Beyond image quality: designing engaging interactions with digital products

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ABSTRACT

Ubiquitous computing (or Ambient Intelligence) promises a world in which information is available anytime anywhere and with which humans can interact in a natural, multimodal way. In such world, perceptual image quality remains an important criterion since most information will be displayed visually, but other criteria such as enjoyment, fun, engagement and hedonic quality are emerging. This paper deals with engagement, the intrinsically enjoyable readiness to put more effort into exploring and/or using a product than strictly required, thus attracting and keeping user's attention for a longer period of time. The impact of the experienced richness of an interface, both visually and degree of possible manipulations, was investigated in a series of experiments employing game-like user interfaces. This resulted in the extension of an existing conceptual framework relating engagement to richness by means of two intermediating variables, namely experienced challenge and sense of control. Predictions from this revised framework are evaluated against results of an earlier experiment assessing the ergonomic and hedonic qualities of interactive media. Test material consisted of interactive CD-ROM's containing presentations of three companies for future customers.

Keywords: Ambient Intelligence, interaction design, user interfaces, richness, challenge, control, engagement

1. INTRODUCTION

We live in dynamic times. And this has to be taken literally since our environments and the products inhabiting these spaces become increasingly dynamic and interactive. The main reason is that a growing variety of consumer and professional products is being equipped with sensors, data storage capacity, information processing technology, actuators and new display technologies. Furthermore, advancements in network and wireless communication technology begin to make it feasible to connect such products into smart environments that can sense and reason about user intentions in a natural setting and react and anticipate accordingly. It is envisaged that in such smart environments humans will be continuously connected to each other and information will be available anytime and everywhere[1]. There is a growing awareness that these developments will definitely have a major impact on our everyday life in near future (e.g. healthcare[2]). Therefore, it is important to take a careful look at these developments and investigate how these new technologies can be geared to the needs and wishes of humans. To this end, one should not only focus on the technological development but also investigate its consequences on human-product interaction and the changing role of humans as individuals and as community members.

1.1 Trends in technology: Ambient Intelligence

The above-mentioned technological development was first articulated by Marc Weiser[3] of Xerox PARC in 1991 and is known under various names, but probably the most familiar term for these smart environments has become the one introduced by Aarts and Marzano[1] at the beginning of this century: Ambient Intelligence. Within the concept of Ambient Intelligence, the following challenges have been identified (Aarts & Marzano, 2003, p. 14):

1. Embedding: how to integrate networked devices into the environment?
2. Context awareness: how can these devices recognize you and your situational context?

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3. Personalization: how can they be tailored to your needs?
4. Adaptivity: how can they change in response to you?
5. Anticipation: how can they anticipate your desires without conscious mediation?

These challenges have a number of interesting implications for the way humans will interact with their environments and products. First, there will be a large diversity of environments, ranging from natural environments to completely virtual ones with in-between different varieties of mixed and augmented realities. Secondly, they suggest an important change in thinking about human-product interaction. Until now, the analysis of these interactions was mainly focused on the following questions: *what* do you like to do (functionality), *how* do you like to accomplish this (interaction style) and *with what* (which input/output devices are available). But now these questions have to be extended with the following: *when* and *where* will the interaction take place and the most challenging one: *why*? Thirdly, the list of challenges indicates a growing necessity to understand the user in the human-product interaction. Interestingly, this sense of urgency comes from the technology itself. While the first challenge is clearly technology-oriented (e.g. miniaturization, connectivity between different materials), the others depend increasingly on a thorough understanding of human behavior. An extreme challenge is the planned development of technology to anticipate human intentions: a perfect illustration of a technology push for human-centered design!

1.2 Human-product interaction: From user-friendliness to human centered design

These technological developments will have a major impact on human-product interaction. Some even claim that due to the "…revolution in information technology…." we are currently witnessing a paradigm shift in the field of human factors and ergonomics[4]. Up till now the focus has been mainly on respecting human physical and cognitive capabilities and limitations and adapting equipment accordingly[5]. Nowadays, the focus is increasingly on how products can collaborate symbiotically with humans to enhance human capabilities "…well outside the range of normal biological variation thereby altering traditional boundary constraints on the adaptability of humans in complex system design…" (Boff, 2006; p. 392). This may even be accomplished by achieving a tightly coupled neural fit between equipment or computing devices and the central nervous system. Cochlear implants are a good first indication in which direction this will evolve. Such symbiotic collaborations amplifying human capabilities imply a shift from user-friendliness to a human centered design approach, with user context playing a key role. This approach requires thorough knowledge about the way humans perceive and reason about their environments. Moreover, insight is needed on how humans accept and appreciate smart products and environments[6].

1.3 User perspective

The development of smart products and environments has two main implications from the user perspective. Most importantly, the interface does not have to be confined to a single display anymore. This is often referred to as "…the interface goes beyond the desktop" introducing a possible new element to the development of user interfaces, namely the experience of being almost immersed by the interface. In the field of virtual and augmented reality the subjective experience of presence is closely linked to this phenomenon[7]. Secondly, it will become increasingly more common that groups of individuals will be simultaneously immersed in and interacting with the same environment, both physically (e.g. smart rooms, smart homes) and virtually (e.g. Second Life, MySpace). More broadly speaking, this trend of going beyond the desktop indicates that the evaluation of user interfaces cannot be confined to usability (effectiveness, efficiency and ease-of-use) anymore. It clearly underlines the importance of understanding the user experience and the underlying emotional dimensions. And this is nicely reflected in recent developments in evaluation methodology now starting to focus on other (emotional) criteria such as enjoyment, fun, engagement, beauty and hedonic quality[8,9,10]. Note that this development does not imply that the traditional usability elements should be forgotten. More than ever it is crucial to assess the mental model a user has about the current or future situation. But what it *does* imply is that all aspects of human behavior (needs, desires, beliefs, emotions, and knowledge, skills, experiences, perceptions and (re) actions) should be taken into account and translated into workable variables. Additionally, attention should be paid to understanding group processes and the role individuals play in groups as described by James Surowiecki[11] in his book on "*The wisdom of crowds*". This will introduce topics like how to induce human cooperation in sharing and distributing content in decentralized Peer-to-Peer Television systems[12].

1.4 Beyond image quality

Recently, Panasonic's futuristic system known as *LifeWall* was demoed at the Consumer Electronics Show 2008[13]. *LifeWall* is literally a wall created by a High Definition projection system that acts like a hypersensitive computer screen recognizing faces, gestures and a person's motions. This allows for new ways of interaction. For example, an image on the wall can follow a person's movement through the room, detecting the distance from the viewer and optimizing the size of the image. Or, by automatically recognizing a person's face, a customized table of contents can be displayed. Whether *LifeWall* will succeed in "….enhancing the human experience by bringing people together around a whole new kind of digital hearth, one that goes far beyond the boundaries of our living rooms, a place that enables new ways to learn, laugh, communicate and interact, not just with friends and family, but with new friends all around the world…" (Panasonic president Sakamoto at CES2008), is not clear yet. But what it clearly illustrates is the growing dependence of new technologies on fast and accurate interpretation of human behavior.

The emergence of smart environments and products also implies a major impact on future imaging technology including the way new imaging systems should be evaluated. Some twenty years ago, at the beginning of the series of SPIE conferences on Human Vision and Electronic Imaging, perceptual image quality was considered the ultimate measure for the successful performance of an imaging system and much research was devoted to the development of methods for assessing image quality[14]. Subsequently, it was shown that image quality is a multidimensional phenomenon[15] that can only indirectly be connected to the underlying technology variables via physical image parameters and viewer perceptions (the "nesses" like darkness, sharpness, colorfulness), a concept that is adequately summarized in Peter Engeldrum's Image Quality Circle[16]. Gradually image quality turned out to be a compromise between various variables which was explicitly demonstrated for color images of natural scenes where quality judgments could be explained by a linear combination of naturalness and colorfulness judgments[17]. This led to the suggestion that image quality must be interpreted as a compromise between two conflicting demands imposed on an image, namely (1) maximizing naturalness and (2) maximizing visibility and discriminability of details in the image[18]. Nowadays, and in line with the emergence of smart environments, the focus is shifting from image quality to viewer experience (e.g. Philips Ambilight[19]). In this context, Seuntiens et al.[20] observed that image quality may not be the most appropriate term to capture the evaluative processes associated with experiencing 3D images. Image quality even turned out to be just one of the underlying dimensions of naturalness and 3D visual experience!

1.5 Designing engaging interactions

The previous discussion on the viewer experience does not imply that image quality is not relevant anymore. Ambient Intelligence promises a world in which information is available anytime anywhere and with which humans can interact in a natural, multimodal way. In such world, perceptual image quality remains an important criterion since most information will be displayed visually, but other criteria such as enjoyment, fun, engagement and hedonic quality are emerging and should be dealt with. In particular, it becomes relevant to investigate the relations between the various criteria in a systematic way.

In the next section a study is presented showing the usefulness of understanding user experiences and emotions. The study concerns the relation between the experienced richness of an interface and engagement, the intrinsically enjoyable readiness to put more effort into exploring and/or using a product than strictly required, thus attracting and keeping user's attention for a longer period of time. The study is an extension of research described in Rozendaal[21]. The extension concerns the refinement of Rozendaal's conceptual framework for engagement linking engagement to richness and sense of control.

2. RICHNESS, CHALLENGE, CONTROL AND ENGAGEMENT

2.1 Introduction

Rozendaal[21] investigated how the experience of engagement in interaction can be explained by examining (1) the experiences of richness and control and (2) how these experiences are influenced by the features of a digital product, the expertise of a person and the type of task. To this end, three types of prototypes were designed: a digital pool table, a videogame called "Game of Flight" and a voicemail browser[22] (Fig. 1). These prototypes have in common that the number of features of the user interface could be varied, both in audiovisual appearance and in the number of possible manipulations. The experience of richness, interpreted as the range of possibilities afforded by the three interactive

Fig. 1: Impression of the three prototypes. From left to right: digital pool table, multi-player video game called “Game of Flight” and voicemail browser. In the game of pool a pen is used to manipulate the movements of virtual balls projected from underneath. The video game is presented in an audiovisual format on a desktop computer and contains an aircraft-avatar that can be manipulated via keys on the keyboard. The voicemail browser comprises16 voicemail slots along its ridge with one voicemail message per slot. The messages can be accessed by performing gestures above the slots. The middle slot serves as a base for the input device. Pictures taken from Rozendaal[21].

media, was always found to increase monotonically with the number of features of the user interface. The experimental results on engagement presented below are based on the videogame only. Eight games were selected varying in experienced richness between 1.6 and 6.7 on a scale from one to ten.

2.2 Method

Fourteen subjects participated in the experiment. They were either students or employees at the faculty of Industrial Design Engineering at Delft University of Technology. Their age varied between 19 and 33 years with an average of 24 years. They were told that the experiment was about evaluating the playability of several video games. Half of the participants played the video games while the user interface increased in richness (both visually and number of possible manipulations). The other half played the games in the reversed order. The games were played over a period of three days. During a session, one game had to be played within ten minutes but participants were free to stop earlier. The game resembled a classic arcade game and was played on a desktop computer. In the game, a virtual aircraft-avatar interacts within a virtual game world and points are earned by performing a variety of actions such as shooting objects and collecting items. After playing a game, participants were asked to evaluate the game play on twelve items by means of numerical category scales ranging from 1 to 10. The list of items included questions assessing self-confidence, ease and efficiency as well as pleasure, motivation, challenge, excitement, experiencing skill development and discovering new possibilities.

2.3 Results and discussion

In both experimental conditions, playing time increased systematically with experienced richness of the game. On average, the richest games (with a rating of 6.7) were played in about five minutes. These results suggest that playing time may be used as a behavioral measure of playability and/or perceived richness.

A Principal Components Analysis on the item ratings resulted in two components, each with an Eigenvalue higher than one and together explaining 81% of the total variance (Table 1). Rozendaal[21] combined the items into two clusters on the basis of their weights on the two components. The first cluster formed the first dimension called *engagement* and included the following seven items: challenge, excitement, engagement, motivation, pleasure, new possibilities and skill-development. The remaining items (control, ease, efficiency, self confidence and playability) were clustered into a second dimension labeled *control*. Subsequently, experienced richness, control and engagement were combined in a conceptual framework in which engagement (E) is derived from experienced richness (R) and control (Co) by taking the square root of the product of control and richness, or

$$E = (R \cdot Co)^{0.5} \quad . \tag{1}$$

Table 1: Principle Component Analysis with Varimax rotation. Factor loadings < .30 have been omitted.

	I	II
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	1.50
Variance explained	68.9%	12.1%

An alternative interpretation of the Principle Component Analysis is the following. The first dimension labeled *challenge* is determined by combining the items on challenge and excitement. The second dimension labeled *control* is determined by combining the items on control and ease. The remaining items form two clusters with different weights on the two dimensions: *engagement* (engagement, motivation, pleasure, new possibilities and skill-development) and *playability* (efficiency, self confidence and playability). This interpretation suggests that both engagement and playability depend on the experienced challenge and sense of control (further analysis of playability is left out of this paper). Analogous to eq.(1), the relation between engagement (E), challenge (Ch) and control (Co) can be presented as follows:

$$E = (Ch \cdot Co)^{0.5} \;;\; Ch = f(R),\ Co = g(R). \qquad (2)$$

This equation suggests that engagement is affected by experienced richness via two intermediating variables, namely experienced challenge and sense of control. But how are challenge and control related to richness?

To answer this question, the average judgments of experienced challenge, sense of control and experienced engagement were plotted as a function of the level of experienced richness (Fig. 2a). The data were averaged across the two experimental conditions, i.e. decreasing and increasing richness of games. Figure 2 shows a monotonic increase of challenge as a function of richness ($Ch = f_{mon}(R)$) but a non-monotonic function for control. Increasing richness first induces an increase in the sense of control, but further increase in richness results eventually in a decrease in control. Apparently, there is an inverted U-shaped relation between richness and control ($Co = g_{\cap}(R)$). Interestingly, the engagement ratings lie between those for challenge and control supporting the implications of eq. (2). This is confirmed in Fig. 2b where model predictions from eq. (2) are compared with the experimental data on engagement.

The experimental data for the decreasing and increasing richness conditions were also analyzed separately. The results can be found in Figs. 3 and 4. A comparison of the two conditions denotes significantly different results at the high richness levels. Starting at high levels and then decreasing the experienced richness of the games induced not only an increase in control and engagement but also in challenge! Apparently, decreasing richness first made the game more challenging, probably because of less confusion, before the experienced challenge decreases. In contrast, starting at low levels and then increasing the experienced richness of the games suddenly evoked an increase in control and thus engagement at the high richness levels. A comparable order effect was found by Docampo Rama et al.[23] investigating the ability to handle one- and two-layered user interfaces. Despite the observed differences at high richness levels, both conditions resulted in satisfactory fits between experimental data and model predictions (Figs. 3b, 4b).

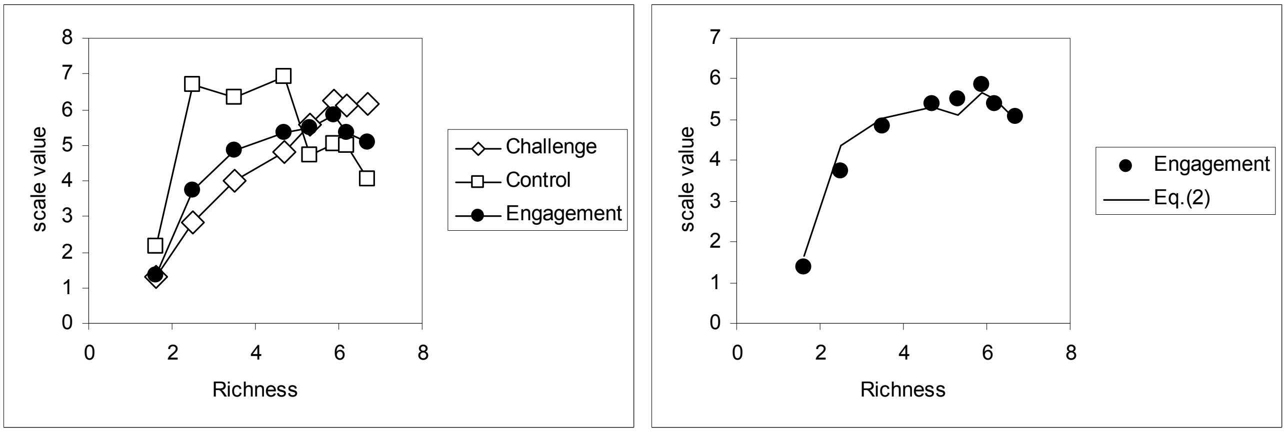

Fig. 2: (a) Experienced challenge, control and engagement as a function of experienced richness. Data have been averaged across the decreasing and increasing richness conditions. (b) Comparison between experienced engagement and model predictions using eq.(2).

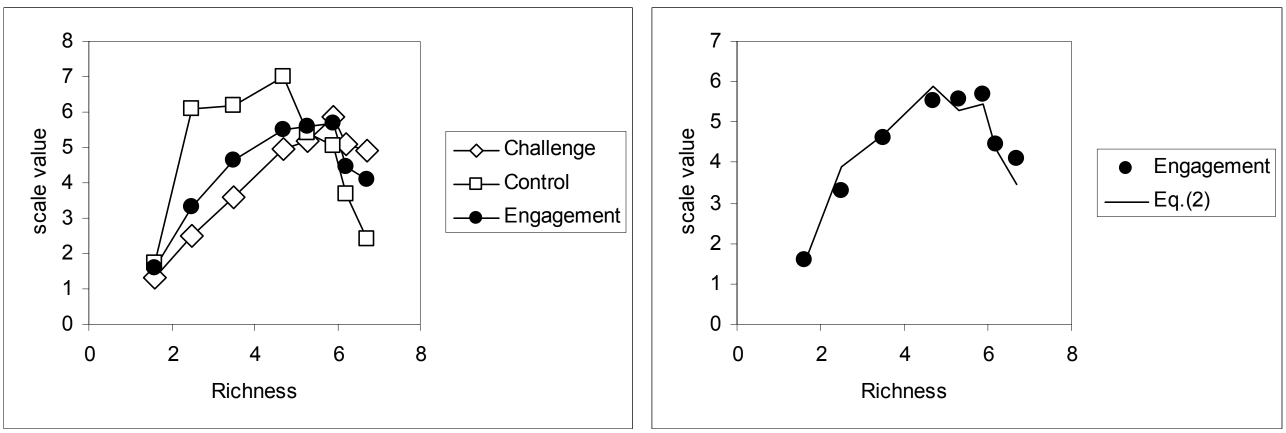

Fig. 3: Same as Fig. 2. Data for the decreasing richness condition only.

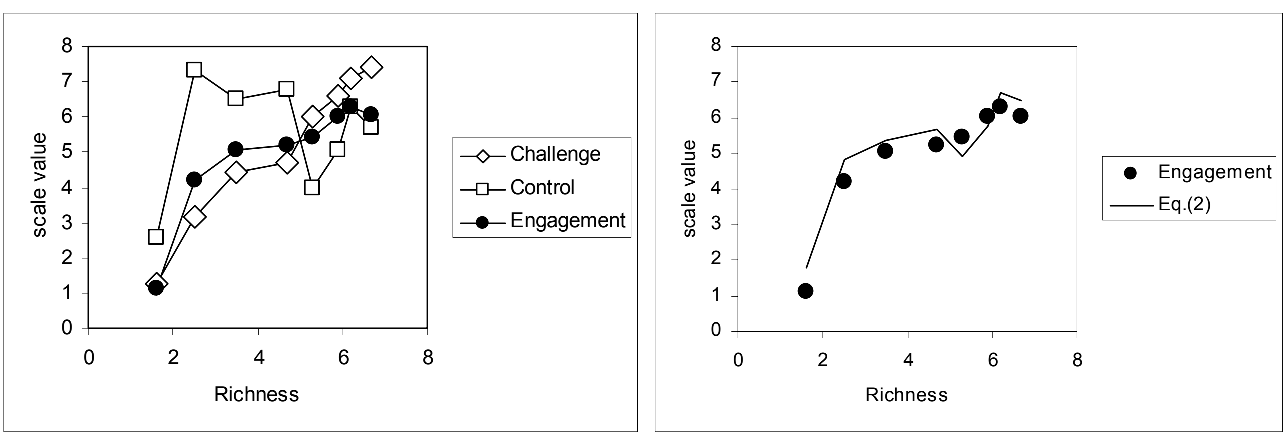

Fig. 4: Same as Fig. 2. Data for the increasing richness condition only.

In summary, the present study supports the new interpretation of the experimental data as presented in Rozendaal[21]. The main conclusion is that engagement depends on the richness of a user interface via experienced challenge and sense of control. Users appreciate the challenges evoked by the richness of an interface, provided that they still have the feeling that they are in control. This sense of control can be threatened in two ways: (1) the system is too simple in the sense that it does not provide enough means to fulfill one's goals and (2) the interface is too complex confusing the user. In other words, developing successful user-centered interfaces is a delicate game requiring thorough knowledge about humans.

3. HEDONIC AND ERGONOMIC QUALITY

3.1 Introduction

In 2000 Hassenzahl et al.[24] published a paper on the distinction between hedonic quality (e.g. novelty, originality) and ergonomic quality (e.g. simplicity, controllability). This paper initiated a study aimed at varying these subjective impressions by manipulating interactive media products, in this case interactive CD-ROM's containing presentations of three companies for future customers[25]. The stimulus set consisted of nine different CD-ROM's: the three existing ones, three simplified versions and three enriched versions (enriched by adding manipulative and audiovisual elements). At that time the data were somewhat puzzling. But the new insights provided by the conceptual framework on engagement may better explain these results. We therefore decided to re-analyze these data.

3.2 Method

The eighteen participants in the experiment were representative for the potential users of the CD-ROM's: they worked in companies and had experience with web pages and other interactive multimedia. Their age varied between 23 and 59 years with an average of 33 years. Each participant was instructed to evaluate three CD-ROM's each containing the presentation for one of the three different companies with one in its original format, one simplified version and one enriched version. For each CD-ROM, they had to carry out a number of tasks (e.g. searching for a name) and then evaluated the CD-ROM on 23 items. The list of items was taken from Hassenzahl et al.[24] including the bipolar five-point rating scales.

3.3 Results and discussion

A Principal Component Analysis with Varimax rotation resulted in two components. The following items (with a factor loading between .87 and .72) grouped around the first component: clear-confusing, simple-complex, comprehensible-incomprehensible, motivating-discouraging, supporting-obstructing, trustworthy-shady. This component was labeled *Ergonomic quality* and can be associated with sense of control in eq. (2). Similarly, the following items (with a factor loading between .81 and .71) grouped around the second component: exciting-dull, impressive-nondescript, exclusive-standard, original-ordinary, interesting-boring, innovative-conservative, attractive-unattractive. This component was labeled *Hedonic quality* and can be associated with experienced challenge in eq. (2). The following items had factor loadings larger than .4 on both components: pleasant-unpleasant, good-bad, sympathetic-unsympathetic, inviting-rejecting, desirable-undesirable. Together they represent *Appeal* as described by Hassenzahl et al.[24]. If appeal can be associated with engagement, than eq. (2) should also hold for this data set.

Figure 5 summarizes the experimental data following the above-mentioned clustering of items. Each panel represents the data for one company. Version 2 is the original CD-ROM presentation, version 1 the simplified version and version 3 the enriched one. Hedonic quality always appears to increase, but the impact of the manipulations on the ergonomic quality depends on the kind of presentation. For company A the ergonomic quality hardly varied suggesting that the manipulations were not able to change the already high ergonomic quality of the original. For company B, in contrast, the ergonomic quality systematically decreased from the simplified to the enriched CD-ROM. Here, the original version seems to possess the highest appeal. Finally, for company C the simplified as well as the enriched version seem to have lower ergonomic quality than the original one.

The results in figure 5 indicate that in most cases the appeal judgments lie in between those for the ergonomic and hedonic quality. This is in line with predictions from eq. (2) (Fig. 5, solid lines). Apparently, these data are also consistent with the conceptual framework presented in the previous section. Interestingly, a similar pattern as predicted by this framework has been observed in research on the relation between naturalness and quality when the colorfulness of color images of natural scenes was varied[17]. Further research is needed to verify how generic our conceptual framework is, that is, whether it is not confined to engagement only.

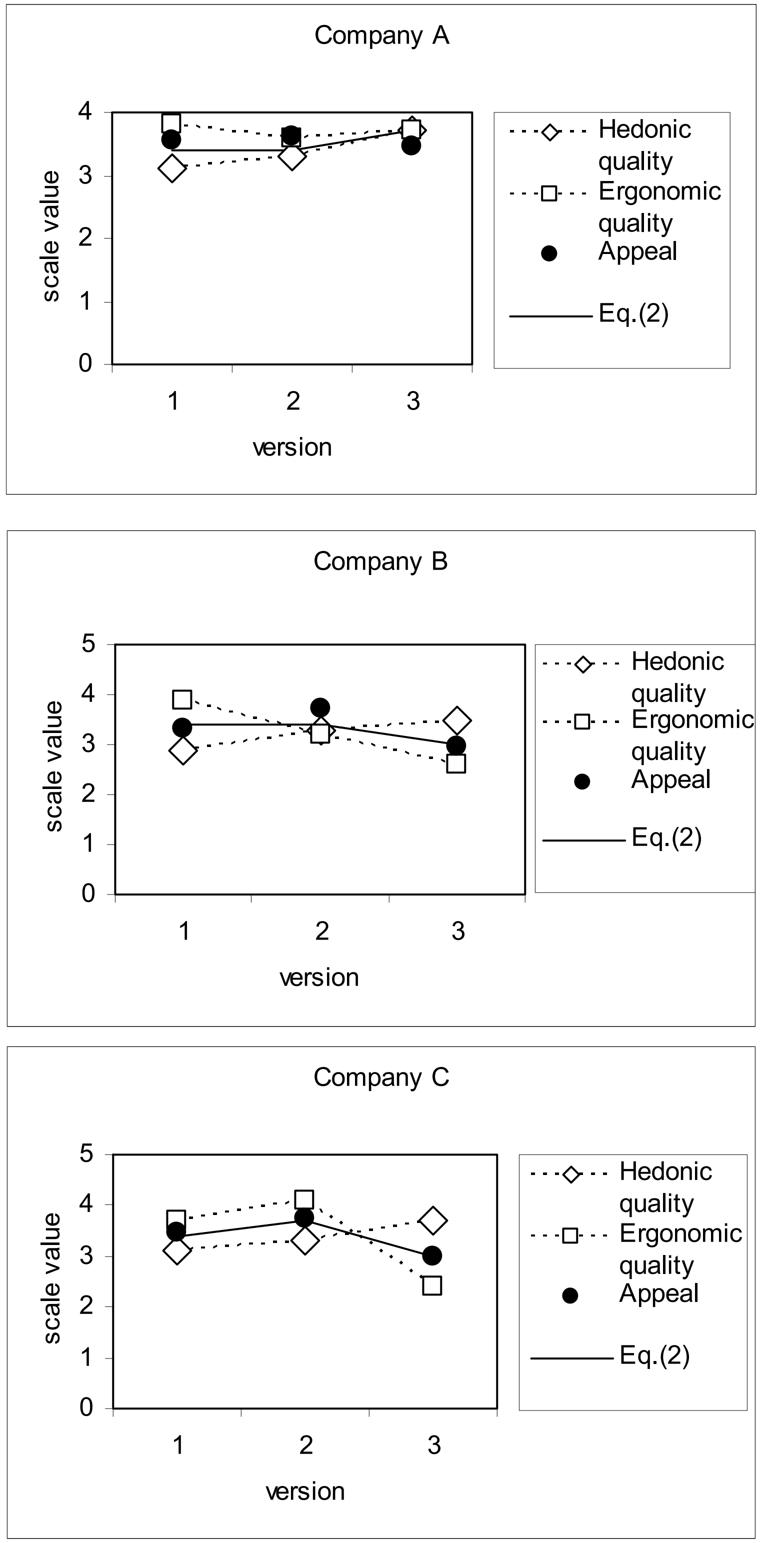

Fig.5: Hedonic quality, ergonomic quality and appeal of interactive CD-ROM's containing presentations of three companies for future customers. Version 2 is always the original one, version 1 stands for a simplified version and version 3 for an enriched version.

4. CONCLUSIONS

The first study concentrated on the subjective impression of engagement. The objective was to provide knowledge that could help improve the development of engaging interactions with digital products and smart environments. This resulted in an extension of the conceptual framework on engagement as introduced by Rozendaal[21]. The main conclusion is that engagement depends on the richness of a user interface via experienced challenge and sense of control. Users appreciate the challenges evoked by the richness of an interface, provided that they still have the feeling that they are in control. This sense of control can be threatened in two ways: (1) the system is too simple in the sense that it does not provide enough means to fulfill one's goals and (2) the interface is too complex confusing the user. The second study showed that the conceptual framework is also able to explain the way hedonic and ergonomic quality determine the appeal of interactive media. Finally, the first study revealed the influence of the direction in which the richness of an interface is changed. This calls for further studies into factors influencing the experienced engagement and its underlying dimensions. Preliminary results on the impact of the expertise of a user and the type of task can be found in Rozendaal[21].

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