PRESENCE AND FLOW IN VIRTUAL ENVIRONMENTS:

AN EXPLORATIVE STUDY

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Jari Takatalo

ABSTRACT

Virtual environments (VEs) are thought to elicit a sense of presence to the user. The sense of presence is considered as a psychological experience of being in a world generated by the computer instead of using the computer from the outside. As a field of research the psychology of VE is quite new and not well explored. In this study the three components of the sense of presence are examined: spatial awareness, attention and the realness of the VE. The three components solution of presence is accused of following Cartesian tradition in separating perception from action. Interaction is considered an important part of the experience of presence. Some authors consider it as the only determinant of presence.

The purpose of this study was to explore empirically this human experience. The idea was to integrate the presented presence components into a cognitive-emotional appraisal process from the environment. This type of an appraisal process in generating emotions dominates the field of modern psychological emotion theories. It has also been presented that similar appraisal process precedes optimal experience, i.e., flow.

Flow has been used as a metrics to evaluate human computer interaction. However, there are only few studies in which both presence and flow has been measured. In this study the participants gained experiences while conducting a simple search task in a virtual CAVE^{tm}. These experiences were measured with a questionnaire.

Based on the results a three-dimensional framework was constructed. This framework integrated the experience of presence and interaction as well as an appraisal process from the environment based on one's skills and challenges provided by the environment. In the appraisal process also personal relevance and evaluation of the interactivity of the VE are included. Framework also included two basic emotional dimensions arousal and control, which are considered important in producing the overall emotional experience.

The framework was used to explain different endpoint experiences gained by the users. The results showed that the sense of presence is an integral part of the flow experience in VEs and in order to experience VE positively a user should experience both presence and flow in VE. Although, the framework needs more careful studying, it provides a fair depiction of the basic dynamics behind a subjective experience in VE.

PREFACE

This thesis emerged from the need to expand the existing knowledge concerning scientific computing and visualisation using the concept of a virtual environment. The experiential aspect of this study is interdisciplinary, focusing on the psychological aspects of the user using this kind of technology. This project was conducted in co-operation between the CSC - Scientific Computing Ltd. (CSC), the Multimedia and Telecommunication Laboratory of the Helsinki University of Technology (TML) and the Department of Psychology at the University of Helsinki.

I would like to thank Leif Laaksonen from CSC, who without prejudice decided to expand the knowledge and believed and guided me throughout my exploration to the virtuality. I am grateful to all the people in CSC for providing a stimulating and supporting environment for me during the long hours in Otaniemi. Especially, I owe a great deal for both Jyrki Hokkanen and Jarmo Pirhonen, who were there from the beginning helping me out with the technology. I would also like to thank all the virtual wizards of the TML, especially Matti Gröhn, Tommi Ilmonen and Mikko Laakso, who did all the work in EVE and let me use their computers.

I am also grateful to my advisor, Göte Nyman, who put me on the field, but let me decide the tactics, still encouraging and giving me ideas along the way. Along the way also Aapo Puskala and Jukka Häkkinen provided me thankful help. During the past 15 months, I have discussed about these topics to many people, who I am not able to thank individually, but to whom I express my gratitude collectively. Especial thanks to all my friends and relatives and above all, to my beloved wife, Sini ...for just being there.

CONTENTS

1. INTRODUCTION

Someday the interaction with the computers will differ greatly from the way we use today's keyboards and 17" displays that force us into actions that are far from our normal ways of interacting with our environment. Computers will probably effect on our daily lives more, but their role is likely to be more invisible. The interaction will take place in spaces shared with humans and computers instead of interfaces, that require lot of adaptation and compromise from the user. Although, the technology today is not yet that invisible, new ways for human-computer interaction already exist. Virtual reality (VR) technology today, including hardware, software and interaction devices has the capability of immersing the user into a computer generated virtual environment (VE), in where the interaction takes place (van Dam, Forsberg, Laidlaw, LaViola Jr. and Simpson, 2000). To understand, how the user experiences psychologically these new ways of interacting is important for the further development of this technology.

The sense of presence, i.e., being in the VE is in the centre of the psychological research in VEs (Schubert, Friedmann and Regenbrecht, 1999). However, it is difficult to study and measure the true nature of presence (Schuemie, Van Der Straaten, Kriijn and Van Der Mast, 2001; Freeman, Lessiter and IJsselsteijn, 2001). Because of this it is hard to conclude the causes and effects of it (e.g., Nichols, Haldane and Wilson, 2000). It has also been argued that the research on presence has followed a conventional Cartesian viewpoint, separating perception from the action and thus separating mind from body (Sheridan, 1999). It has also been criticised on ignoring the emotional aspects on developing human experience (Huang and Alessi, 1999).

The goal of this study is to explore the reciprocal human-environment interaction thought to involve both mind and body as suggested by, e.g., Damasio (1994). Besides the current research on presence the user's appraisal of the situation and the emotions it evokes are considered. This type of a functional perspective on emotions dominates the field of modern psychological emotion theories (Frijda, 2000). The appraisal of the situation is also central to Csikszentmihalyi's (1975) theory of flow, i.e., the optimal experience, which has been studied, e.g., in well-defined human-computer interactions (Csikszentmihalyi, 1990; Novak, Hoffman and Yung, 2000).

1.1 Defining VE

VEs are envisioned as "systems that will enhance the communication between humans and computers" (Stanney, Mourant and Kennedy, 1998, p. 327). They can be defined as a general impression of technically created but real-like objects, environment or space (Hämäläinen, 1998). This impression can be created via a host of technologies starting from traditional desktop PCs and ending to a more sophisticated and more immersive displays such as CAVE's™ (e.g., Mania and Chalmers, 2001).

Reitamaa, Vanhala, Kauttu and Antila (1995), list the characteristics that all the different VE applications should possess. They suggest that VE should be interactive, i.e., it should respond to the user's actions. On the basic level this would include the naturalistic change of point of view trough head movements (Hodges et al., 1994). Secondly, the user should autonomously be able to react to events and stimuli provided by the VE. Third requirement is determinability

and fidelity, which means that the interaction should not be random in nature. Immersion, the fourth characteristic, is the VEs ability to mislead one's senses so well that the illusion of being somewhere is created. Slater and Wilbur (1997) distinguish two aspects of immersion as immersion and presence. They define immersion as a description of technology and presence as a person's subjective experience of the VE. Also other authors have approved this distinction (e.g., Bystrom, Barfield and Hendrix, 1999) and it has been confirmed in a factor analysis conducted by Schubert, Friedmann and Regenbrecht (2001).

VE applications introduced by Monnet (1995) can be roughly divided into three main categories: 1) entertainment, 2) simulation and 3) visualisation. Games and interactive virtual environments such as virtual shopping malls form the first category. Simulations are widely used in areas such as education, medicine and training. There are also applications for psychotherapy purposes, e.g., moderate post-traumatic stress disorder symptoms (Hodges, 2001) and social phobias (Slater, Pertaub and Steed, 1999). For visualisation VEs are used by, e.g., engineers, architects, chemists and designers. Van Dam et al. (2000) consider immersive VE to be an especially useful tool for scientists, mathematicians, and engineers who struggle with problems that produce larger and more complex models and data sets.

1.2 Defining presence

Presence is defined as the user's feeling of "being there" in a mediated environment (e.g., IJsselsteijn, deRidder, Freeman and Avons, 2000). Lombard and Ditton (1997) define it as the illusion of non-mediation in which the user no longer perceives the display medium. Synonymous with the term presence are terms such as synthetic presence, virtual presence,

ego presence and telepresence, which all refer to the same phenomenon of being in a mediated environment (Draper, Kaber & Usher, 1998).

Due to its psychological nature, presence is relevant in attempting to evaluate human experience in VEs (IJsselsteijn et al., 2000). Besides VEs, presence is also used as a global measure to explain the human experience in many other media (Freeman, Avons, Meddis, Pearson and IJsselsteijn, 2000). Compared to more traditional media such as television, radio and telephone, VR technology among all new technologies, e.g., high definition television, home theatre and video conferencing, is said to elicit stronger sense of presence (Lombard and Ditton, 1997; Steuer, 1992). Because of this, presence has become a design goal for VE designers (Biocca, 1997).

Some authors have speculated on the role of presence in the real world (e.g., Usoh, Catena, Arman and Slater, 2000). Our sense of presence in a physical world is such an everyday phenomenon, of which we do not think about, we just feel it (Huang and Alessi, 1999). Feelings are thought to follow emotions (Fehr and Russell, 1984), but Damasio (1994) use "the sense of being" as an example of a quite neutral background feeling that originates from the background body state instead of an emotion. These background body states are considered to prevail between the emotional states. Thus, presence in the real world is a "basic state of consciousness" (Biocca, 1997, p.17), a rather stable feature of our awareness, that does not change continuously (Freeman et al., 2000).

When processing mediated stimuli emotions play a strong role (Dietz and Lang, 1999). There are many factors, e.g., quality and size of the display and media content (Simons, Detenber,

Roedema and Reiss, 1999), which may cause the emotional feeling to supersede the background body feeling (Damasio, 1994). This may end the sense of being as it is understood in a real world setting, and begin the sense of presence in VE. Lessiter, Freeman, Keogh and Davidoff (2001) suggest that the concept of presence is more useful when restricted in mediated environments and they name, e.g., attention, involvement and arousal as potential psychological constructs that can be used to describe similar experiences in the real world.

1.2.1 Presence concepts

As the sense of presence has been used to describe human experiences from non-immersive and non-interactive books to highly immersive and highly interactive VEs (Schuemie et al., 2001), there are many different descriptions of it. Lombard and Ditton (1997) have grouped descriptions found in the presence literature under six interrelated but distinct conceptualisations:

- Presence as transportation
- Presence as immersion
- Presence as realism
- Presence as social richness
- Presence as social actor within medium
- Presence as medium as social actor

A thread in conceptualisations can be found, for example, in the WWW discussions on the Presence-L Listserv during the spring of 2000 (Lombard, 2000).

These conceptualisations can be further divided into two broad categories: personal (also the

term physical is used) presence, i.e., a sense of being physically located somewhere and social presence, i.e., being together and communicating with someone (IJsselsteijn et al., 2000). The relationship between the two categories is not fully understood. Some authors believe that social interaction increases personal presence (Thie and Wijk, 1998; Schubert, Regenbrecht and Friedmann, 2000; Slater, Sadagic, Usoh and Schroeder, 2000), and even diminishes the system requirements in creating it (Heeter, 1992). But there are also studies suggesting that these two may not correlate at all (e.g., Blake, Casanueva and Nunez, 2000).

1.2.2 Defining personal presence

For the sake of simplicity, the focus of this study is on the personal presence. It is composed of three components described earlier by Lombard and Ditton (1997): presence as realism, presence as transportation and presence as immersion. Although presence has been widely studied in the past few years, the often used simple rating scales have been quite unstable and ignored the many-faceted nature of the personal presence (Freeman, Avons, Pearson and IJsselsteijn, 1999). According to Schuemie et al. (2001), there are two questionnaires that are considered valid and reliable in the context of measuring the presence construct: Igroup Presence Questionniare (IPQ) by Schubert et al. (2001) and Independent Television Commission -Sense of Presence Inventory (ITC-SOPI) by Lessiter et al. (2001). Despite the theoretical and methodological differences between these two questionnaires, they both can be used to measure the previously described components of personal presence.

In developing the IPQ, Schubert et al. (2001) used principal component analysis to extract the

three presence components out of the data they had gathered from the WWW. Most of their subjects were males using a desktop based interactive 3D-games, which restricts and profiles their results into a certain type of user population and media. The theory behind their questionnaire is based on Glenberg's (1997) embodied cognition framework, which states that every environment is represented in the human mind as a spatial-functional model, based on the perception and memory. Lessiter et al.'s (2001) ITC-SOPI is based on the traditional definitions of presence (e.g., Lombard and Ditton, 1997). It was developed using the data gathered across different media, e.g., television, movies, IMAX 2D and 3D and video game consoles. The three presence components were extracted using a principal axis factor analysis.

Schubert et al. (2001) call presence as transportation as Spatial Presence. According to their theory it describes an active process of constructing a spatial-functional model, which represents actions in 3D-space. Lessiter et al. (2001) name their corresponding scale as the Sense of Physical Space. It is noteworthy, that their scale also includes items measuring interaction with and control over mediated environment. From the Presence-L Listserv (Lombard, 2000) discussion thread it is described to occur when the user fails to acknowledge the role of technology that makes it appear that the user is in a physical location and environment different from the actual location and environment in the physical world.

Also the term psychological immersion is used to describe this type of presence in which user's perception is directed toward the virtual world, and away from the physical world (Lombard, 2000). Schubert et al. (2001) call the presence as immersion as Involvement. They consider this sort of an active involvement to be essential for the active construction of a spatial-functional mental model of the VE. The existence of Spatial Presence -and

Involvement components confirms their Embodied cognition -theory of presence. Lessiter et al. (2001) name their corresponding scale as Engagement, and find it correlating strongly and significantly with their Sense of Physical Space – scale. The ability to allocate attentional resources to the VE from the other possible sources is seen as central by many authors (e.g., Biocca, 1997; Bystrom et al. 1999; Draper et al., 1998; Witmer and Singer, 1998).

Presence as realism is also called as sensory presence, perceptual realism, naturalness and tactile engagement. It is believed to occur when user perceives that the virtual environment looks, sounds, smells and feels similar to the physical world (Lombard, 2000). Schubert et al. (2001) call presence as realism as Realness and Lessiter et al. (2001) as Ecological Validity.

1.2.3 Consequences of presence

The effects of personal presence on user are unclear (Lombard and Ditton, 1997). High level of presence is thought to help a user to remember a VE as more of a place visited rather than as a set of pictures seen (Slater et al., 1999). Greater presence is also considered to lead to a similar behaviour in VE than in a real world (Slater and Wilbur, 1997). The sense of presence is shown to induce similar emotions and physiological responses as the real world experience, e.g., enjoyment (Nichols et al., 2000) or anxiety (Hodges et al., 1994) and increased level of skin conductance (Meehan, 2000) in virtual heights. Schuemie et al. (2001) indicate that the relationship between presence and emotional responses is quite weak and the causality of this relationship is unclear.

Also the causality between the sense of presence and task performance has not been clearly confirmed (Slater, Linakis, Usoh and Kooper, 1996; Welch, 1999). Bystrom et al. (1999) reason that presence is a vital prerequisite for performance in VE. Nichols et al. (2000) and Biocca (1997) support this by stating that high presence elicits the sensation of working within as opposed to being outside the computer-generated environment or a database. This quality of high presence may be especially useful when the natural way of observing visualised data is to be surrounded by it, e.g., an aircraft computer aided design (CAD) geometry (Mizell, Jones, Slater and Spanlang, 2000).

The relationship between the sense of presence and simulator sickness, experienced by some users during their exposure to VE is also unclear (Schuemie et al., 2001). The symptoms of the simulator sickness resemble those of motion sickness, but they tend to be less severe (Kennedy, Lane, Berbaum and Lilienthal, 1993). Some authors have found a negative correlation between the two (Witmer and Singer, 1998). Nichols et al. (2000) conclude that the sense of presence and sickness symptoms are linked but that enjoyment may outweigh distress caused by mild symptoms of simulator sickness. One such link could be the vection, i.e., the impression of self-motion, which is thought to be one of the causes of simulator sickness (Laviola, 2000) as well as presence (Prothero, 1998).

1.2.4 Causes of personal presence

Potential causes of presence experience can be grouped into user characteristics and media characteristics (e.g., Freeman et al., 2001; Lessiter et al. 2001; Lombard and Ditton, 1997).

Media characteristics can be further divided into media form and media content. It is likely that the experience of presence is a result of interaction between these three categories (Lessiter et al., 2001). For more detailed review, see, e.g., Freeman et al. (2001), Lessiter et al. (2001) or Lombard and Ditton (1997).

According to Freeman et al. (2001), user's physiological and visuomotor characteristic, e.g., visual and stereoscopic acuity, susceptibility to motion sickness and visuomotor coordination are likely to affect the presence experience. They also list user's psychological characteristics that may have an impact on the experience, e.g., personality, cognitive style, and ability to concentrate. They further add, that these characteristics are likely to vary with age and sex of the user. Lombard and Ditton (1997) emphasise user's willingness to suspend disbelief, i.e., they have to want to get involved in the VE. Also prior experience with mediated experiences affects the presence ratings (Freeman et al., 1999).

Media form includes objective qualities of a system (Lessiter et al., 2001), which can be modified by the administrator in order to enhance the level of immersion the system produces (Schuemie et al., 2001). Steuer (1992) provides two ways to enhance this level. One way is to increase the vividness, i.e., the extent and fidelity of sensory information of the system and the other is to enhance user's ability to interact with and modify the VE in real time. Also adjustments in the match between the user's actions and the environmental responses to those actions affect on the experience (Freeman et al., 2001).

Media content is considered to include all the objects, events and actors depicted by the VE system (Freeman et al., 2001). It is also described as an overall theme, narrative or story

provided by the medium (Lessiter et al., 2001). Slater and Wilbur (1997) call it the plot, which they saw as VEs ability to create an alternative reality with its own drama that captures the user away from the everyday reality.

1.2.5 The relationship between causes and components

Figure 1 shows the assumed relationship between the causes and measured components of physical presence based on the studies of Lessiter et al. (2001) and Schubert et al. (1999, 2000,2001). Lessiter et al. (2001) asked the users of the different media to rate their presence experiences and compared presence ratings between different media groups. Besides the presence ratings, Schubert et al. (1999, 2001) measured participants' evaluations of the media characteristics in their questionnaire. Lessiter et al. (2001) suggest that the media form variables may interact in a compensatory way. As an example they use the low fidelity but highly interactive video game console condition, which had the second highest score in Sense of Physical Space (Presence as Transportation) after high fidelity IMAX 3D.

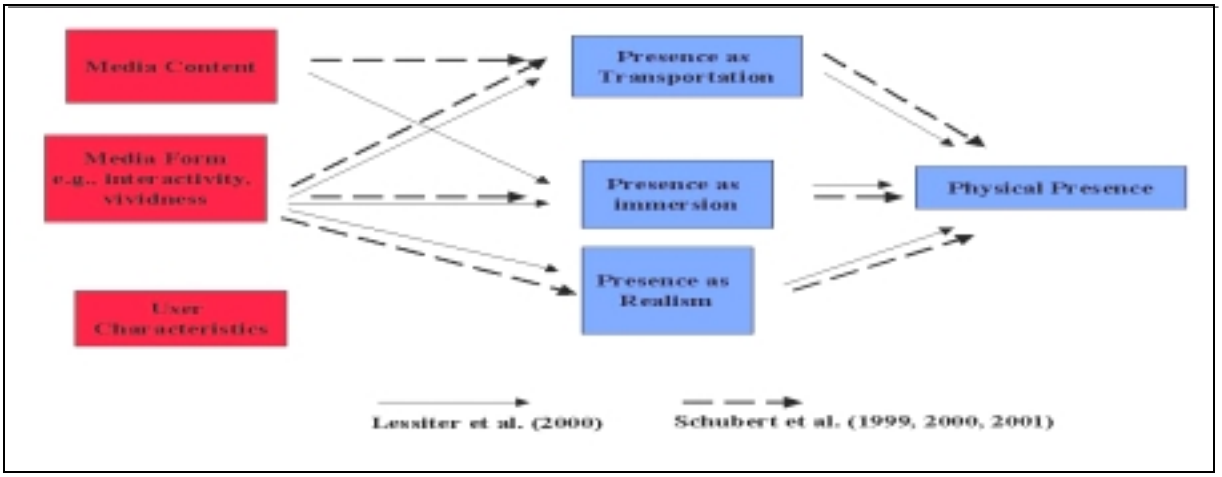

Figure1. The relationship between the causes and components of the physical presence based in the studies of Lessiter et al. (2001) and Schubert et al. (1999, 2000, 2001).

Schubert et al. (1999, 2001) extracted three immersion components (Quality of Immersion, Drama and Interface Awareness) and two interaction components (Exploration and Predictability) to measure participants' evaluations of the media characteristics. Although the Drama loaded on the immersion component in their second order PCA, it is considered here as a media content factor. Figure 1 shows the assumptions they made based on a path analysis (Schubert et al., 1999). The positive relationship between interaction, Spatial Presence (Presence as transportation) and Realness (Presence as Realism) has also been confirmed by Schubert et al. (2000).

1.3 Interaction in VEs

Interaction is acknowledged as one of the prime causes of presence in VE by many authors (e.g., Steuer, 1992, Lombard and Ditton, 1997; Draper and al., 1998). Steuer (1992) considers interaction as the participant's ability to participate in modifying the content, e.g., moving around in the VE, of a mediated environment in real time. He lists three important factors for interactive media:

- Speed with which the medium responses to the user's actions.
- Range of possibilities for action in VE.
- Mapping between the user actions and medium responses as natural as in the real world.

These factors are similar to those listed by Schuemie and van der Mast (1999).

There are also authors who consider successfully supported action as the only determinant of sense of presence. Action in VE is considered here as the human-VE interaction. These

ecological approaches to the sense of presence (e.g., Flach and Holden, 1998; Schuemie and van der Mast, 1999; Zahorick and Jenison, 1998) are based on the ontological views of Gibson (1979) and Heidegger (2000). The ecological view considers action to be successfully supported, when the environmental reaction is perceived as lawful and close to one in the real world. Feedback is thought to connect action into perception in a reciprocal manner and enhance presence in an environment (Schuemie and van der Mast, 1999; Zahoric and Jenison, 1998). Presence is thus more related to the functionality of the VE than its appearance (Flach and Holden, 1998). Because of this, the evaluation of the VE can be solely based on how the task is done in terms of perceiver-environment dynamics. How the task is completed or how it feels to do it is concerned irrelevant (Zahoric and Jenison, 1998).

1.3.1 Situational appraisal and emotion

There has been arguing against the bottom-up Gibsonian (1979) view of direct perception, in which the organism is considered to directly pick up the action supportive information (affordances) from the environment without mentally representing it. Cognitive, top -down information should also be integrated in the perception, because it is “not just what the organism perceives, but how it takes what it perceives” (Fodor and Pylyshyn, 1981, p.189). The role of the memory and previous experience in this process is emphasised (Glenberg, 1997). For example, a perception of, e.g., a tennis rack affords playing tennis, as Gibson (1979) suggests, but it is also likely to evoke some memories from the implicit memory towards the game as well (Glenberg, 1997). Damasio (1994) points out, that in this process emotion can not be separated from reason. Emotions are considered to motivate the perceiver

to act (e.g., Ellsworth and Smith, 1988; Lazarus, 1991), which underlines the importance of emotions in human-environment interaction.

Appraisal theories of emotion point out the role of a cognitive appraisal process of the situation that precedes the emotional experience (Dalgleish, 1998). One part of this process is thought to include the meaning of the situation in terms of goals and concerns at a given time to the perceiver (Lazarus, 1991). Another part includes a variety of dimensions, whose combination is evaluated leading to the emotion detached to that particular situation (Ellsworth and Smith, 1988).

In the theory of flow, the evaluation process concerns balance between a person's perceived skills and the challenges the situation provides (Csikszentmihalyi, 1975). Human behaviour is explained in terms of situational variables and trough the meaning of the situation to the particular individual (Ghani and Deshpande, 1994). Included in the theory are the three basic dimensions of emotion: arousal, control and valence, originally introduced by Wundt (1897). These dimensions are considered as "pervasive in organising human judgements for a wide range of perceptual and symbolic stimuli" (Bradley and Lang, 1994, p.49).

1.4 Defining flow

Flow has been studied among different cultures and socio-economic classes (Csikszentmihalyi, 1990), and many researchers from different disciplines have found it to be a useful framework when studying a variety of human activities (Ghani and Deshpande, 1994). Csikszentmihalyi (1975, p.36) describes flow as a "dynamic state" and "the holistic

sensation that people feel when they act with total involvement". In a state of flow a particular activity is perceived so enjoyable and intrinsically interesting that it is considered worth doing for its own sake (Csikszentmihalyi, 1990).

To reach a state of flow, one should perceive a match between the level of skills possessed and the challenges provided by the situation. The level of these both should also exceed a critical threshold (Csikszentmihalyi and Csikszentmihalyi, 1988). Activities leading to flow should also "facilitate concentration and involvement by making the activity as distinct as possible from the so-called "paramount reality" of everyday existence" (Csikszentmihalyi, 1990, p.72). Such activities should also provide a clear goal and instant feedback to the actor as well as increase the actor's sense of control (Csikszentmihalyi, 1997, 1990). Examples of this kind of activities are, e.g., playing games, sports and arts. While engaging to them an actor usually loses self-consciousness, time passes more rapidly and an actor gains enjoyable experiences (e.g. Csikszentmihalyi, 1990; Ghani and Deshpande, 1994).

The different outcomes of the evaluation process of skill and challenge are introduced in the eight-channel flow model (Massimini and Carli, 1988). In the model, arousal is considered as an outcome of a moderate skill and high challenge situation, whereas control follows situations where skills are high and challenges are moderate. Novak et al. (2000) report that skill and control as well as challenge and arousal form two higher order constructs that correspond to the higher level of flow. The causality from skill to control and from control to flow is also found by Ghani and Deshpade (1994). The relationship between flow and valence is hypothesised, e.g., Csikszentmihalyi (1975) and Novak et al. (2000). The relationship was established by Csikszentmihalyi and LeFevre (1989), who also found a positive correlation

between flow and motivation. Novak and al. (2000) found greater importance (motivation) relating positively to both skills and challenges.

1.4.1 Flow and presence

The first to study these two interdependently was probably Fontaine (1992), who studied flow and presence in an intercultural interaction in real life. He considered them differentiating in terms of attentional focus, flow having more narrow focus than presence. Measuring different aspects of human attention trough self-report procedures is however claimed to lack, e.g., construct validity (Moran, 1996). Presence in a real world setting may also differ from presence in VE, as it was described earlier in this study.

Draper et al. (1998) assume that (tele)presence could be a special type of flow experience that occurs during teleoperations. Bystrom et al. (1999) introduce a loop between the task characteristics, attentional allocation and presence. According to them, a more engaging task attracts more attention and increases the sense of presence. They considered this loop similar to the flow theory (Csikszentmihalyi, 1975) and Zahoric and Jenison's (1998) ecological coupling between perception and action. Hoffmann and Novak (1996) hypothesised that presence is likely to attract more users' attention into the computer-mediated environment and lead to the greater flow.

The only study found by the author, in which presence and flow were examined together, is the Novak et al. (2000) study concerning the users' experience in the WWW. In this study,

presence is measured with an eight item Self-reported Telepresence Scale (Kim and Biocca, 1997) and interactivity is measured only in terms of its speed. However, the constructs used to measure flow integrated a great deal of information from various previous flow studies and may thus be considered quite comprehensive.

Novak et al. (2000) find, that a focused attention is related to presence and presence again corresponds to a greater flow. They hypothesise that a greater interactive speed would correspond to presence, focused attention and flow. A significant relationship was only found between interactive speed and flow. However, interactive speed increased challenges, which affected the focus of attention. Focused attention in turn was positively related to presence as it is shown e.g., Lessiter et al. (2001) and Schubert et al. (2001). Novak et al. (2000) conclude that a better measurement of presence as well as interactivity is needed to fully investigate the relationship between the concepts.

1.5 Research hypothesis

This study investigates the relationship between a VE user's subjective perceptions concerning personal presence, perceived and evaluated interaction and cognitive appraisal process in terms of user's skills, challenges and personal relevance. Also two basic emotional dimensions, arousal and control are taken into consideration. These constructs are also used to explain the different endpoint feelings gained from the VE exposure. Because the field studied is quite new and not well established, the nature of this study is an explorative one. The main goal here is to test the suitability of the used constructs in measuring this type of experiences and to create a foundation for the future studies concerning the users' experiences in

computer-mediated environments.

It is hypothesised that:

1) There is a clear distinction between subjective presence perceptions and cognitive appraisals of the situation in terms of skills and challenges.
2) A sense of presence is a prerequisite for flow to occur in VE, i.e., those experiencing presence are likely to experience flow, flow can not be experienced without presence but presence may be experienced without flow.
3) Interaction has an impact on presence.
4) Presence and flow are positively related to the positive outcomes from the VE exposure and negatively related to the negative outcomes.
5) High skills and challenges have an impact on flow.

2. METHOD

2.1 Pilot study

A pilot study was conducted before the main study. The participants (n = 11, females = 6, males = 5) in the pilot were mostly from the Department of Psychology at the University of Helsinki, who had only a minor knowledge about the technology used, but a more thorough insight related to measurement and research design issues. After the participants had gone through the test procedure, they were interviewed and asked to fill in the Experimental Virtual Environment -Experience questionnaire (EVEQ) and encouraged to evaluate it critically. One of the participants was already familiar with the questionnaire and was only interviewed after the VE exposure.

The pilot study provided information about the WWW based test information pages itself, which included a test schedule system and a demographic data questionnaire. The pilot study was also needed to test the proper function of the software and hardware of EVE, to see that the task used fulfilled the expected demands and that the instructions were adequate. The pilot showed no needs for any major changes in the test procedure or the questionnaire.

2.2 Main study

2.2.1 Technology used

The main study was conducted in the Experimental Virtual Environment (EVE), hosted by the Multimedia and Telecommunication Laboratory at the Helsinki University of Technology

(http://eve.hut.fi). EVE is a rear -projection based VR system, in which the user is surrounded by three 3 meters wide and high screens (Figure 2). The resolution of the display is 1024 by 768 pixels. Stereoscopic images are produced and reflected to the screens by a Silicon Graphics (SGI) Onyx2 computer with two Infinite Reality graphics pipelines and two raster managers, which are driving four ElectroHome Marquee 8500 LC Ultra projectors. In order to view the environment in 3D, Stereographics© shutter glasses are worn.

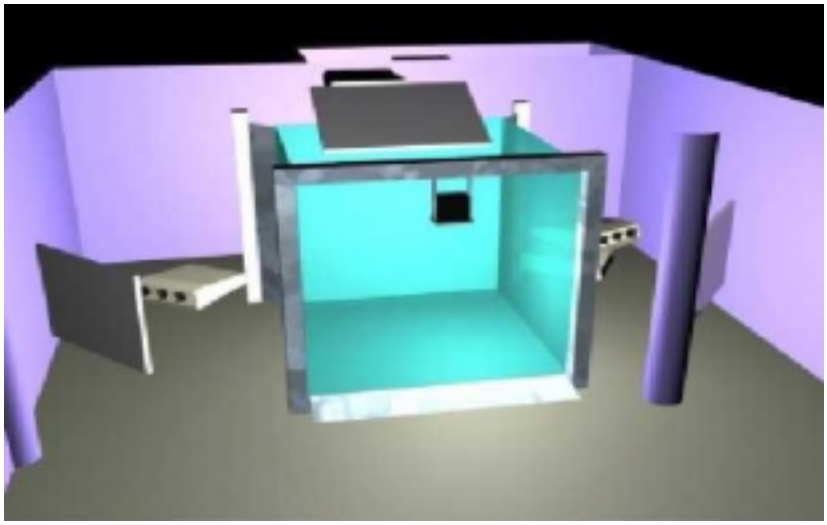

Figure 2. The design of the 2nd phase of the EVE (Mantere, 2001). In this study the floor was not in use.

The projectors are producing approximately 1000 ANSI lumens per eye in which shutter glasses, mirrors and screens diminish almost 90%, leaving approximately 100 ANSI lumens per eye. Shutter glasses also divide the refresh rate of the display (120 Hz) into half (60 Hz). The participants were able to interact with the environment by a Logitech© radio mouse, which was equipped with a six degrees of freedom tracking device by Motionstar©. The instructions on how to use the radio mouse and move in VE were linked to the test information pages in WWW. All the participants were familiarised with the instructions

before entering the EVE.

The software used was a modified version of the HCNav by Laakso (2001). The model of a virtual house, where the test task took place, was from the “Friends of performer” -collection (misc94/house.dwb). The model was relatively simple with only 4657 triangles and 31 textures. The extra objects used were imported from the 3D-cafe (http://www.3dcafe.com/). All the sounds used were from a set of commercial sound effect compact discs or SGI software synth’s sound library. The participants heard the sounds trough EVE’s 3D-audio system with a volume of approximately 65 dB. For a more comprehensive description of the software and hardware used, see Jalkanen (2000) and Laakso (2001).

2.2.2 Participants of the study

An e-mail concerning the test was sent to the mailing list of the psychology students in the University of Helsinki, two different lists of cognitive science students also in the University of Helsinki and the staff list of the CSC - Scientific Computing Ltd. The mail included a Web link to the information and test schedule pages. The mail also included an encouragement to forward it to all that might be interested in VEs. The total amount of participants in the main test was 58. Due to a small number of subjects and minor changes conducted after the pilot to the test procedure and questionnaire the participants from the pilot were added into the total amount of participants (n=68) and used as one sample.

The sample consists of 43 males (63.2%) and 25 (36.8%) females. There was an attempt to

increase the lower amount of females but only four females out of nine invited took part in the test. The age of the participants range from 18 to 45 (M=28.15 years, SD=5.50). In the occupational wise the sample was representative. The educational background of the participants was mainly high school graduates (n=32, 47.1%) and university degree holders (n=31,45.6%). All the participants reported to have at least a basic knowledge on computers. The time of computer use by the participants per week ranged from 0 to 60 hours (M=28.51 hours, SD=16.78). Only nine participants (13.2%) had prior experience on virtual environments like EVE. Twenty-two of the participants (32.4%) reported not to play computer games at all and only three participants (4.4%) played computer or video games more often than every other days.

2.2.3 Test procedure

The author administered all the 11 pilot tests as well as the 58 main tests. Participants were instructed to stand in the middle of the EVE facing the front yard of an American style of small-detached house, which was embedded into a village model. They were informed, that this is the environment where the action will take place. To familiarise the participants with the environment, a short ride around the house was given. The author gave the ride from the control table. It took approximately one minute and included "flying" around the house sideways, facing the house all the time and landing back to the front yard (Figure 3).

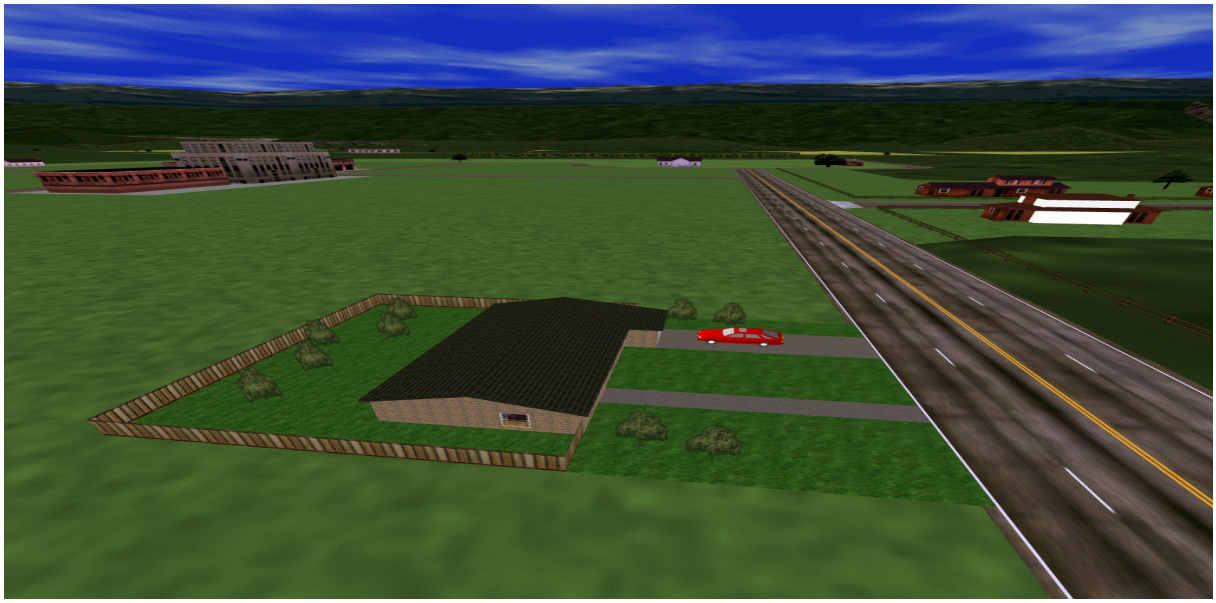

Figure 3. “Flying” around the test environment.

After landing, the "fly" -mode was turned off so that the participants were only able to use “walk” –mode, i.e., move on the ground level. Then the author repeated the radio mouse instructions and allowed the participant to rehearse moving outside the house. The rehearsal period was not restricted in any other ways but entering the house or peeking in the windows. The author instructed the participant if necessary in finding an effective way to move around. The rehearsal period took approximately five minutes.

2.2.4 Task

The idea of the task was to provide the participants a meaningful and quite neutral activity for 10 to 15 minutes in EVE. The task was to go into the house and explore it in order to find objects that do not belong into a normal house. The house was a normal five-bedroom place with two bathrooms (Figure 4). There was only one “wrong” object at the time and when it

was found the participants were instructed to collide it. The collision made an object disappear and produced a small sound. At the same time another object turned up somewhere else in the house. The objects and their placing were carefully planned so that confusions would be avoided. The names, places and corresponding sounds of the objects are presented in Appendix 1.

Figure 4. A view inside the house, from the living room to the kitchen.

There were a total of 10 objects in the house and one at the backyard. The participants were informed about this and asked to look out the windows once in a while if they could not find anything inside the house. The object outside the house was a Boeing-747. The instructor emphasised that it is better to go and check all suspicious objects than just consider them as a part of the furniture. There was no collision detection, so the participants were able to walk trough walls and furniture. However, they were not encouraged to do so.

When the instructions were understood the author restored participant's viewpoint to the beginning of the short passageway leading to the main entrance of the house. Then the participant was instructed to enter the house. The administrator was observing the test from behind letting the subject concentrate fully to the VE. When the participant found all the objects or reached the limit of 15 minutes the author aborted the task. The whole procedure took approximately 20-25 minutes. Afterwards the participants were asked not to share any details concerning the test procedure with anybody who might still take part in the study. Participants were asked to fill in the EVE –Experience Questionnaire (EVEQ) and served coffee or tea and a bun in a nearby cafeteria.

2.3 Measures

The items of the EVE -Experience questionnaire (EVEQ) were collected from the various questionnaires published in the following articles by Fontaine (1992), Ghani and Deshpande (1994), Havlena and Holbrook (1986), Kim and Biocca (1997), McQuarrie and Munson (1992), Novak et al. (2000), Usoh et al. (2000), Webster and Martccio (1992) and Witmer and Singer (1998). Some of the items were collected from the various WWW pages. The IPQ used in Schubert et al. (2001) study was found from the http://www.igroup.org/pq/ipq/. Television questionnaire (TQ) (http://nimbus.ocis.temple.edu/~mlombard/research.htm.) by Lombard et al. (2000) was also used. Some of the items were created in this study. Because the Lessiter et al.'s (2001) ITC-SOPI is not available publicly in the WWW, it was asked from the authors and some of its items were used in this study. Due to the commercial nature of ITC-SOPI, links to its items used are not reported. This information may be requested from the author.

All the items were translated from English or Germany into Finnish. Those items having the same semantic meaning but different grammatical form were combined into one item. The aim of the combination was to reduce items but keep those who measured different aspects of various phenomena. Most of the items from different questionnaires were transformed into a 7-point Likert -scale (1 = Strongly Disagree to 7 = Strongly Agree). Also 7-point semantic differentials were used. In the final version the different items were blended.

2.4 Construction of the scales

In order to analyse the relationships between the 135 variables, the data was reduced into 21 scales. The scales were divided into two categories: presence and flow components and endpoint feelings from the VE exposure. Presence and flow components are thought to be involved in a dynamic process, which leads to the endpoint feelings from the exposure. For example, the three presence components are thought to lead to the endpoint Being there.

The scales were formed in a principal factors analysis (PFA). Since the desirable subject to variable ratio in a factor analysis is 1:5 (Tabachnick and Fidell, 1996), an analysis for the whole data was not possible. To form the scales, a PFA was conducted for the part of the data and the factor scores with Bartlett's method were computed. The small amount of subjects restricted the maximum amount of variables in a one PFA to 13. Because of the formation method, the criterions to include a variable into a factor were critical. The variables were first grouped according to their usage in previous studies. The fit of a variable to the semantic meaning of the rest of the group was considered important. The fit of a group of variables to PFA was measured with Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and

Bartlett's test of sphericity. KMO measures for all the factors were well above the critical threshold of .50. Also in every case the Bartlett's test was significant ($p<.000$).

Only those variables loading above .30 to the first factor were kept in a scale (Tabachnick and Fidell, 1996). Also the communality, i.e., an estimate of the variance in each variable accounted for by the factors in the factor solution was observed. The items, loadings of the items to a factor (scale), eigenvalues of the factors and the percent of a variance explained by each factor are presented in Finnish in the Appendix 2 and in English in Appendix 3. Usually the second highest factor in the solution had an eigenvalue less that 1, which indicates a one-dimensional solution. The normality of the factor scores was measured through a Kolmogorov-Smirnov -test of normality, according to which all but two were normally distributed (>.05). Missing values were replaced with means in order to keep all the observations. Outliers were detected by observing the distributions and plots and if found their scores were changed so, that they were one unit larger than the next most extreme score (Tabahcnick and Fidell, 1996). The internal reliability of the formed scales was measured by using the Cronbach's alpha.

2.4.1 Presence and flow scales

Scales formed in this study are in bold. **Spatial** (presence as transportation) -scale included nine items concerning spatial awareness and the sense of being somewhere instead of looking at something from outside. The scale reliability (Cronbach's alfa) was 0.84. Included were items from the IPQ's (Schubert et al., 2001) "Spatial presence" -scale (alfa's in two different

studies .80 and .77), Lombard et al.'s (2000) Television questionnaire (TQ) and Slater-Usoh-Steed -questionnaire (SUS) (Usoh et al., 2000).

Attention (presence as immersion) -scale included items concerning user's ability to stay focused on the VE, not being aware of the real world, concentrating on the present moment and the experiences of time distortion. The alpha coefficient for 11 items was .90. The items were previously used in the "Focused attention" - and "Time distortion" -scales of the Novak et al.'s (2000) Flow survey (FS). All four items that formed IPQ's (Schubert et al., 2001) "involvement" -scale (alphas in two different studies .76 and .76). One item was from the "involvement" –cluster of the Witmer and Singer's (1998) Presence Questionnaire (PQ). One item, which was split into two different items, was from the Fontaine's (1992) Experience Questionnaire (EQ).

The alpha for six items forming **Real** (presence as realness) –scale was .83. It described how believable and real the VE was felt. Included were three out of four items from the IPQ's (Schubert et al., 2001) "Realness" -scale (alphas in two different studies .68 and .70). Other items were used in PQ (Witmer and Singer, 1998), TQ (Lombard et al., 2000) and EQ (Fontaine, 1992).

Three different scales that measured different aspects of interaction were formed. **Action** –scale could be described as the experience of active and real-like participating in the events in VE. Its seven items had the reliability coefficient of .82. It was consisted of items previously used in TQ (Lombard et al., 2000) and IPQ (Schubert et al., 2001). The **Interaction SMR** (alpha = .81, four items) gathered Steuer's (1992) determinants of interactivity described

earlier, speed, mapping and range. It can be considered as the user's subjective evaluation of a quality of the system. Included were items used in FS's (Novak et al., 2000) interaction speed scale (alpha = .69). Last scale concerning interaction was **Exploration**, which was a description of the perceived ability to visually explore and examine the virtual environment. The alpha for these three items was .74. These items were previously used in PQ (Witmer and Singer, 1998) and IPQ (Schubert et al., 2001).

The 11 items **Skill** –scale (alfa = .91) had five items from the FS's (Novak et al., 2000) skill scale (alphas in two different studies .86 and .86). One item was previously used in PQ (Witmer and Singer, 1998). Rest of the items were created in this study in order to measure different skill dimensions, i.e., using the VE and performing the task in it. However, all the items loaded into the same factor. All but one of the six items forming the **Challenge** -scale (alpha = .84) were used in the FS's (Novak et al., 2000) challenge scale (alphas for two different studies .88 and .80). One item concerning the challenge of the task was created in this study. All the other items concerned challenges using the system. All the items loaded on the same factor, like it was the case with the skill items.

Personal relevance –scale (alpha = .87) consisted of seven items concerning the motivation and personal relevance of the participant. Most of the items were seven point semantic differentials, previously used in the McQuarrie and Munso's (1992) importance scale (alpha = .95). The same scale (alphas in two different studies .88 and .92) was used by Novak et al. (2000). One additional item was created in this study. Scales for **Control** (alpha = .82) and **Arousal** (alpha = .67) had four items each and scale for **Valence** (alpha = .86) had five items. They all were composed of semantic differentials derived from the original six items version

(e.g., Russell, 1980) by Havlena and Holbrook (1986). In addition to that, there was one extra item in Valence from the original scale. Havlena and Holbrook (1986) report that all the coefficient alphas exceed 0.90. Also Novak et al. (2000) use the same reduced scales in their FS. They report following coefficient alphas: control (.69), arousal (.65) and positive affect (valence) (.86). Valence is reported here although it was used as an endpoint feeling in this study.

2.4.2 Scales for endpoint feelings

The nine items of the **Flow** –scale (alpha = .85) outline the feelings described by persons that believe they are experiencing the flow. This type of an experience is characterised by the feelings of being creative and innovative, free and alive and everything is happening easily and without constraints. It is composed of items used in an FS's (Novak et al., 2000) playfulness scale (alphas in two different studies .78 and .83), originally published by Webster and Martocchio (1992) (alphas in five studies .86 - .90). Also items from the EQ (Fontaine, 1992) was used. One item was developed in this study. **Being there** –scale (alpha = .84) consisted five items describing the classical definition of the presence, i.e., the sense of being somewhere else where one's body is located. It is mostly composed of items that have been used in simple rating scales to measure users' sense of presence (Usoh et al., 2000; Kim and Biocca, 1997). The Kim and Biocca scale was used in the FS (Novak et al., 2000), but the alpha was not reported.

The nine items forming **Impressed** -scale (alpha = .87) were used in the IPQ (Schubert et al.,

2001). It was a description of a strong experience that felt exciting and impressed the participant. **Pleasant** –scale (alpha = .77) was formed from six items that describe the experience as sensible and agreeable. Most of the items were constructed in this study. **Mediarichness** –scale (alpha = .84) was composed of the seven items used in TQ (Lombard et al., 2000). This scale measured how personally and emotionally the media is perceived.

The Anxiety –scale (alpha = .82) is entirely composed of items constructed in this study. Its seven items imply that acting and performing in VE is frustrating, boring and anxiety evoking. **VE distracted** –scale included four items (alpha = .61), that account for the difficulties experienced during the VE exposure. Among three items created in this study there was also one item from the PQ (Witmer and Singer, 1998). A set of items measuring negative effects in VE was also included. These items were previously used in, e.g., IPQ (Schubert et al., 2001) and TQ (Lombard et al., 2000). Most of these items were originally introduced in the Simulator Sickness Questionnaire (SSQ), developed by Kennedy et al. (1993). The 11 items used in this study did not distribute normally. Two scales, **Nausea** (alpha = .85) with six items and **Tiredness** (alpha = .70) with five items were formed.

2.5 Statistical analysis

All the statistical analyses were conducted with the SPSS 11.0 statistical program. The 11 scales measuring presence and flow were factored as of a second order factor analysis in order to explore their relationships. To further analyse the user experiences, the participants were divided into groups in a hierarchical cluster analysis according to the same 11 scales used in a factor analysis. The Squared Euclidean distance measure was used when forming the clusters.

Ward's method was used as a linkage rule when clusters were linked together. The standardised z - score of each variable was used in the analysis in order to eliminate the bias of the, e.g., differences in standard deviations and different type of scales used in the questionnaire (semantic differentials and 7-point Likert –scales) (Hair, Anderson, Tatham and Black, 1995).

The group means in different scales were compared with a one-way analysis of variance (ANOVA). For those scales having unequal variance among the groups the Brown-Forsythe statistic was used to overcome the obstacles of standard ANOVA. Because the sample sizes of the groups were unequal, the Tukey-Kramer (Tukey–b) post hoc comparison was chosen to further analyse differences between the groups. In the case of scales having also unequal variance the Games-Howell post hoc comparison was conducted (Howell, 1997). Small sample size and high number of compared groups lowered the power of the post hoc comparison. Because of this also two groups' comparisons were made.

3. RESULTS

3.1 Presence and flow

The relationship between the 11 scales measuring presence and flow components was explored in a PFA (Table 1). Varimax rotation was used to rotate the solution. The factorability of the matrix was inspected with KMO (.77) and the Bartlett's test of sphericity ($p<.001$). Three factors with an eigenvalue greater than 1.0 were extracted. The critical cut-off level to include a variable into a factor was .30 as recommended by Tabachnick and Fidel (1996).

Table 1.
The loadings of the 11 scales on three factors, eigenvalues and variances explained by each factor. Bold indicates the factor a scale belongs into.

Scale	Factor 1	2	3
FACTOR 1: SUBJECTIVE EXPERIENCES (SE)			
Spatial	**.89**	.01	.27
Action	**.82**	.30	.10
Attention	**.72**	.08	.17
Real	**.71**	.22	.13
Arousal	**.52**	.28	.16
FACTOR 2: CHALLENGE APPRAISAL(CA)			
Challenge	.24	**.77**	-.09
Personal relevance	.08	**.58**	.03
Interaction SMR	.44	**.49**	.17
FACTOR 3: SKILL APPRAISAL (SA)			
Exploration	.25	.08	**.60**
Control	.14	.18	**.59**
Skill	.07	-.20	**.55**
Eigenvalue of the factor	4.35	1.66	1.18
Variance explained by each factor	39.52%	15.10%	10.75%

3.2 Different groups of users in EVE

In order to investigate how the 11 presence and flow scales effected on the endpoint experiences in EVE, the participants were divided into five groups, according to these scales, in a hierarchical cluster analysis. Although, the agglomeration schedule of the Ward's linkage did not support the five-cluster solution, the explorative nature of the study and the significant differences between the group means in given scales justified the extracted solution. This type of use of the cluster analysis is supported by, e.g., Hair et al. (1995). The formed groups differed also significantly in all the other endpoint scales but simulator sickness scales Nausea and Tiredness. However, the impact of these two to the overall experience can be considered strong. Some of the highest scoring participants in these two scales had to for example terminate the test. There were seven high scoring outliers in Nausea and two in Tiredness, one participant was an outlier in both scales. All in all eight participants reported remarkably strong negative experiences. Four of these participants belonged into a Group 1, three into a Group 5 and one into a Group 2.

The eight participants were removed from the data and a hierarchical cluster analysis corresponding to the first one was conducted for the remaining participants (n=60). Groups 3 and 4 were intact and the only change in Group 2 was the withdrawal of the one participant scoring high in Nausea. Group 1 lost four participants and Group 5 three, but in a new analysis these groups were reorganised so that eight participants moved from the Group 5 to Group 1 and five participants moved from the Group 1 to Group 5. Group 6 was formed from the eight removed participants, of which three females and one male had to terminate the test.

The information considering the six groups after the reorganisation is presented in Table 2. The number of females and males differentiated between the groups ($p<.01$, Fisher's exact). Groups 1, 2 and 3 were dominated by males and Groups 5 and 6 by females, which can be seen from the sex percent ratios within each group. Other background variables (see Appendix 3) did not differentiate between the groups.

Table 2.
Sizes and sex ratios of the six groups.

Group number	N	Females (% within a group)	Males (% within a group)
Group 1	24	7 (29.0%)	17 (71.0%)
Group 2	14	2 (14.0%)	12 (86.0%)
Group 3	6	0 (0.0%)	3 (100.0%)
Group 4	6	3 (50.0%)	3 (50.0%)
Group 5	10	7 (70.0%)	3 (30.0%)
Group 6	8	6 (75.0%)	2 (25.0%)

Also the six groups differentiated significantly across the 11 scales, which validates the reorganised solution. Two scales, Control and Spatial, did not support the equal variance assumption (Levene) of the ANOVA. These two scales were tested with the Brown-Forsythe (B-F) asymptotically F-distributed test, which supported the statistical difference between the groups in both scales. The presence-flow profiles of the six groups are presented in Figure 5. The group means, standard deviations and F-test statistics in different scales are presented in Appendix 4.

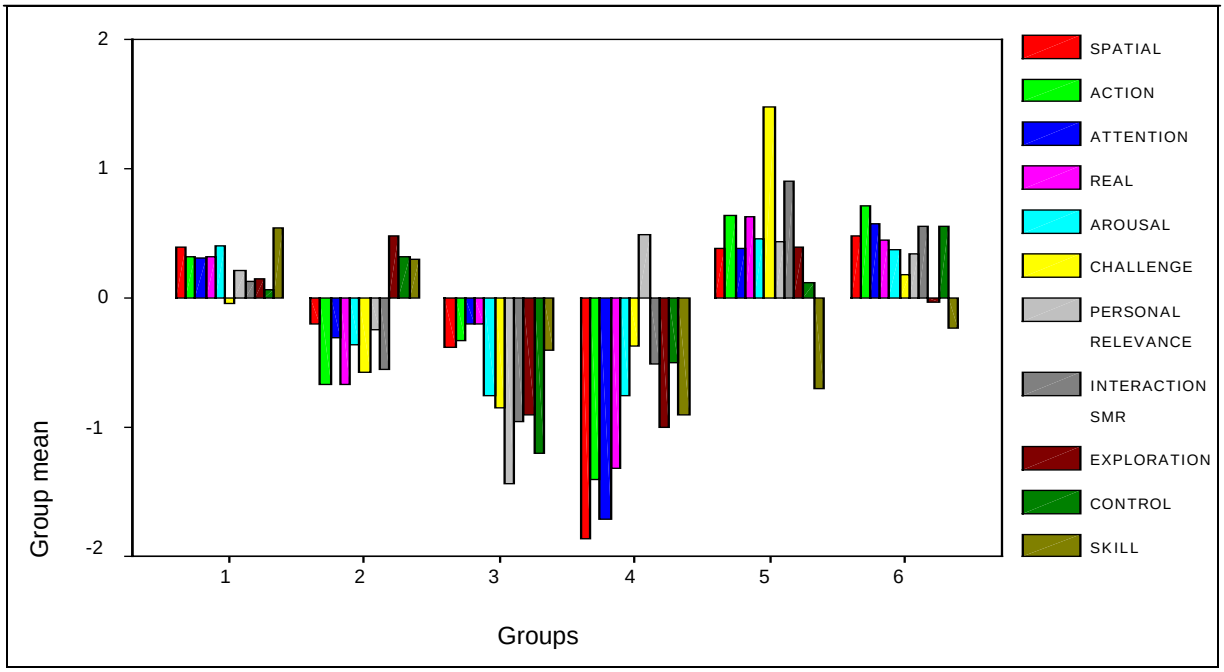

Figure 5. The profiles of the scale means measuring different presence and flow components across the six different groups of participants. First five scales are related to subjective experiences, scales 6-8 are related to challenge appraisal and scales 9-11 to skill appraisal.

The profiles of the endpoint feelings of the six different groups are shown in Figure 6. The groups differentiated significantly in scales Pleasant, Impressed, Mediarichness, Being there, Flow and Nausea. Impressed and Tiredness did not support the equal variance assumption. When the Brown-Forsythe test was used, the groups differentiated significantly in Impressed, but not in Tiredness. Also Valence, VE distracted and Anxiety did not differentiate significantly across the six groups. The group means, standard deviations and F-test statistics in different endpoint scales are presented in Appendix 4.

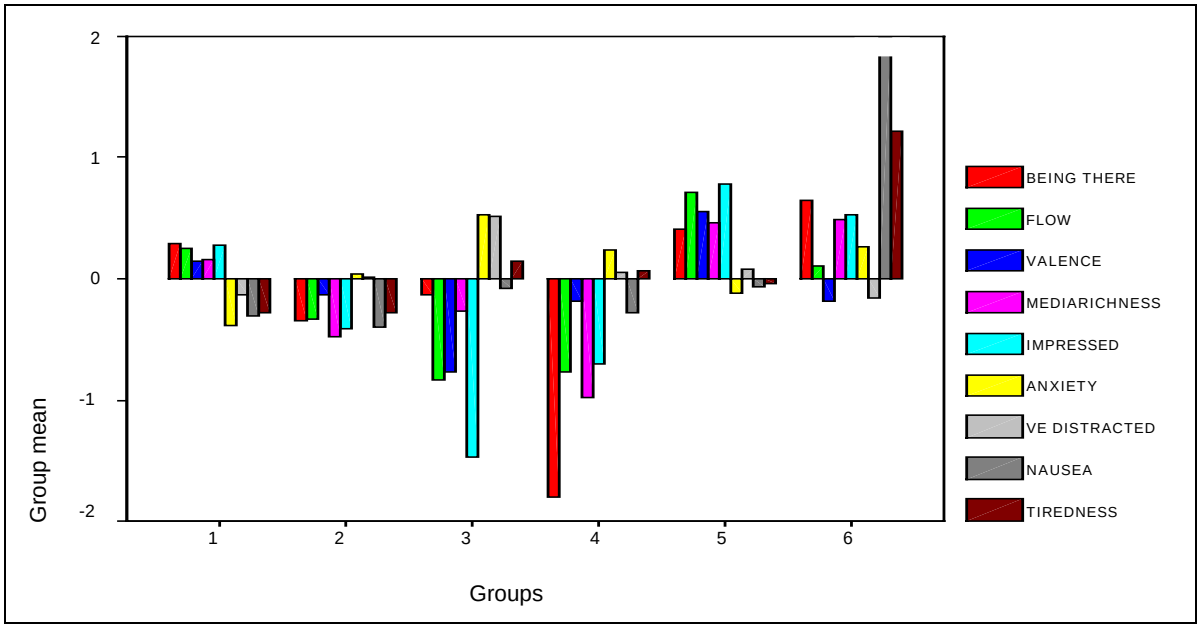

Figure 6. The profiles of the scale means measuring endpoint feelings across the six different groups of participants.

To explicate the hypothesis, correlation between the scales was investigated. All the correlations are shown in Appendix 5. Comparisons between two groups were also conducted, besides the six groups' comparisons. All the two group comparisons were made between Group 1 and all the other groups. Group 1 was the largest group consisting 35.3% of all the participants and thus considered as a reference group. Although, most of its participants were males, it was thought to describe a general positive experience with a sense of presence and flow. It was named as a "General positive" -group. F-test statistics from these comparisons are presented in Appendix 6.

Group 2 was also large, having 20.6% of the participants. It was considered to describe a general negative experience, with low sense of presence and flow, and named as a "General negative" -group. Group 3 described a special negative experience. It was consisted solely of males and scored lowest in Personal relevance in the six groups' comparisons. It was named

as “Unmotivated males” -group. Group 4 described also a special negative experience, with especially low scores in presence components. It was named as “Low presence” -group. Group 5 consisted mostly of females having a positive experience and was named as a “Special positive” -group. Group 6 was expected to describe the effects of the simulator sickness symptoms on the presence and flow experiences and was named as “Symptom” -group. The groups were named merely to help the reader to follow the comparisons and the group names should be considered as such.

3.3 Different experiences in EVE

3.3.1 Presence as a prerequisite for flow

The results showed, that flow followed presence in EVE. None of the six groups experienced high flow and low presence. “Low presence” -group (Group 4) and “Special positive” -group (Group 5) reported higher endpoint Flow than Being there, but both the scores in “Low presence” -group were negative and both the scores in “Special positive” -group were positive. The endpoint feelings of Being there and Flow were positively correlated, $r = .30$, $p < .05$. Next the relationship between presence and flow is further examined across the different groups.

The members of the “General negative” -group (Group 2) did not experience presence or flow in EVE, but they considered themselves skilled. When they were compared to “General positive” -group (Group 1), they scored lower in both Being there ($F(1,36) = 5.64$, $p < .05$) and Flow ($F(1,36) = 4.43$, $p < .05$). “General positive” -group also scored higher in all the

presence scales Spatial ($F(1,36) = 8.51$, $p < .01$), Attention ($F(1,36) = 5.02$, $p < .05$) and Real ($F(1,36) = 22.62$, $p < .001$). In flow scales, it scored higher in Challenge ($F(1,36) = 8.14$, $p < .01$), but not in Skill.

The participants of the "Unmotivated males" -group (Group 3) may have experienced presence, but not flow in EVE. Besides low scores in Personal relevance they also scored low in endpoint Flow. When they were compared to "General positive" -group (Group 1) they experienced the same amount of endpoint Being there. The groups did not differentiate in presence scales Attention or Real. However, "General positive" -group scored higher in presence scale Spatial ($F(1,28) = 6.38$, $p < .05$). "General positive" -group scored also higher in both flow scales Skill ($F(1,28) = 7.29$, $p < .05$) and Challenge ($F(1,28) = 11.21$, $p < .01$).

The "Low presence" -group (Group 4) was challenged in EVE, but experienced neither presence nor flow. Among all the groups, "Low presence" -group scored lowest in endpoint Being there and presence scales Spatial and Attention. It also scored lowest in Real, differing from all the others, but "General negative" -group (Group2). When compared to "General positive" -group (Group 1), "Low presence" -group scored lower in endpoint Flow ($F(1,28) = 9.82$, $p < .01$). It also scored lower than "General positive" -group in flow scales Skill ($F(1,28) = 17.88$, $p < .001$), but the two groups did not differentiate in Challenge.

"Special positive" -group (Group 5) and "Symptom" -group (Group 6) experienced both presence and flow. They did not differentiate form "General positive" -group (Group 1) in either endpoint Being there or Flow. The groups did not differentiate in any of the presence scales. In flow scales, "Special positive" -group scored higher in Challenge ($F(1,32) = 48.55$,

$p < .001$), but lower in Skill ($F(1,32) = 15.28$, $p < .001$) than “General positive” -group. Also “Symptom” -group differentiated from the “General positive” -group having lower scores in Skill ($F(1,30) = 5.27$, $p < .05$).

3.3.2 The role of interaction

Interaction was closely related to presence experience. It was also related to both level of arousal and perceived challenges of the situation. The endpoint Being there was positively correlated with all three interaction scales Action ($r = .67$, $p < .01$), Interaction SMR ($r = .34$, $p < .01$) and Exploration ($r = .35$, $p < .01$) as well as Arousal ($r = .38$, $p < .01$). The relationship between presence, interaction and challenge is shown in the factor analysis (Table 1). Action loaded on the Subjective experience (SE) -factor with the presence scales Spatial, Attention and Real. Interaction SMR loaded also on the SE –factor (.44), although it was considered as a part of the challenge appraisal of the situation. Also Action (.30) loaded on the Challenge Appraisal (CA) –factor besides the SE –factor. This relation is also affected by Arousal, which loaded on the SE -factor but showed tendency towards CA -factor (.28). The three factors in Table 1 did not correlate themselves because of the non-correlation rotation used.

3.3.3 Endpoint feelings associated with presence and flow

Presence and flow were associated with the positive endpoint feelings from the VE exposure. The endpoint Being there correlated positively with Valence ($r = .34$, $p < .01$), Pleasant ($r =$

.38, $p < .01$), Impressed ($r = .46$, $p < .01$) and Mediarichness ($r = .42$, $p < .01$) and negatively with the negative outcome Anxiety ($r = -.30$, $p < .05$). Also the endpoint Flow was positively correlated with Valence ($r = .35$, $p < .01$), Pleasant ($r = .47$, $p < .01$), Impressed ($r = .36$, $p < .01$) and Mediarichness ($r = .51$, $p < .01$) and negatively correlated with Anxiety ($r = -.35$, $p < .01$).

Although, the relationship between presence, flow and positive endpoint feelings seemed straightforward, group comparisons revealed some exceptions. Perceived presence, positive skill appraisal or challenge appraisal alone was not enough to produce positive endpoint feelings. Positive endpoint feelings depended on the right combination of the perceived presence and positive appraisals of the situation. Also the experienced flow depended on this combination.

"General negative" -group (Group 2) did not experience presence or flow, but considered to have skills. When it was compared to "General positive" -group (Group 1), it scored lower only in Impressed ($F(1,36) = 9.24$, $p < .001$), Pleasant ($F(1,36) = 5.05$, $p < .05$) and Mediarichness ($F(1,36) = 6.63$, $p < .05$). "Unmotivated males" -group (Group 3) experienced presence but not flow. They were low in both Challenge and Skill and especially low in personal relevance. When they were compared to "General positive" -group, they scored lower in Valence ($F(1,28) = 5.22$, $p < .05$), Impressed ($F(1,28) = 28.58$, $p < .001$) and Pleasant ($F(1,28) = 9.28$, $p < .01$) and higher in Anxiety ($F(1,28) = 8.37$, $p < .01$).

"Low presence" -group (Group 4) did not experience either presence or flow. They were high in Challenge but low in Skills. When compared to "General positive" -group (Group 1) the

groups did not differentiate in Pleasant or Valence. “General positive” -group scored higher in Impressed ($F(1,28) = 6.13$, $p < .05$) and Mediarichness ($F(1,28) = 10.83$, $p < .01$).

“Special positive” -group (Group 5) experienced presence and flow. It scored higher in Challenge and lower in Skills than “General positive” -group (Group 1). In endpoint feelings “General positive”-group scored only lower in Impressed ($F(1,32) = 4.23$, $p < .05$), than “Special positive” -group. When “General positive”- group was compared to “Symptom” -group (Group 6), differences were found only in simulator sickness factor Tiredness ($F(1,30) = 75.09$, $p < .001$). This finding can be explained by the special formation method of the “Symptom” -group.

When “Special positive” and “Symptom” - groups are referred to “General positive” -group, it should be kept in mind, that the groups differentiated in sex ratios. Males scored higher in Skill ($F(1,66) = 10.70$, $p < .01$) and lower in Challenge ($F(1,66) = 7.76$, $p < .01$) than females. Females scored higher in endpoint feelings Impressed ($F(1,66) = 21.13$, $p < .001$), Mediarichness ($F(1,66) = 4.32$, $p < .05$) and Nausea ($F(1,66) = 7.88$, $p < .01$). They also scored higher in Personal relevance ($F(1,66) = 8.72$, $p < .01$), Action ($F(1,66) = 8.01$, $p < .01$) and Interaction SMR ($F(1,66) = 17.14$, $p < .001$).

3.3.4 Balance between challenges and skills

The relationship between flow and challenges of the situation was clear, but the relationship between flow and perceived skills was more ambiguous. Also the clear ratio of high

challenges and skills in those reporting flow was not found. The endpoint Flow correlated significantly with Challenge ($r = .47$, $p < .01$) but not with Skill. Skill and Challenge correlated negatively ($r = -.26$, $p < .05$). In the six groups' comparisons, "General positive" -group (Group 1) and "Special positive" -group (Group 5) scored higher than "Unmotivated males" -group (Group 3) in endpoint Flow. "Unmotivated males" –group scored low in both Skill and Challenge. "General positive" -group was moderate in Challenge and high in Skill, whereas "Special positive" -group was high in Challenge but low in Skill. This is explained by the differences in sex ratios between "General positive" -and "Special positive" groups.

The sex of the participant did not have an effect on reported Arousal and Control, which were considered close correlates for Challenge and Skill. Arousal correlated with Challenge ($r = .31$, $p < .01$) and Control with Skill ($r = .27$, $p < .05$). Both Arousal ($r = .50$, $p < .01$) and Control ($r = .26$, $p < .05$) correlated positively with endpoint Flow as well as with each other ($r = .31$, $p < .05$).

The level of arousal and the sense of control predicted better the experienced flow than challenges and skills. In six groups' comparisons the low endpoint Flow group, "Unmotivated males" (Group 3), scored significantly lower in both Control and Arousal than the high endpoint Flow groups "General positive" (Group 1) and "Special positive" (Group 5). The ratio of Arousal and Control in "General positive" and "Special positive" was similar, Arousal being higher than Control. More evidence can be found from the "General negative" -group (Group 2). It reported high Control and low Arousal, which lead to the low endpoint Flow. Other group scoring low in endpoint Flow, "Low presence" (Group 4), scored higher in Control than Arousal, but both the scores were low.

4. DISCUSSION

The purpose of this explorative study was to test the different psychological constructs that could be used to explain and improve the user's experience of being and acting in VE. These constructs included the three components of physical presence (e.g., Lessiter et al., 2001; Lombard and Ditton, 1997; Schubert et al., 2001), measures of interaction (e.g., Falch and Holden, 1988; Zhaoric and Jenison, 1998) and constructs leading to the flow experience (Csikszentmihalyi, 1975). The process of flow is thought to include a cognitive evaluation process between the perceived skills and challenges the situation provides. It is similar to the cognitive-emotional appraisal of the situation as suggested in the appraisal theories of emotion (e.g., Lazarus, 1991; Ellsworth and Smith, 1988). Included were also emotional arousal and the sense of control, which are thought to have an impact on the way perceptions are judged and organised (Bradley and Lang, 1994).

The resulting framework integrated perception, cognition, emotion and person-environment interaction. It was used to compare the relationships between presence and flow as well as the relationship between these two and different endpoint feelings gained from the VE exposure. There are not many studies concerning the relationship between presence and flow in VEs. Due of this, current results are mainly compared to Novak et al. (2000) study conducted among the users of the WWW. Although, the used media in this study was far more advanced, the similar results of these two studies support the idea of certain kind of mental structure, used to process mediated stimuli across different media.

4.1 Presence-flow framework (PFF)

The PFF shows how the process of flow is extended to concern optimal experience in VEs by adding presence and interaction components into it. The three factors solution supported the hypothesised distinction between subjective experiences and the user's cognitive appraisal process from the mediated environment (Figure 7). The evaluations of the system's interactivity were integrated into the cognitive appraisal process. This distinction is consistent with Schubert et al.'s (2001) notion of difference between subjective experiences and system evaluations.

The first factor included subjective presence and interaction experiences. This supports the third hypothesis concerning the close relationship between presence and interaction. The existence of this factor in PFF integrated perceptual and attentional aspects into the flow process. This integration is consistent with Novak et al. (2000) study, in which attention was related to flow through presence. The three presence components in this factor were similar to those extracted by Lessiter et al. (2001) and Schubert et al. (2001). By integrating presence and interaction, this factor also supports the notion of close coupling between perception and action as suggested by the ecological theories (e.g., Falch and Holden, 1988; Zhaoric and Jenison, 1998).

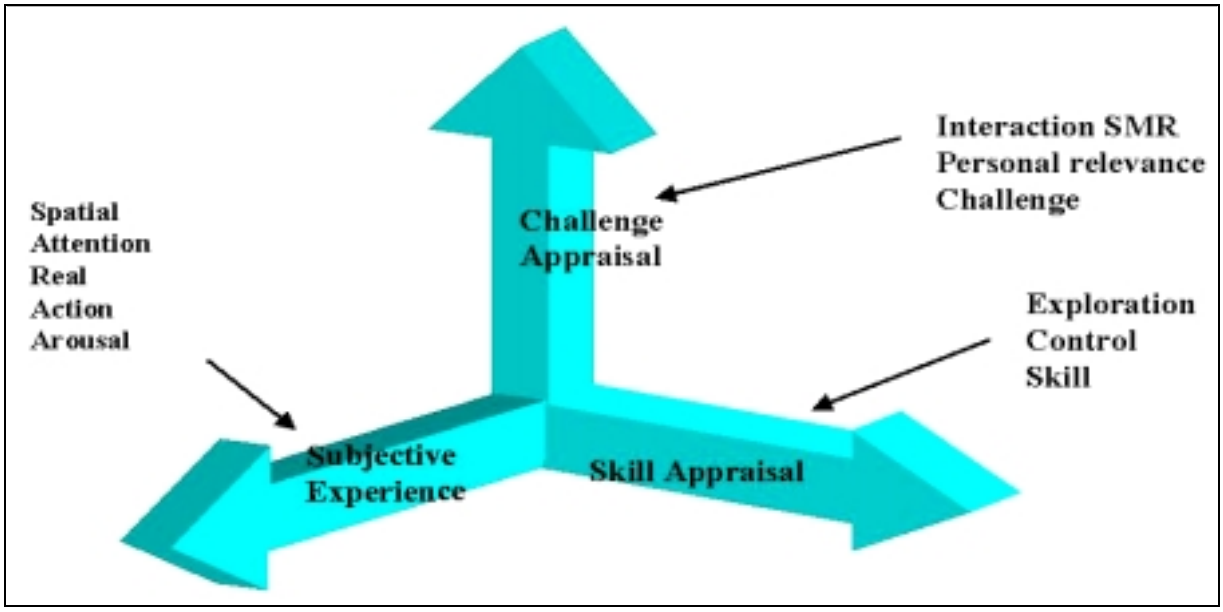

Figure 7. The three dimensions of flow experience in VE.

Together factors two and three described a cognitive appraisal process, in which the evaluations of the system interactivity were integrated. Included in the factor two were environmental evaluations in terms of personal relevance, challenges and interactional speed, range and mapping as suggested by Steuer (1992). The relationship between these three was supported in Novak et al. (2000) study. Factor three evaluated environment in terms of user's potential in the situation: perceived skills, sense of control and using those skills in the environment, i.e., to explore it. The relationship between skills and control is consistent with previous studies (Novak et al., 2000; Ghani and Deshpade, 1994). The cognitive appraisal process in this study is similar to the two dimensions of the eight-channel flow model (Massimini and Carli, 1988). It also shares similarities with the situational appraisal leading to the different emotional state as described by Ellsworth and Smith (1988) and Lazarus (1991).

In this study, arousal and challenge were positively correlated, but they loaded on different

factors. Novak et al. (2000) considered the relationship between these two more close. This difference could be explained by the more immersive VE used. It has been noted that the media form itself has an impact on the level of arousal (Dillon, Keogh, Freeman and Davidoff, 2000; Simons et al., 1999). In this study also the evaluations of the system interactivity correlated with all the presence measures, which was not consistent with Novak et al. (2000) study. These differences could be explained by the more complex presence and interaction measures used in this study.

4.2 PFF in practise

4.2.1 Presence and flow

The hypothesised role of presence as a prerequisite for flow is supported by the findings that there were no groups experiencing high levels of flow and low levels of presence. Instead there was a group of participants reaching presence at least in some level but not flow at all. These findings are congruent with Novak et al.'s (2000) study, which presents a direct path from presence to flow. As it was found in this study, increased scores in few presence components were not enough to evoke flow. The role of the interaction and its impact to arousal and challenge seems to be central in creation of flow. Interaction was also considered important in development of flow by Novak et al. (2000). This study also revealed, that challenges and thus flow are affected also by the personal relevance of the user. Personal relevance did not affect the perceived presence, but had an impact on the other endpoint feelings. This finding indicates, how the cognitive appraisal process works independently from the presence perceptions.

It is quite difficult to say how many participants actually reached flow in EVE. In this study the relationship between challenges and skills turned out to be a negative one. This could have been caused by the trivial nature of the task and the rehearsal period with the interface before the actual test. Also sex differences in evaluation of the skills and challenges may have distorted the ratio. According to Csikszentmihalyi (1975) the level of both skills and challenges should be high in order to reach flow. In this study, the hypothesised relationship between challenges, skills and flow was further studied by comparing the levels of emotional components arousal and control. These two were not biased by the sex of the user. The comparison of these two to the flow experience was consistent with the flow theory (Csikszentmihalyi, 1975), high arousal and control associated with high flow. The use of arousal and control in predicting flow is supported in Novak et al. (2000) study.

4.2.2 The endpoint feelings

High presence and flow were associated with positive endpoint feelings as it was hypothesised. However, heightened presence alone was not enough to produce positive endpoint feelings. In order to have a positive experience, both heightened presence and positive cognitive appraisal of the situation were needed. The whole process is described in the three dimensions of the PFF. High scores in all three dimensions are also likely to lead into the flow experience. The relationship between positive endpoint feelings and flow is found by, e.g., Csikszentmihalyi and LeFevre (1988). The unability to explain endpoint feelings solely on presence perceptions is also supported by the previous studies, which have

not found causality between presence and emotional feelings, positive or negative (Schuemie et al., 2001).

The endpoint feelings of Valence, VE distracted and Anxiety did not differentiate across the six groups as expected. Lowered power of the statistical methods used due to the large amount of groups and small amount of participants may have been one reason. These scales are also likely to be sensitive for other scales. Also Novak et al. (2000) had problems with their valence scale, which correlated strongly with all the other scales.

4.2.3. Simulator sickness

Contrary to the hypothesis, participants in the simulator sickness symptoms group did not experience low presence or flow. The specially formed group seemed to evaluate and experience EVE as highly interactive, which can be assumed to increase experienced vection. The highly experienced vection could have caused the simulator sickness symptoms as suggested by the vection theory of simulator sickness (Laviola, 2000). However, these results should be interpreted carefully because other variables are also likely to be involved. For example, the simulator sickness scores were biased by the sex of the participant, females scoring higher than males. It seems, that males do not easily report such symptoms, although they may be suffering from them.

The partial use of the original SSQ (Kennedy et al., 1993) may have also mixed results. The use of questionnaire in general may explain this odd finding. If the symptoms started in the

end of the test, participants who terminated it and started to fill in the questionnaire may have felt that all in all they experienced presence and even flow in EVE. Strong feelings and enjoyment in VE are also thought to outweigh the possibly negative effects experienced by some users (Nichols et al., 2000). Nevertheless, these issues were not the main focus of this study and need more careful studying.

4.3 Limitations of this study

High number of measured variables and a small sample size forced to use statistical methods that were difficult to report shortly. The explorative nature of this study was emphasised along the way. It is considered here as an excuse to include many different variables in order to explore presence and flow in VE as much as possible. The small sample size also lowered statistical power, especially in six groups' comparisons. This would have been avoided by using only few groups, but this would have probably left some findings unnoticed. The uniqueness of this study has also made it hard to compare the results to any previous studies.

To measure subjective human experiences, emotions and cognitive processes with a questionnaire also limits this study. Many of the measured phenomenon are thought to vary in time and thus to be difficult to measure afterwards. The questionnaire may have also caused the one-dimensionality of the scales measuring skills and challenges. More careful phrasing of the questions could have revealed some differences between the skills of doing the task in VE and skills of using the VE application. It could also have revealed different dimensions between the challenges of the task and the challenges of the using the VE application. The simplicity of the task and the rehearsal period may have also effected on the one-

dimensionality of these two.

4.4 Contributions of this study

According to the author's best knowledge this is the first attempt to integrate the components of presence and flow in this extent in an immersive VE. These components comprise perceptual, cognitive-emotional and interaction dimensions, which all are important, when human experience is considered (Damasio, 1994). The resulting multidimensional framework can be used to describe a human experience in VEs. The results support the role of presence as a one dimension in a way leading to the flow experience in VE. The integration of presence into the two-dimensional flow model (Massimini and Carli, 1988), takes also attentional aspect into consideration. Although it is difficult to measure, attention is seen as a bridge between perception, cognition and action (Moran, 1996) and cannot be ignored when a holistic model of the human experience is considered.

With slight modifications the dimensions of the PFF can also be applied to the non-interactive as well as non-immersive media. In non-interactive media, in which measures concerning skills and challenges are difficult to conduct, e.g., in movies, the appraisal process can be conducted in terms of the emotional dimensions of arousal and control. When applied to less immersive media, e.g., portable devices, the measures concerning presence could be more related to other attentional aspects than the realness or spatial awareness of the environment produced by the device. Studying and understanding more of the dynamics described in PFF, will enhance the knowledge on how different media is experienced and what are the components contributing mostly to these experiences in a particular medium.

EVE-Experience Questionnaire (EVEQ) is the first this kind of a questionnaire in Finland. It can be used as a tool, when designing new VE applications. When the dimensions of the PFF are considered, a VE application should possess such properties that really help the user to get into the virtual world. This should lead to flow experience, which is likely to increase the performance level of the user, whatever the task may be. When VEs are used as tools, for example in scientific visualisation, the user can be assumed to consider VE personally relevant and is motivated to work there. Then it is the main task for the VE application to keep that user motivated. In this quest, PFF can be seen to enrich simple usability measures based on speed or accuracy, by including an experiential viewpoint into the design process.

When VEs are designed as tools for work or education, it is important to have the means to measure the basic variables thought to have an impact on, e.g., learning. A mediated content that evokes emotions is considered to have an impact on attention, enjoyment, evaluation and memory (Dietz and Lang, 1999). These all are likely to be positively correlated with learning and should be mastered in design phase in order to expect any results from the application. To master these, one should have a way of measuring the basic emotions, as arousal and control, evoked by the media. The way media form and content affects the basic emotions should also be understood when VEs are used in psychotherapy purposes. In order to enhance this sort of applications, PFF provides a more versatile description of the dynamics in human mind than measures concerning only the perception of presence.

4.5 Future

The development of the EVEQ into an easily used tool is an important task. The skill-challenge items should be studied more carefully in order to find out if there are different dimensions for the using the application and performing a particular task with it. Also the effects of the participants' sex on these two should be clarified. Because the aim of this study was to find out the dynamics behind a single user's experience, the first version of EVEQ also lacks all the social aspects considered relevant for future VE applications. The integration of the social presence would complete the PFF and extend its use to the shared VEs. It would also be interesting to test PFF in a more demanding test design than a simple search task.

EVE stands for Experimental Virtual Environment. Technologically it is a top line VE, more suitable for experiments concerning new technologies and user experiences than carrying around with the user. However, one vision of the future is very mobile and has no room for the applications of the scale of EVE. The limitless imagination of the mankind produces handheld devices with good graphics and audio or even devices hidden into ones environment or clothes. Although, these differ greatly from the applications as EVE, the dynamics producing the user experience are the same and should be taken into consideration when these devices are designed.

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