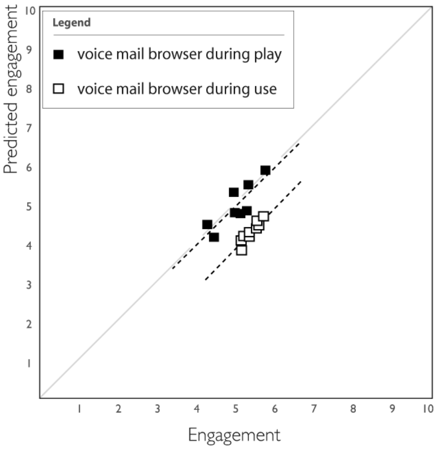


Figure 5.7. Figure showing the actual and predicted levels of engagement of 9 prototypes across playful and goal-directed tasks in Study IV. Actual levels of experienced engagement are projected on the x-axis and predicted levels of experienced engagement are projected on the y-axis. During goal-directed tasks, the predicted levels of experienced engagement were systematically lower compared to the actual engagement scores. Adding a constant factor to these scores can re-align the predicted engagement scores with the actual ones.

9 [E = 1.00 ($R^{0.5}$ $C^{0.5}$) - 0.10] Mean scores of the voicemail browsers on richness-, control- and engagement-scores for both play and use were based upon 14 participants (N=126).

10 [E = 1.04 ($R^{0.5}$ $C^{0.5}$) - 1.42] See above.

Using prototypes goal-directed within a limited amount of time led to different richness perceptions compared to playing with them. Results of Study IV showed that for identical prototypes having many voicemail messages the levels of experienced richness decreased during the search task while levels of experienced richness increased for prototypes having few voicemail messages ($F(2,52)=4.272$, $p<.019$). The varieties of voicemail messages may not have been fully experienced when the task involved searching for one specific voicemail message within the assortment of messages, while the varieties of meanings and intonations within potential target voicemail messages may have been increasingly attended to. Results of Study II suggest that a game version that allowed virtual balls to be moved across the playing field and pushing other balls by its own movement led to lower levels of richness when the goal was to pot the virtual balls as quickly as possible compared to playing with them freely. This behavioral feature remained undiscovered when balls were moved directly into the pocket; spatial trajectories between balls and pocket did not cross. This effect was indirectly observed given that levels of engagement decreased for this game during goal-directed tasks while the levels of experienced control did not change (Study II: Interaction effect: Richness-rank and Task-type on engagement: $F(4,88)=3.949$, $p<.005$). These findings suggest that play may have resulted in a broader focus of attention and increased explorative behavior compared to goal-directed tasks. As a result, levels of experienced richness could vary since some product features remained unnoticed or were not discovered while others were increasingly attended to.

Using prototypes in a goal-directed manner affected the levels of experienced control compared to playing with them. Results of study II showed an interaction effect of task type and the amount of product features on experienced control ($F(4,88) = 4.684$, $p<.002$). Playing with games slightly decreased experienced control as the amount of game features increased. When the goal was on potting balls, levels of experienced control split into a high and low experienced control cluster that corresponded to high and low levels of task performance. The product features that influenced task performance were the product mechanisms that related to the perceptual-motor coordination that was needed to pot the virtual balls by means of the physical pen. A main effect of task type on experienced control was found for Study IV ($F(1,26) = 7.176$, $p<.013$). Levels of control slightly decreased as the amount of voicemail increased while playing with the voicemail browser. Increasing the amount of voicemails in the search task slightly lowered experienced control given decreased levels of task performance since the range of potential voicemail targets increased. However, task performance was mainly lowered across prototypes as a result of the random distribution of voicemails across the tangible product and as a result of the minor fluctuations within the tracking technology. These results suggest that during play the levels of experienced control slightly decreased as the amount of product features increased while during pragmatic tasks, levels of experienced control varied based upon task performance. The amount of product features may have lowered task performance when these features interfere with identifying goal-relevant aspects within the range of sensations and possibilities the product provides. Further, task performance can decrease as a result of the effectiveness or efficiency in which manipulation features can bring about desired functional ones. Lastly, task performance also depends upon the goal that is specified and the amount of time within which the goal should be attained.

## Design recommendations

In this section, design recommendations are distilled from the framework. The recommendations are targeted at digital consumer products. With these types of products, functions, manipulations and appearances can freely vary across products over time and people are free to choose these products compared to having to use it. Optimal engagement in interaction is attained when both richness and control are optimized given the (1) product, (2) person and (3) task. Based upon the results across the four studies, a total of six aspects have been identified as affecting experienced engagement via experienced richness and control: (1) In terms of digital products these are (a) the amount of possibilities, (b) the amount of sensorial stimulation and (c) the connections between product features: (2) In terms of a person this is (d) the level of expertise that is considered to increase in time: (3) In terms of a task these are (e) having an experiential or goal-directed orientation on interaction and (f) the amount of time that is available to attain a pursued goal.

(1) Digital products can be made engaging by (a) extending the amount of functions hereby increasing the range of possibilities and (b) using multiple types of media and modes in which digital functions can appear hereby increasing the amount of sensorial stimulation. In these cases, the levels of experienced engagement are increased through experienced richness; people are stimulated to discover a product. However to feel engaged, a sense of control must also be experienced. Based upon a product the levels of experienced control can be optimized by (c) organizing product functions in an orderly fashion within a product and by minimizing time delays between human action and product feedbacks. Randomness, jitter and time delays can cause confusion about the workings of a product and can cause frustration in product handling hereby leading to lower levels of engagement. Based upon product appearance, levels of experienced control can be optimized by designing it in such ways that each (multi-) sensorial aspect remains distinguishable from the other sensorial aspects. A lack of organization of these sensorial features can result into a cluttered appearance hereby decreasing the levels of engagement.

(2) Engagement with digital products can be maintained when product features are changed in time. As discussed previously, experienced richness can decrease in time due to increased familiarity. Experienced control can decrease in time when levels of experienced control have been maximized due to increased expertise. To compensate for these effects product features should be changed in time. (d) On a superficial level richness can be increased by changing the appearance of a product hereby affecting the ambience in which interactions take place. Examples are changing the look of a desktop environment or changing the ring tones of a mobile phone. On a deeper level, richness can be increased by changing functions or by changing the interrelations between functions. Changing product features on this level may also decrease experienced control hereby allowing experienced control to be regained in time. Examples are levels in videogames; each level

allows new possibilities undermining the levels of experienced control that can be regained as players develop the required skills.
(3) Interacting with a digital product in a goal-directed manner can lead to higher levels of engagement compared to just experiencing a digital product. Interaction that is structured around a clearly defined goal can lead to increased levels or concentration especially when this goal should be completed within a limited amount of time. (e) Digital products can be made engaging during these goal-directed interactions when the amount of product features leading to experiences of richness are relevant for the goal that is set. Given the focus of attention and goal-directed behavior, these aspects are increasingly attended to while non-related aspects remain unnoticed. Further, engagement is promoted when it is clear which product features within the total amount of behavioral and perceptual features are relevant for goal pursuit. As described above, not clearly communicating information through the appearance of a product or not allowing functions to be brought about effectively or efficiently may lead to frustration since task performance is lowered. Lowered task performance in turn lowers the levels of experienced control hereby lowering the levels of experienced engagement. (f) The time that is available to attain a goal also influences task performance. When the available time is decreased, product features should be increasingly efficient in terms of their physical organization to maintain higher levels of experienced control.

## Utility and limitations of the framework

The relevance of the conceptual framework for interaction-design practice lies within the knowledge and inspiration it can provide interaction designers. Using the conceptual framework as a resource in the initial phase of the design process might lead to interactions that are engaging since the designer is aware of the dynamics between product, user and task and can - based on this awareness - design the appropriate product features. The experiences with the framework during the research were positive: The framework was flexible enough to generate multiple solutions and hereby allowing designers freedom within their designs. Using the conceptual framework as user models in product intelligence might lead to products that maintain engagement across various contexts over time by dynamically changing its features autonomously. However, for using the conceptual framework in this way, knowledge is needed about the correspondence between experienced engagement and observable behavior such as usage patterns or physiological measures.

The framework is based upon three different prototypes that were investigated within an experimental setting. The question is if the framework can be generally applied given the limited application of the prototypes, given the use of relatively short time-series and given the laboratory setting. Richness, control and engagement were stable constructs across the four studies given the similar clustering of the questionnaire items based upon the principal component analyses. However, the question remains to what extent experiences of excitement and enjoyment are also experienced simultaneously in real-world user-product interaction. It would therefore be interesting to find ways in which engagement can be assessed across a variety of products within naturalistic settings over longer periods of time.

In terms of the amount of product features manipulations, some limitations can be given. The amount of functions did not vary to a large extent compared to many currently available digital products such as mobile phones and personal digital assistants. Further, the manipulation of product features across function, manipulation and appearance aspects were not independently varied across the four studies: In study I and II product function and manipulation co-varied, in study III, product function, manipulation and appearance co-varied and in study IV, function and appearance co-varied. By examining these aspects in isolation, it becomes possible to assess how each aspect affects experienced richness, control and engagement individually and how specific interactions will occur between each combination of these aspects.

## Final remarks

Combining the worlds of research and design during this project was sometimes found to be a difficult struggle. As touched upon in the introduction, a research through design approach involves designing highly experiential prototypes driven by research questions that are assessed in controlled or naturalist settings. In my view, the added value of this approach is that it builds *general* design knowledge based upon - and being attentive to – the design of the *specific*. General design knowledge can be applied across a variety of products and services and allows others to challenge and develop such knowledge. At the same time, knowledge is based on specific designs that can also provide inspiration by showing how this knowledge can be implemented via enabling technologies in specific contexts. Researching engagement with digital products affords many interesting research and design opportunities given the rapid developments of interaction technologies. The role of the interaction-design-researcher should be to engage with these developments critically through reflection and design. In this way, the possible future in which people can interact with digital environments can be explored.

# SUMMARY

This thesis investigates the experience of *engagement* when interacting with digital products. The aim of this research is to gain insight into the constituents of the experience of engagement and the design factors that can influence it. Digital products are products that incorporate information and communication technology. Such products are able to collect, process and produce information. Computers, digital camera's, mobile phones and videogames are examples of such products. Whereas in the past such products were mostly used to compute scientific calculations, digital products are nowadays used for various purposes, as the examples mentioned above demonstrate. It is not surprising that the usability requirements for these products have changed over time: It used to be important that a product functioned well, later on that it was easy to use, and nowadays it is also important that product usage is experienced as enjoyable.

Engagement is a term used to interpret this enjoyment. In the literature the term engagement is described as a form of pleasure that is experienced during activities driven by intrinsic motivation. One can, for example, experience engagement while interacting with a product because it looks good, is interesting to use, or because the product allows one to achieve goals that are personally relevant. The experiences of *richness* and *control* are presented in this thesis as two experiential qualities that can positively influence the levels of experienced engagement. Experienced richness refers to the experienced variety and complexity of the actions and perceptions involved in interaction and influences the extent a person feels excited and challenged. Experienced control refers to how easily a product can be understood in terms of its functioning and/or how easily these functions to be manipulated. The level of experienced control can influence the level of experienced engagement due to the sense of freedom that can arise when people use a product to fit their own purposes.

Four studies were conducted investigating how the experiences of richness, control and engagement relate to one another as well as

how the product, the user and the task might influence these experiences. In these studies experiments were done using prototypes that were tested by different participants in artificial task surroundings. The findings were mapped out using questionnaires. Based upon the results of these studies a conceptual framework was constructed out of which design recommendations were deduced. Before elaborating on the conceptual framework, there follows a brief summary of the four studies below.

### *Study I*

Study I investigated how the number of product features influenced the experience of richness. A videogame was created that resembled a game of pool. Five balls and a pocket were located in a playfield area. Virtual balls projected upon a glass table from underneath could be directly manipulated by placing a pen upon the touch sensitive tabletop. Participants were asked to explore the digital pool game while manipulating its behavioral and appearance aspects. Behavioral aspects were manipulated by varying the ways in which the balls could behave. In one version, virtual balls could only be tapped by the pen. In a second, more complex, version they could also be dragged and in the last version, virtual balls could additionally even be thrown. Product appearance varied by changing the colorfulness and level of detail of the visual design of the game in three steps. After each session the participants were asked to judge the experienced richness. The results showed that a product was judged to be richer as the experienced interactivity and vividness increased by raising the number of ball behaviors and the amount of visual elements in the game.

### *Study II*

In study II the digital pool game was utilized again, this time to examine how the levels of experienced richness and experienced control were related to the level of experienced engagement during experiential and goal-directed tasks. In the experiential task participants were given time to explore the virtual pool game. In the goal-directed task participants were asked to make the five virtual balls disappear as fast as possible within a specific time span. The study showed that as the number of product features increased, and making the interaction a richer experience, the levels of engagement increased but the level of experienced control decreased. As a result of the latter, the increasing levels of engagement in relation to the increasing levels of richness slightly decreased. From these findings it can be deduced that the levels of experienced richness and control can influence the levels of experienced engagement and that an optimal level of engagement exists based on the number of product features.

Furthermore, results show that playing games toward a specific goal led to higher levels of engagement compared to exploring the game without constraints or limitations. A goal-directed task may lead to higher levels of engagement because the goal structures the playing activity. The task was also found to influence the level of experienced control. Whereas during an experiential task levels of experienced control decreased as the number of product features were increased, during a goal-directed task, levels of experienced control varied depending on how efficiently product features could mediate the goal that was set. These differences were caused by varying complexities in hand-eye coordination required to make the balls disappear into the hole.

### *Study III*

In study III two experiments were run. The first experiment investigated again the relationship between the number of product features and the levels of experienced richness. The second experiment investigated how levels of experienced control and engagement were influenced, by varying the number of product features in the game over time. For this study a digital product was developed that can be characterized as a computer game in which a virtual aircraft can fly in a virtual two-dimensional world using the keyboard. Points could be earned by making the aircraft do various maneuvers. The product was designed so that the number of product features varied according to the number of functions in the game. This study showed that experienced richness and experienced control were systematically linked; differences in engagement could be explained by differences in richness and control. As with study II, this study showed that as the number of product features increased the level of experienced richness increased and the level of experienced control decreased, and that the level of experienced control fluctuated with levels of efficiency in which goals could be attained (‘points’ in this case).

Time influenced the level of experienced richness and the level of experienced control. In the games that contained a large number of product features, the level of experienced richness decreased over time and the level of experienced control increased after which the level of experienced control would also drop. This leads to the deduction that experienced engagement is at first determined by the challenges product features afford, and later on by the degree to which these features can be used in the game. A sense of apathy can occur once the maximum level of experienced control is reached and no new challenges are perceived.

### Study IV

Study IV investigated the relationship between the number of product features and the levels of experienced richness, control and engagement, during goal-directed and experiential tasks. A digital voicemail browser was developed resembling a flying saucer containing 16 slots along the ridge. Voicemail messages could be stored – virtually – above one of the physical slots and accessed by placing a hand held input device above the slot containing a message. Product features were manipulated by varying the number of messages that could be heard and by increasing the range of sounds and gestures in which these messages could be accessed. In the experiential tasks, participants were given time to explore the voicemail browser. In the goal-directed task participants were told to find a specific message in a limited time span. In this study a systematic link was found such as the one in study III, showing how levels of experienced richness and control were linked to levels of experienced engagement. This study again demonstrated that as the number of product features increased, levels of experienced richness increased and levels of experienced control decreased.

Furthermore, it showed that levels of experienced engagement were higher if participants worked towards a specific goal than when left to explore the device at will. As with the pool game it would seem that structuring an activity leads to higher levels of engagement. At the same time, the random placement of messages in the product decreased the efficiency to find voice mail messages and decreased the level of experienced control as a result. This study also showed that approaching a product in an experiential or goal-directed manner led to different richness perceptions: Product features leading to rich experiences may have differed during experiential tasks given that people had adopted a broader focus of attention and performed more explorative behaviors compared to people during goal-directed tasks.

### Results

In the final chapter the results of the four studies were combined into a conceptual framework, out of which design recommendations have been deduced. In short the framework describes how the levels of experienced richness and control relate to levels of engagement and how product features, level of expertise and task orientation may influence these experiences. The levels of experienced richness and experienced control influence the level of engagement through the enjoyment experienced in the interplay between excitement and freedom while interacting with a product. Richness and control lead to engagement following a multiplication rule. Thus, low levels of experienced richness and/or control lead to a strong decrease in the levels of experienced engagement. Increasing the number of product features increased levels of experienced richness and decreased levels of experienced control; consequently increasing the number of product features will at first increase the level of experienced engagement, but later on the level of experienced engagement will decrease. Contrarily, as user expertise increases in time, levels of experienced richness decrease and levels of experienced control increase. Consequently, the number of product features should be increased over time (or simply modified) to maintain optimal levels of experienced engagement. A product can lead to different richness perceptions during experiential tasks compared to goal-directed tasks since behavior is explorative rather than goal-directed and the focus of attention is broad rather than narrow. This difference in behavior and perception may influence which product features, affecting the experience of richness, are encountered or are consciously experienced. Moreover, during goal-directed tasks, levels of experienced control are lowered compared to experiential tasks if product features do not efficiently support goals.

The design recommendations distilled from the conceptual framework can offer interaction designers a resource to design towards increased levels of experienced engagement when interacting with digital products. Engagement can be increased by making a (multi) sensory stimulating design by adding features to the product's appearance in an orderly manner, or by adding various functions to the product that are consistent and give direct feedback to user's actions. However, it is important to note that having too many elements within the appearance of a product and by increasing the number of functions too far can decrease the levels of experienced engagement. Engagement can be maintained over time by adjusting the appearance and the functions of a product to the expertise of a user dynamically. This requires a modular design approach, within an application domain wherein the direction and rapidity of changes are mapped out and where a choice is made as to which system is used to show these changes. The level of experienced engagement can be maintained within goal-directed and experiential tasks by offering multiple functionalities, while still allowing pursued functions to be brought about efficiently. An increase in functionalities stimulates exploration and will not necessarily lead to a decrease in efficiency if these functions

are directly accessible. Various manipulations can activate the same digital functionality allowing a person freedom to bring about functions either playfully or efficiently. Increasing the number of elements in the appearance of a product boosts sensory stimulation and using contrasting stimuli aids the perception of goal-directed information.

This research has lead to insights in the way levels of experienced engagement are shaped whilst interacting with digital products. By combining a modeling approach with a design approach this thesis can contribute to the discussion on product experience and could be of value in practical design applications. To develop the framework further, it should be used in other contexts and further applied in product design.

# SAMENVATTING

In dit proefschrift wordt de beleving van betrokkenheid (Eng: engagement) onderzocht die tijdens interacties met digitale producten kan ontstaan. Het doel van dit onderzoek is inzicht te krijgen in ervaringen die onderdeel uitmaken van deze beleving en hoe de ervaren betrokkenheid door de vormgeving van het product beïnvloed kan worden.

Digitale producten zijn producten waarin informatie en communicatie technologie zijn geïntegreerd. Zij kunnen informatie verzamelen, verwerken en produceren. Voorbeelden van dergelijke producten zijn computers, digitale camera's, mobiele telefoons en videospellen.Waar vroeger digitale producten alleen voor specifieke doeleinden werden gebruikt, bijvoorbeeld om wetenschappelijke berekeningen te maken, worden digitale producten nu voor zeer diverse doeleinden gebruikt zoals de bovengenoemde productvoorbeelden illustreren. Niet verwonderlijk zijn ook de kwaliteitseisen voor deze producten in de tijd mee veranderd. Waar er eerst belang aan werd gehecht dat het product goed functioneerde en er later ook belang aan werd gehecht dat het product makkelijk te gebruiken was, is het tegenwoordig van belang dat er met het product ook wat leuks te beleven valt.

Betrokkenheid is een begrip waarmee aan deze leuke belevingen invulling gegeven kan worden. Betrokkenheid wordt in de literatuur besproken als een vorm van plezierigheid en van vrijwillig verwikkeld zijn in iets dat je de moeite waard vindt. Zo kan je betrokkenheid ervaren tijdens een product-interactie omdat het product er leuk uit ziet of omdat het op een interessante manier in elkaar steekt. Je kan je ook tijdens een product-interactie betrokken voelen omdat je het resultaat van de interactie belangrijk vind en dat je naar dit resultaat toewerkt.

De ervaringen van rijkheid en controle worden in dit proefschrift voorgesteld als twee ervaringskwaliteiten die de ervaren betrokkenheid positief kunnen beïnvloeden. De ervaren rijkheid relateert aan de ervaren variëteit en complexiteit van handelingen en waarnemingen

die tijdens een interactie met een product kunnen ontstaan. De ervaren rijkheid kan de ervaren betrokkenheid beïnvloeden doordat een persoon door het product wordt gestimuleerd en wordt uitgedaagd. De ervaren controle relateert aan het ervaren gemak waarmee productaspecten begrepen kunnen worden of door handelen tot uiting kunnen worden gebracht. De ervaren controle kan de ervaren betrokkenheid beïnvloeden doordat een persoon het product voor eigen doelen kan inzetten en daardoor een gevoel van vrijheid ervaart.

Vier studies zijn uitgevoerd waarin werd onderzocht hoe de ervaringen van rijkheid, controle en betrokkenheid met elkaar samenhangen en hoe het product, de persoon en de taak deze ervaringen kunnen beïnvloeden. In deze studies zijn experimenten gedaan met behulp van prototypes die door verschillende proefpersonen zijn getest in artificiële taaksituaties. Met behulp van vragenlijsten werden de ervaringen in kaart gebracht. Op basis van de resultaten is een conceptueel raamwerk opgezet van waaruit ontwerprichtlijnen zijn gedestilleerd. Alvorens het conceptuele raamwerk uiteen te zetten worden hieronder eerst de vier studies kort samengevat.

### *Studie I*

In studie I werd de relatie tussen de hoeveelheid productaspecten en ervaren rijkheid onderzocht met behulp van een digitaal product dat kan worden gekarakteriseerd als een digitaal biljartspel. Het biljartspel bestaat uit vijf virtuele ballen rondom een virtueel gat waarin de virtuele ballen kunnen verdwijnen. Het biljartspel werd met een videoprojector vanaf de onderkant geprojecteerd op een tafelblad. Vanaf de bovenkant konden de virtuele ballen worden gemanipuleerd met behulp van een pen door deze direct op de tafel bovenop de balprojecties te zetten. Proefpersonen werden gevraagd verschillende malen het digitale biljartspel te exploreren waarbij de productaspecten werden gemanipuleerd door de actiemogelijkheden en de visuele verschijningsvorm van het spel te variëren. Zo konden de virtuele ballen in eerste instantie alleen met de pen aangestipt worden. In een complexere situatie konden ze ook worden versleept en ten slotte konden ze ook nog worden gegooid. De visuele verschijningsvorm van het digitale product werd gemanipuleerd door de mate van kleurverzadiging, detail en vormdiversiteit in drie stappen te variëren. Na iedere speelsessie werden de proefpersonen naar de ervaren rijkheid gevraagd. De resultaten lieten zien dat de interactie als rijker werd beleefd naarmate het product als interactiever en visueel prikkelender werd ervaren door het aantal actiemogelijkheden en het aantal visuele elementen van het spel te verhogen.

### Studie II

In studie II werd het digitale biljartspel nogmaals ingezet om te onderzoeken hoe de ervaren rijkheid en de ervaren controle samenhangen met de ervaren betrokkenheid tijdens een ervaringsgerichte en doelgerichte taak. In de ervaringsgerichte taak kregen de proefpersonen de tijd om het digitale biljartspel te exploreren. In de doelgerichte taak kregen de proefpersonen de opdracht de vijf virtuele ballen zo snel mogelijk te laten verdwijnen binnen een begrensde tijdsperiode. De studie toonde aan dat naarmate het aantal productaspecten toenam en de interactie als rijker werd beleefd de ervaren betrokkenheid toenam maar de ervaren controle afnam met als gevolg dat de stijging van de betrokkenheid ten opzichte van de ervaren rijkheid ook iets afnam. Vanuit deze bevinding kan worden afgeleid dat de ervaren rijkheid en de ervaren controle met de ervaren betrokkenheid samenhangen en dat er op basis van het aantal productaspecten een optimale betrokkenheid bereikt kan worden. Verder bleek dat de betrokkenheid die men tijdens de interactie ervoer hoger was als men met het digitale biljartspel naar een specifiek doel toewerkte dan als men het biljartspel op een vrije manier exploreerde. Een doelgerichte taak leidt mogelijk tot het ervaren van meer betrokkenheid omdat het doel de activiteit structuur geeft. Tevens beïnvloedde de taak de ervaren controle. Waar tijdens een ervaringsgerichte taak de ervaren controle iets afnam als het aantal productaspecten toenam varieerde de ervaren controle tijdens een doelgerichte taak met de mate waarin de productaspecten het doel efficiënt kon mediëren. Verschillen in deze efficiëntie werd veroorzaakt door verschillen in de coördinatie die nodig was om met de pen de ballen te laten verdwijnen in het gat.

### Studie III

In studie III werden twee experimenten uitgevoerd. In het eerste experiment werd de relatie tussen de hoeveelheid productaspecten en ervaren rijkheid opnieuw onderzocht. In het tweede experiment werd onderzocht hoe de ervaren controle en ervaren betrokkenheid werden beïnvloed door de hoeveelheid productaspecten te variëren in de tijd. Voor deze studie werd een digitaal product ontwikkeld dat kan worden gekarakteriseerd als een computerspel waarin men via het toetsenbord met een virtueel vliegtuigje door een tweedimensionale wereld kan vliegen. Door verschillende acties met het vliegtuig uit te voeren konden punten worden behaald. Het product was zo ontworpen dat de hoeveelheid productaspecten via het aantal functies in het spel was te variëren.

Deze studie toonde aan dat de ervaren rijkheid en de ervaren controle systematisch samenhingen; de mate van ervaren betrokkenheid kon worden verklaard uit de mate van ervaren rijkheid en de mate van ervaren controle. Gelijk aan studie II toonde deze studie aan dat naarmate het aantal productaspecten van het vliegspel toenam, de interactie als rijker werd beleefd maar de ervaren controle afnam. Verder bleek dat de ervaren controle fluctueerde als functie van de efficiëntie waarmee er in het spel doelen (punten) konden worden behaald.

De tijdsdimensie beïnvloedde de ervaren rijkheid en de ervaren controle. Voor de spellen met een hoog aantal productaspecten nam de ervaren rijkheid in de tijd af. De ervaren controle nam eerst in de tijd toe waarna de ervaren controle ook begon af te nemen. Hieruit kan worden afgeleid dat de ervaren betrokkenheid eerst wordt bepaald door de uitdagingen die de productaspecten bieden waarna de ervaren betrokkenheid wordt bepaald door de mate waarin deze productaspecten in het spel kunnen worden ingezet. Er kan een gevoel van apathie ontstaan als de ervaren controle maximaal is maar er geen nieuwe uitdagingen meer worden waargenomen.

### *Studie IV*

In studie IV werd de relatie tussen de hoeveelheid productaspecten en de ervaren rijkheid, controle en betrokkenheid onderzocht tijdens een doelgerichte en ervaringsgerichte taak. Daartoe was een digitale voice mail melder ontwikkeld die een gelijkenis vertoont met een vliegende schotel waarin een zestiental gaatjes met regelmaat langs de rand zijn gedistribueerd. Een gesproken bericht kan ruimtelijk gepositioneerd worden in één van deze fysieke gaatjes en kan beluisterd worden door een tweede object dat in de hand wordt gehouden boven het gaatje te plaatsen waarin het gesproken bericht zich bevindt. Productaspecten werden gemanipuleerd door de hoeveelheid te beluisteren gesproken berichten te variëren en door het aantal mogelijkheden te vergroten waarmee de gesproken berichten via gebaren en geluid konden worden ontsloten. In de ervaringsgerichte taak kregen de proefpersonen de tijd om de voice mail melder te exploreren. In de doelgerichte taak moesten de proefpersonen in een kort tijdsbestek een specifiek bericht zien te vinden in een selectie van verschillende gesproken berichten. In deze studie werd eenzelfde systematiek als in studie III gevonden waarmee de ervaren rijkheid en de ervaren controle samenhangen met de ervaren betrokkenheid. Deze studie toonde opnieuw aan dat naarmate de hoeveelheid productaspecten toenam de interactie rijker werd ervaren en de ervaren controle afnam.

Verder bleek dat de betrokkenheid die men tijdens de interactie ervoer hoger was als men met de voice mail melder naar een specifiek doel toewerkte dan als men de voice mail melder op een vrije manier exploreerde. Net als bij het biljartspel lijkt ook hier structuur in de activiteit tot hogere betrokkenheid te leiden. Tevens werd tijdens een doelgerichte taak de ervaren controle negatief beïnvloed door de willekeurigheid waarmee de gesproken berichten over het product werden verdeeld. Deze willekeur verlaagde de efficiëntie waarmee de gesproken berichten konden worden gevonden. Een nieuwe vinding van deze studie is dat de ervaren rijkheid ook beïnvloed werd door de taak. Het hebben van een doelgerichte of ervaringsgerichte houding ten opzichte van het digitale product beïnvloedt de aandacht en het gedrag waardoor de specifieke producteigenschappen die tot een rijke beleving leiden anders kunnen zijn.

### *Resultaten*

In het laatste hoofdstuk worden de resultaten van de vier studies geïntegreerd in een conceptueel raamwerk waaruit ontwerprichtlijnen zijn gedestilleerd. Kort samengevat wordt in het raamwerk beschreven hoe de ervaren rijkheid en de ervaren controle met de ervaren betrokkenheid samenhangen en hoe productaspecten, gebruikersexpertise en taaksituatie deze ervaringen beïnvloeden. De ervaren rijkheid en de ervaren controle beïnvloeden de mate van betrokkenheid, middels het plezier dat het “spel” tussen de spanning en de vrijheid tijdens interacties kan opleveren. De wijze waarop rijkheid en controle resulteren in betrokkenheid wordt binnen het raamwerk via een eenvoudige productregel zodanig beschreven dat lage waarden van rijkheid en/of controle de ervaren betrokkenheid sterk doen afnemen. Bij het toenemen van het aantal productaspecten neemt de ervaren rijkheid toe en neemt de ervaren controle af. Dit gebeurt op zodanige wijze dat het toenemen van het aantal productaspecten de ervaren betrokkenheid eerst zal doen toenemen waarna deze weer afneemt. Hieraan tegengesteld neemt onder invloed van toenemende gebruikersexpertise de ervaren rijkheid af en de ervaren controle toe. Daaruit volgt dat het aantal productaspecten in de tijd dient toe te nemen (of alleen te veranderen) om de gewenste ervaren betrokkenheid te behouden. Tijdens een doelgerichte taak kan het product tot een andere rijkheidsbeleving leiden dan tijdens een ervaringsgerichte taak omdat men doelgericht handelt in plaats van exploreert en alleen oog heeft voor doelgerelateerde productaspecten in plaats van dat men een open blik heeft. Tevens kan er tijdens een doelgerichtheid taak minder controle worden ervaren dan tijdens een ervaringsgerichte taak wanneer

de productaspecten doelen niet efficiënt ondersteunen.
De ontwerprichtlijnen die uit het raamwerk voortvloeien kunnen ontwerpers houvast bieden bij het zodanig vormgeven van een product dat de ervaren betrokkenheid tijdens interactie wordt bevorderd. De ervaren betrokkenheid kan via het product beïnvloed worden door het product (multi)sensorisch prikkelend te maken middels het op een geordende wijze toevoegen van beeldende elementen aan de verschijningsvorm. Ook kan dit worden bereikt door meerdere actiemogelijkheden in het product te creëren welke consistent zijn en welke direct terugkoppeling geven op de acties van de gebruiker. Hierbij moet wel rekening worden gehouden met het feit dat te veel sensorische prikkels en actiemogelijkheden de ervaren betrokkenheid zal doen afnemen. De ervaren betrokkenheid kan in de tijd behouden worden door de verschijningsvorm en actiemogelijkheden van het product aan te kunnen passen aan het expertiseniveau van de gebruiker. Dit vereist een modulaire ontwerpaanpak waarin, binnen een applicatiedomein, de mogelijke richting en de snelheid van verandering in kaart worden gebracht en een keuze wordt gemaakt in de systematiek waarmee veranderingen in het product tot uiting worden gebracht. De ervaren betrokkenheid kan zowel tijdens doelgerichte als ervaringsgerichte taken behouden blijven door meerdere actiemogelijkheden te bieden waarmee beoogde functies efficiënt tot uiting kunnen worden gebracht. Een toename van het aantal functies stimuleert exploratie maar hoeft de efficiëntie niet te laten afnemen wanneer iedere functie direct toegankelijk is. Verschillende manipulaties kunnen eenzelfde digitale functie activeren zodat handelingen naar gelang speels of efficiënt uigevoerd kunnen worden. Met de toename van het aantal beeldende elementen in de verschijningsvorm van het product wordt de sensorische stimulatie bevorderd en kan door gebruik te maken van contrasten de doelrelevante informatie goed waarneembaar blijven.

Dit onderzoek heeft inzicht gegeven in de manier waarop de ervaren betrokkenheid tijdens interacties met digitale producten tot stand komt. Door het combineren van een modelmatige aanpak met een ontwerpaanpak heeft dit proefschrift een bijdrage kunnen leveren aan de theoretische discussie over productbeleving en een bijdrage kunnen leveren aan de ontwerppraktijk. Voor een verdere verdieping is het gewenst dat in de toekomst meer inzicht in de betekenis van het raamwerk wordt verkregen door het te toetsen in andere contexten en door het te gebruiken in productontwikkeling.

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# CURRICULUM VITAE

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