

# AFFECTIVE LUDOLOGY: SCIENTIFIC MEASUREMENT OF USER EXPERIENCE IN INTERACTIVE ENTERTAINMENT

Lennart Erik Nacke

Blekinge Institute of Technology  
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School of Computing



# **Affective Ludology:**

## **Scientific Measurement of User Experience**

### **in Interactive Entertainment**

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No 2009:04

# **Affective Ludology: Scientific Measurement of User Experience in Interactive Entertainment**

**Lennart Erik Nacke**



School of Computing  
Blekinge Institute of Technology  
SWEDEN

**MAIN SUPERVISOR**

Craig A. Lindley, Ph.D., Blekinge Institute of Technology

**ADDITIONAL SUPERVISORS**

Niklas Ravaja, Ph.D., Helsinki School of Economics

Christoph Klimmt, Ph.D., Johannes Gutenberg-University Mainz

Staffan Björk, Ph.D., Chalmers University of Technology

Maic Masuch, Ph.D., University of Duisburg-Essen

Bo Helgeson, Ph.D., Blekinge Institute of Technology

Stefan Johansson, Ph.D., Blekinge Institute of Technology

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"A scientist in his laboratory is not a mere technician:  
he is also a child confronting natural phenomena that impress him  
as though they were fairy tales."

Marie Curie

*Dedicated to my family—this would have been impossible without your  
love and support*



## ABSTRACT

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Digital games provide the most engaging interactive experiences. Researching gameplay experience is done mainly in the *science and technology* (e.g., human-computer interaction, physiological and entertainment computing) and *social science* (e.g., media psychology, psychophysiology, and communication sciences) research communities. This thesis is located at the intersection of these research areas, bringing together emerging methodological and scientific approaches from these multi-faceted communities for an affective ludology; a novel take on game analysis and design with focus on the player.

The thesis contributes to game research with three important results: (1) the establishment of an objective/subjective correlation methodology founded on psychophysiological methods, (2) the creation of a formal theoretical framework in which to conduct user experience (UX) research related to games, and (3) the combination of results regarding cognitive and emotional factors for describing, defining, and classifying the interactive relationship between players and games.

Two approaches for measuring gameplay experience are used in this thesis. First, the *objective* assessment of physiological user responses together with automated event-logging techniques, so called game metrics, allows collecting essential player- and game-related variables for a comprehensive understanding of their interaction. Second, using psychometric questionnaires allows a reliable assessment of players' *subjective* emotion and cognition during gameplay. The benefit of psychophysiological methods is that they are non-intrusive, covert, reliable, and objective. To fully understand psychophysiological results, a correlation between subjective gameplay experience ratings and psychophysiological responses is necessary and has been done in this thesis and the prior work it builds on.

This thesis explores *objective* and *subjective* assessment of gameplay experience in several experiments. The experiments focus on (1) level design implications from psychophysiological and questionnaire measurements, (2) the impact of form and age on subjective gameplay experience, (3) the impact of game audio and sound on objective and subjective player responses, and (4) the impact of game interaction design on and the relationship between experi-

ence and electroencephalographic measures.

In addition, this thesis includes a theoretical framework for UX research in games, which classifies *gameplay experience* along the dimensions of abstraction and time. One remaining conceptual and empirical challenge for this framework is the huge variety of vaguely defined experiential phenomena, such as immersion, flow, presence, and engagement. However, the results from the experimental studies show that by establishing correlations between psychophysiological responses and questionnaire data, we are approaching a better, scientifically grounded, understanding of gameplay experience.

Many possibilities open from here. More detailed analyses of cognition will help us understand to what extent gameplay experience depends more on emotional or cognitive processing. In addition, the inclusion of more complex and detailed gameplay metrics data together with psychophysiological metrics will enable a comprehensive analysis of player behavior, attention, and motivation. Finally, the integration of new measurement technologies in interactive entertainment applications will not only allow a detailed assessment of gameplay, but also improve physical and mental interaction with future games.

*"A man's friendships are one of the best measures of his worth."*

Charles Darwin

## ACKNOWLEDGMENTS

---

This doctoral thesis marks the academic coming of age of a researcher, the culmination of knowledge on a specific topic, which can never be realized in solitude. If it would not have been for the scientific acumen, motivation, support, cooperation, help, patience, and love from my family, friends, acquaintances, partners, students, collaborators, and colleagues, this thesis would have never seen the light of day. You know who you are. Thank you! Dankeschön! Tack så jättemycket!

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at HGO, some of them were Prof. Dr. Mikael Fridenfalk, Dr. Alain Becam, Nicolaas Mul, Denise Lengyel, and Swen Gaudl. At BTH those consisted of my fellow Ph.D. students: Charlotte Sennersten, Maria Bäcke, Jussi Holopainen, Lee Sandberg, Olle Hillborn, and Gideon Mbiydzenyuy; as well as people from the Game Systems and Interaction Research Laboratory: Dr. Kari Rönkkö, Prof. Dr. Bo Helgeson, Dr. Stefan Johansson, Stefan Petersson, and Karin Svahnberg; and teachers from the School of Future Entertainment (SOFE): Andreas Persson, Stefan Ek, Kostas Gialitakis, and Robert Hennings.

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## PUBLICATIONS RELATED TO THIS THESIS

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### PAPERS INCLUDED IN THIS THESIS

This thesis includes a descriptive introductory research summary together with the following 9 papers. The papers were slightly reformatted and partially extended with annotations and figures, however their primary content remained unchanged.

- (α) Nacke, L. and Drachen, A. Logged and Loaded: A Theory and Methodological Taxonomy of Gameplay Experience Measurement. Submitted for publication.
- (β) Nacke, L. Models of Flow Experience in Gameplay: A Review and Suggestions for Measurement. Submitted for journal publication.
- (γ) Nacke, L., Lindley, C., and Stellmach, S. (2008). Log Who's Playing: Psychophysiological Game Analysis Made Easy through Event Logging. In Proceedings of Fun and Games, Second International Conference, Lecture Notes in Computer Science 5294 (pp. 150–157). Eindhoven, The Netherlands: Springer-Verlag, Berlin, Heidelberg. doi: 10.1007/978-3-540-88322-7\_15
- (δ) Nacke, L. and Lindley, C. A. (2010). Boredom, Immersion, Flow: Psychophysiological Assessment of Affective Level Designs in a First-Person Shooter Game. To be published in Special conference issue (*Design for Engaging Experience and Social Interaction*) of Simulation & Gaming: An Interdisciplinary Journal of Theory, Practice and Research.
- (ε) Grimshaw, M., Lindley, C. A., and Nacke, L. (2008). Sound and Immersion in the First-Person Shooter: Mixed Measurement of the Player's Sonic Experience. In Proceedings of AudioMostly, Conference on Interaction with Sound (pp. 9–15). Piteå, Sweden: Interactive Institute.
- (ζ) Nacke, L., Nacke, A., and Lindley, C. A. (2009). Brain-Training for Silver Gamers: Effects of Age and Game Form on Effectiveness, Efficiency, Self-Assessment, and Gameplay Experience. *CyberPsychology & Behavior*. 12(5). doi: 10.1089/cpb.2009.0013.
- (η) Nacke, L., Grimshaw, M. N., and Lindley, C. A. More Than a Feeling: Tonic Measurement of Audio User Experience and Player Psychophysiology in Games. Submitted for journal publication.

- (θ) Nacke, L., Kivikangas, J. M., and Ravaja, N. Psychophysiological Effects of First-Person Shooter Death Events and Game Audio. Submitted for journal publication.
- (ι) Nacke, L. and Lindley, C. A. Wiimote vs. Controller: Electroencephalographic Measurement of Affective Gameplay Interaction. Submitted for publication.

#### AUTHOR CONTRIBUTION TO INDIVIDUAL PAPERS

Most of the included papers present joint research efforts. The author's contribution to each of the papers is listed in the following.

- (α) Initiated the planning of the paper; provided the theoretical concepts the paper is based on; managed the inclusion of the individual contributions; prepared the artwork; led the overall writing and submission process.
- (β) Wrote and submitted the paper individually; developed the concepts and organized the review including feedback from supervisors; prepared the artwork.
- (γ) Led the paper writing effort; included extraordinary student work and organized individual reviews; submitted and presented the paper.
- (δ) Developed the experimental procedure and analyzed the results individually; organized and included individual reviews; submitted the paper and presented an early version of it at the conference: *Design for Engaging Experience and Social Interaction*.
- (ε) Led the experimental development and analysis of the results; wrote the method and results sections and essentially contributed to the rest of the paper.
- (ζ) Conceptualized the experimental procedure; wrote the paper and analyzed the results individually; organized reviews; led the submission process.
- (η) Led the paper writing effort; experimental development and analysis of the results; included reviews and led the submission process.
- (θ) Led the paper writing effort; experimental development; took part in the analysis of the results; included reviews and led the submission process.
- (ι) Conceptualized the experimental procedure; wrote the paper and analyzed the results individually; organized reviews; led the submission process.

## OTHER PUBLICATIONS RELATED TO THIS THESIS

The following publications are related to this thesis but were omitted from it for the sake of brevity and focus.

1. Girouard, A., Solovey, E. T., Tan, D., Mandryk, R. L., Nacke, L., Jacob, R. J. K. (2009) Brain, Body, and Bytes: Psychophysiological User Interaction. Workshop Committee. To appear in CHI 2010 extended abstracts.
2. Nacke, L., Drachen, A., Korhonen, H., Kuikkaniemi, K., Niesenhaus, J., van den Hoogen, W., Poels, K., IJsselsteijn, W., de Kort, Y. (2009) DiGRA panel chair: Playability and Player Experience Research. September 1, 2009. DiGRA 2009: Breaking New Ground: Innovation in Games, Play, Practice and Theory, Brunel University, West London, UK.
3. Nacke, L., Stellmach, S., Sasse, D., & Lindley, C. A. (2009). Gameplay Experience in a Gaze Interaction Game. In Proceedings of The 5th Conference on Communication by Gaze Interaction - COGAIN 2009: Gaze Interaction For Those Who Want It Most (pp. 49–54). Lyngby, Denmark: The COGAIN Association
4. Stellmach, S., Nacke, L., Dachselt, R., & Lindley, C. (2009). Trends and Techniques in Visual Gaze Analysis. In Proceedings of The 5th Conference on Communication by Gaze Interaction - COGAIN 2009: Gaze Interaction For Those Who Want It Most (pp. 89–93). Lyngby, Denmark: The COGAIN Association.
5. Nacke, L. (2009). From Playability to a Hierarchical Game Usability Model. In Proceedings of the Conference on Future Play 2009 (pp. 11–12). Vancouver, BC, Canada: ACM, New York, NY.
6. Nacke, L., Ambinder, M., Canossa, A., Mandryk, R. L., and Stach, T. (2009). Game metrics and biometrics: The future of player experience research. Panel chair at the 2009 Conference on Future Play.
7. Nacke, L., & Lindley, C. A. (2008). Flow and Immersion in First-Person Shooters: Measuring the Player's Gameplay Experience. In Proceedings of the Conference on Future Play (pp. 81–88). Toronto, Ontario, Canada: ACM, New York, NY. doi: 10.1145/1496984.1496998
8. Lindley, C. A., Nacke, L., & Sennersten, C. C. (2008). Dissecting Play—Investigating the Cognitive and Emotional Motivations and Affects of Computer Gameplay. In Proceedings of

- CGAMES. Wolverhampton, UK: University of Wolverhampton.
9. Nacke, L., & Lindley, C. (2008). Boredom, Immersion, Flow: A Pilot Study Investigating Player Experience. In Proceedings of the IADIS Gaming 2008: Design for Engaging Experience and Social Interaction (pp. 103–107). Amsterdam, The Netherlands: IADIS Press. ISBN: 978-972-8924-64-5
  10. Nacke, L. (2008). A Methodology for Psychophysiological Player Logging. Position paper presented at the Nordic Game Research Network: Game Research Methods, Aalborg, Denmark: Aalborg Universitet.
  11. Lindley C. A., Nacke L. & Sennersten C. (2007). What does it mean to understand gameplay? In Ludic Engagement Designs for All (LEDA). Esbjerg, Denmark: Aalborg University.
  12. Nacke, L. (2007). The Fun of Gaming: Measuring the Human Experience of Game Enjoyment. In Reader of the Quo Vadis Conference. (pp. 66–67). Berlin, Germany: Aruba Studios.

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Part I  
RESEARCH SUMMARY



## AFFECTIVE LUDOLOGY

Digital games have grown to be among the favorite leisure activities of billions of people around the world. Today, digital gaming battles for a share of your individual leisure time with other traditional activities like reading books, watching movies, listening to music, surfing the internet or playing sports. According to a recent study of internet users from eMarketer<sup>1</sup>, console, personal computer (PC), and web-based games are already the favorite activity for men aged between 12 to 34. Digital games have fundamentally altered this group's media use. They have also generated revenues that have

*Digital games  
are a growing  
industry*

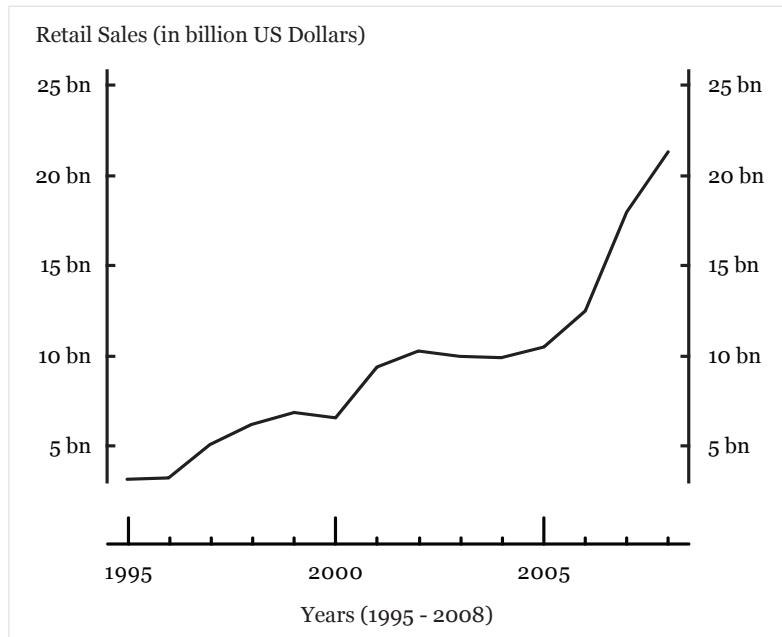


Figure 1.1: Digital game industry revenue in the United States of America for the years 1995–2008. The retail sales are in billion (i.e.,  $1 \times 10^9$ ) US Dollars and include digital game sales, hardware (portable and console), software and accessories.

laid the foundation for a substantial new branch of the Information and Communication Technologies (ICT) industries. Market and sales statistics from the NPD group (a leading market analyst company) show an exponentially increasing trend in hardware, software and

<sup>1</sup> eMarketer: "Favorite Leisure Activities." Retrieved on August 23, 2009 from <http://www.emarketer.com/Article.aspx?R=1007190>

*The discussion of game systems has a long history in science*

accessories sales of digital gaming products in the past decades<sup>2</sup>, made clear in Figure 1.1. Games are—without a doubt—an important economic force with the power to change our lives radically in the future.

Games also impose new research challenges to many scientific disciplines—new and old. Neumann & Morgenstern (1944) were probably the first researchers to discuss games scientifically on a mathematical foundation as a science of economics. More than half a century later, Aarseth (2001) along with other humanities researchers tried to gain an understanding of games based in literature theory, which is where *ludology* was coined as a popular expression (Frasca, 1999), denoting the *study of games* in general. Juul (2005) traced the term ludology back to an abstract from Csíkszentmihályi (1982). It comes from the latin word *ludus*, which means *game*, and the greek word *lógos*, which has many meanings, but should most appropriately be translated to *reasoning, science* or also *measurement*. In the context of this thesis, ludology is understood primarily as the scientific measurement of play activity, thus not interpreting it as part of the humanities debate about gaming but more as the scientific understanding of gaming based on experimental data.

However, games have long been in the center of philosophical and educational debates (Huizinga, 1949; Caillois, 2001; Avedon & Sutton-Smith, 1971), probably since Socrates discussed the very foundations of modern science (Butler, 1997). Ludological research so far centered around aspects such as the definition, function, design, development, and impact of games. The scientific community around *ludology* has only recently visibly emerged and is aimed at being inclusive for all disciplines that have games as their research focus. Interestingly, the terminology *ludology* has not been equally accepted across all disciplines nor is there a common understanding which disciplines contribute to what extent although we have recently seen structured research into this (Bragge & Storgård, 2007).

To gain a better general understanding of game research the ISI Web of Knowledge<sup>3</sup> was searched systematically, which revealed article publications from two major research areas:<sup>4</sup> *Science & Technology* (49.62%) and *Social Sciences* (42.21%). A more detailed search

<sup>2</sup> Based on yearly report data from NPD Group, retrieved on February 28, 2009, from [www.acagamic.com](http://www.acagamic.com).

<sup>3</sup> Thomson Reuters. ISI Web of Knowledge. Retrieved on August 21, 2009 from <http://isiknowledge.com> (Subscription required)

<sup>4</sup> In contrast to what one might expect, Arts & Humanities only constituted 8.17% of this result

on Scopus.com<sup>5</sup> shows the major contributing areas to game research: *Computer Science* (1585 indexed articles), *Engineering* (1030 indexed articles), *Medicine* (852 indexed articles), *Psychology* (752 indexed articles), and *Social Sciences* (722 indexed articles). This not only shows game research itself to be a multidisciplinary field but also elucidates that more traditional fields are starting to direct their attention toward games. Some of these increased research efforts in traditional sciences can eventually be traced back to one of the most highly cited articles in game research (a study by Green & Bavelier (2003), which showed the beneficial aspects of playing games for improving visual selective attention skills). Figure 1.2

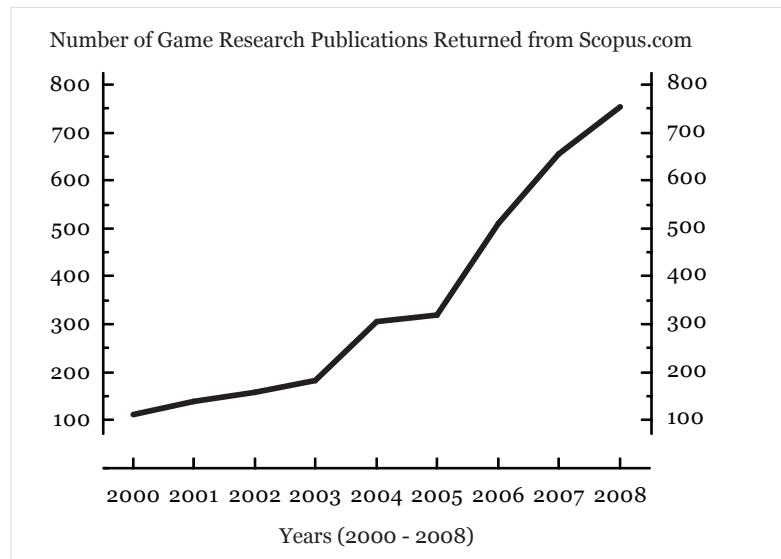


Figure 1.2: Publications (articles, conference papers and books) returned from a search on Scopus.com with the following query:  
 TITLE-ABS-KEY("game research" OR "game studies" OR  
 "computer game" OR "video game" OR "digital game") AND  
 (LIMIT-T0(DOCTYPE, "ar") OR LIMIT-T0(DOCTYPE, "cp") OR  
 LIMIT-T0(DOCTYPE, "bk")). It shows the almost linear increase of game research in different studyfields.

shows the increase in the number of publications in the area of digital games (which includes journal articles, conference papers, and books).

While studies of digital games and violence (Anderson & Bushman, 2001; Bushman & Anderson, 2002; Ferguson, 2007; Griffiths, 1997), addiction (Griffiths & Dancaster, 1995) or improvement of spatial skills (Dorval & Pepin, 1986; Gagnon, 1985; McClurg &

<sup>5</sup> Retrieved on August 20, 2009 from <http://www.scopus.com>, Elsevier B. V.

Chaillé, 1987) have been predominant in the past decades, a growing body of work discusses the beneficial aspects of digital games as, for example, as motivational drivers for learning and for improving education (Gee, 2003; Malone, 1981; Prensky, 2000) and training (Swartout & Lent, 2003). More recently, digital games have been hailed as drivers of innovation in computer science (Ahn & Dabbish, 2008), promoters of mental health (Miller & Robertson, 2009; Pulman, 2007), tools for training cognitive and motor abilities (Pillay, 2002; Lindley & Sennersten, 2008) and as providers of highly immersive and emotional environments for their players (Ravaja et al., 2008; Ryan et al., 2006).

### 1.1 TOWARD AFFECTIVE LUDOLOGY

#### *A shift in game research areas*

Game research has only recently started to attract attention from the human-computer interaction (Barr et al., 2007; Fabricatore et al., 2002; Mandryk & Atkins, 2007; Mandryk et al., 2006; Mandryk & Inkpen, 2004), user research (Ilsbister & Schaffer, 2008; Jegers, 2008; Pagulayan et al., 2003, 2004; Bernhaupt, 2010), and psychophysiology communities (Ravaja et al., 2005, 2006, 2008). With this comes a necessary shift in *ludology*, which has in the past been focused primarily on analyzing games (Juul, 2005; Tychsen et al., 2006) or establishing a design vocabulary (Church, 1999; Hunicke et al., 2004), taxonomies (Lindley, 2003) and ontologies (Zagal et al., 2005). Ludology now acknowledges the need to understand cognition, emotion, and goal-oriented behavior of players from a psychological perspective by establishing more rigorous methodologies (Lindley et al., 2007; Ravaja et al., 2005). It has long been argued that a comprehensive theory of game design and development should incorporate multidisciplinary approaches informed by cognitive science, attention and schema theory, emotion and affect, motivation and positive psychology (Lindley & Sennersten, 2008). The improvement of scientific methodologies for studying players and games will not only help us understand the aesthetics of digital games better, but also the underlying processes involved in creating individual play experiences (Tychsen et al., 2007, 2006).

#### *The emotional and affective experience of gaming*

Gaming is a joyful and affective activity that provides emotional experiences, which may guide how we process information. Norman's definition of emotion is that it works through *neurochemical* transmitters, which influence areas of our brain and successively guide our behavior and modify how we perceive information and make decisions (Norman, 2004). While Norman makes a distinction between affect and cognition, he also constitutes that both are information-processing systems with different functionalities. Cognition refers to making sense of the information that we are pre-

sented with, whereas affect refers to the immediate *gut reaction* or feeling that is triggered by an object, a situation or even a thought.

Humans strive to maximize their knowledge by accumulating novel, but also interpretative information. While experiencing novel information and being able to interpret it may be a cause of *neurophysiological pleasure* (Biedermann & Vessel, 2006), the acquisition of such information can be done by mastering cognitive or motor skills through repetition. However, cognitive processing of novel information activates *endorphins* in the brain, which moderate the sensation of pleasure. In this case, novel information serves as a motivator to repetitively storing and recalling process information. Digital games incorporate this kind of information processing in a very effective way, for example presenting novel cues in a game environment will affect player experience and task learning in the game. This is an excellent example of how cognition and affect mutually influence each other, which is in line with modern emotion theories (Damasio, 1994; LeDoux, 1998). Understanding the affective mechanics of a system may then help us understand and relate to its cognitive impact. Thus, *affective ludology* could provide methods to understand how affective digital game mechanics could help guide players' attention to and understanding of complex systems.

Norman (2004) makes a fine distinction between *emotion* and *affect*, defining emotion as consciously experienced affect, allowing us to identify who or what caused our affective response and why. Emotion indeed may be a more complex mental and physical state, since Plutchik (2001) sees emotion as an accumulated feeling, which is influenced by context, experience, personality, affective state, and cognitive interpretation. Affect on the contrary is defined as a discrete, conscious, subjective feeling that contributes and influences an individual's emotion (Bentley et al., 2005; Damasio, 1994; Russell, 1980). In addition, Moffat (1980) introduced an interesting notion about the relationship between personality and emotion, which are distinguished along the two dimensions: *duration* (brief and permanent) and *focus* (focused and global). For example, an emotion might develop from brief affection into a long-term sentiment or a mood that occurs steadily might become a personality trait. The two dimensions can be plausibly identified at a cognitive level, making a strong pledge for the relation between emotion, cognition, and personality both at the surface and at a deep, structural level.

*The  
connections  
between  
emotion and  
cognition*

*Emotion and  
personality*

With recent efforts in the field of human-computer interaction (Dix et al., 2004), the sensing and evaluation of the cognitive and emotional state of a user during interaction with a technological

system has become more important. The automatic recognition of a user's affective state is still a major challenge in the emerging field of affective computing (Picard, 1997). Since affective processes in players have a major impact on their playing experiences, recent studies have emerged that apply principles of affective computing to gaming (Gilleade et al., 2005; Hudlicka, 2008; Sykes & Brown, 2003). The field of affective gaming is concerned with processing of sensory information from players (Gilleade & Dix, 2004) or their brains (Mason et al., 2004; Nijholt et al., 2008), adapting game content (Dekker & Champion, 2007; Yannakakis & Hallam, 2006; Yannakakis et al., 2008)—for example, artificial behavior of non-player character game agents to player emotional states—and using emotional input as a game mechanic (Kuikkaneni & Kosunen, 2007; Yannakakis & Hallam, 2007).

## 1.2 BENEFITS OF AFFECTIVE LUDOLOGY

*Foundations  
and scope of  
affective  
ludology*

*Gameplay as  
system  
interaction*

*Challenges of  
affective  
ludology*

Building on a foundation laid out by the seminal works of Klimmt (2003), Ravaja (2004), Mandryk & Inkpen (2004), Hazlett (2006), and Mathiak & Weber (2006) the term *affective ludology* is proposed here for referring to the field of research, which investigates the affective interaction of players and games (with the goal of understanding emotional and cognitive experiences created by this interaction). In this context, players can be seen as biological systems that form from the interaction of several complex variables, constituting the processes known as emotion and cognition. Gameplay in digital games emerges from the interaction of biological systems with technological systems. Therefore, the study of games as systems of rules and processes (*ludology*) should be informed by the affective reaction of the biological entity engaging with it (*players*). In line with Picard's definition of affective computing, digital games should be able to recognize, express, foster, and appeal to certain emotions (Picard, 1997). If games of the future should be truly harnessed as more than just entertainment systems, but as tools for learning, training, understanding and communicating, game design needs to be informed by studies of player affect and emotion. To provide this understanding, a major research challenge is to (1) test and establish a set of scientific measures for player affect during gameplay. However, *affective ludology* should also (2) develop and establish theoretical models that explain player experience and how such models could improve the game design process.

Both of these goals have been the foundations of the recently completed EC FUGA project (described below in more detail), of which this Ph.D. project has been a part. In brief, the benefits of this research effort are twofold. First, detailed measurements of affective

player experience will advance the game industry and help game developers succeed in this highly competitive and increasingly complex market. Second, reliable and valid, multi-level and multi-dimensional techniques to assess affective gameplay experience will help *ludology* and game research become a more established scientific discipline.

### 1.3 GOALS, OUTCOMES AND SCOPE OF THIS THESIS

This thesis has been carried out within the FUGA project. FUGA is a project acronym for The Fun of Gaming: Measuring the Human Experience of Media Enjoyment, which was funded by the European Commission under the sixth Framework Program: New and Emerging Science and Technology (NEST). The goal of this project was inventing novel methodologies and improving existing measurement approaches to examine how the different aspects of gaming experience can be assessed comprehensively with high temporal resolution. For improving research practice, FUGA aimed at establishing the construct validity, reliability, and predictive validity of alternative measurement techniques, such as psychophysiological recording, brain imaging, and behavioral observation. Hence, the main objective of this project lay in creating and improving interdisciplinary methods for the scientific assessment of game experience. This is reflected in this thesis, which intends to have a strong methodological impact on research projects focusing on game development.

*Methods for measurement of gameplay experience*

Lindley (2004a) has explained that game systems are becoming more ubiquitous and technical platforms are evolving to incorporate more game-like interactions, which may dissolve some distinctions between working and playing with the potential for making computer-based work tasks less tedious. Thus, the measurement approaches presented in this thesis can be applied for informing novel game designs for alternative purposes, such as education, simulation, and professional training.

The focus of this thesis is methodological, thus it is limited in theoretical contributions but geared toward empirical application of new research methods providing data foundations upon which future theoretical developments may be built. Hence, the primary outcomes of this research were the following.

*Focus and outcomes of this thesis*

- (1) A theoretical contribution was made to an understanding of parts of gameplay experience, framed in user experience methodology. This is summarized below and described in more detail in Chapter 2.

- (2) Psychophysiological data acquisition tools were developed that facilitate the process of game stimuli production and psychophysiological data analysis. A more detailed description can be found in Chapter 4 and in the summary below.
- (3) A series of empirical studies—with focus on psychophysiological methodology—was conducted, which established methodologies for affective player research and provided scientific evidence for partial understanding of gameplay experience constructs. The detailed results and discussions can be found in Chapters 5, 6, 7, 8, 9, and 10.

The laboratory studies encompass a wide range of different participant demographics (students, employees, elderly) and a variety of experimental recording techniques and statistical analyses.

#### 1.4 RESEARCH QUESTIONS OF THIS THESIS

The overarching **research questions** that have been driving these investigations were "*What makes playing games engaging and fun?*" and also "*How can this engaging experience of players be measured empirically?*" They were developed as a direct consequence of the investigative direction of the FUGA project and the scientific direction of the research group this Ph.D. project was conducted in (Lindley & Sennersten, 2008; Ravaja, 2004).

*Origin of the  
research  
questions*

The question of what it is that makes games fun may not be a new question (for examples, see the discussions of Klimmt (2003), Malone (1980), Pagulayan et al. (2004), Lazzaro (2003), and Koster (2005)). However, the gathering of scientific data to find explanations for fun in games by looking at this data that relates to the interaction of the player with the game (i.e., the process called gameplay) is relatively new (Ravaja et al., 2005, 2008; Mandryk & Inkpen, 2004; Tychsen, 2008) and does need more results from scientific experiments for being understood more clearly. Among the many studies presented in this thesis, the data explored and discussed allows the formation of a better understanding of fun and engaging experiences for different individuals. One of the major goals of this thesis is to provide a relation of the analysis and interpretation of psychophysiological player data to concepts describing gameplay experience.

The intent of scientific investigations of gameplay is not to replace existing methods of user experience analysis and usability research in games, but to extend established tools with data-driven analysis methods that focus on players. Ideally, the insights from

the empirical studies, the tools created for such studies and the theoretical discussion of experiential gameplay constructs such as flow may facilitate the definition and exploration of game experience for industry and academia alike.

The more detailed overarching research questions discussed in the individual papers were:

**PAPER  $\alpha$ : Logged and Loaded: A Theory and Methodological Taxonomy of Gameplay Experience Measurement.** Can we break down gameplay experience into a set of layers corresponding to different phases of playing a game, each phase allowing for a specific set of measurements? How can this structural model improve current design practice of digital games?

**PAPER  $\beta$ : Models of Flow Experience in Gameplay: A Review and Suggestions for Measurement.** What is understood by the concept of *flow* in gaming? Which measurement methods have been used to assess flow in gaming? Can psychophysiological methods measure affective experiences related to flow?

**PAPER  $\gamma$ : Log Who's Playing: Psychophysiological Game Analysis Made Easy through Event Logging.** Can we accelerate phasic psychophysiological analysis with gaming tools that allow the logging and analysis of certain types of game events?

**PAPER  $\delta$ : Boredom, Immersion, Flow: Psychophysiological Assessment of Affective Level Designs in a First-Person Shooter Game.** Can we identify whether level design conditions can have empirically assessable impact on player experience as measured with surveys and psychophysiological methods? Specifically, what is the effect of boredom, immersion and flow level design on psychophysiological and subjective indicators of gameplay experience?

**PAPER  $\epsilon$ : Sound and Immersion in the First-Person Shooter: Mixed Measurement of the Player's Sonic Experience.** Is it possible to analyze the impact of game sound and music during gameplay using psychophysiological methodology?

**PAPER  $\zeta$ : Brain-Training for Silver Gamers: Effects of Age and Game Form on Effectiveness, Efficiency, Self-Assessment, and Gameplay Experience.** Does it matter which device a game is played with and does age have an influence on game experience? Can games provide usable tools and enjoyable experiences for the elderly?

**PAPER  $\eta$ : More Than a Feeling: Tonic Measurement of Audio User Experience and Player Psychophysiology in Games.** Can we find out more about the interplay of game sound, music, and potential moderating factors of gameplay experience?

**PAPER  $\theta$ : Psychophysiological Effects of First-Person Shooter Death Events and Game Audio.** When looking at phasic psychophysiological assessment, can we find an interaction between effects of death events and effects of game sound and music on player psychophysiological responses?

**PAPER  $\iota$ : Wiimote vs. Controller: Electroencephalographic Measurement of Affective Gameplay Interaction.** Does a different input device elicit different brain activity or gameplay experience? How does gameplay experience relate to brain activation?

## 1.5 CONTRIBUTIONS TO RESEARCH AREAS

*The thesis papers are located at the intersection of different research areas*

As shown in Figure 1.3, the papers included in this thesis contribute to different research areas and most of them are located directly at the intersection of several of these areas: human-computer interaction (HCI), user experience (UX), computer science, psychophysiology, emotion and affect, and game studies.

**Paper  $\alpha$**  defines a user experience framework that can be employed in academic and professional user experience research. It outlines how the two dimensions time and abstraction interact and how the abstraction layers of UX in games can be assessed with different methodologies from psychophysiological and empirical game research. Thus, the paper is aimed at a UX and HCI research audience.

Next, an analysis of relevant literature on the *flow* concept (Csíkszentmihályi, 1990) in gaming is conducted in **paper  $\beta$** . This paper mainly contributes to the area of game studies, but outlines methodological considerations for measuring flow and hence is close to the intersection of UX and psychophysiology research.

**Paper  $\gamma$**  describes the development of a tool that contributes to automated gameplay analysis by logging events<sup>6</sup>, putting it at the intersection of UX, computer science, and psychophysiology research of emotion & affect.

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<sup>6</sup> For example, game events can be logged to psychophysiological data acquisition hardware, eliminating the need for scoring the data with a video file.

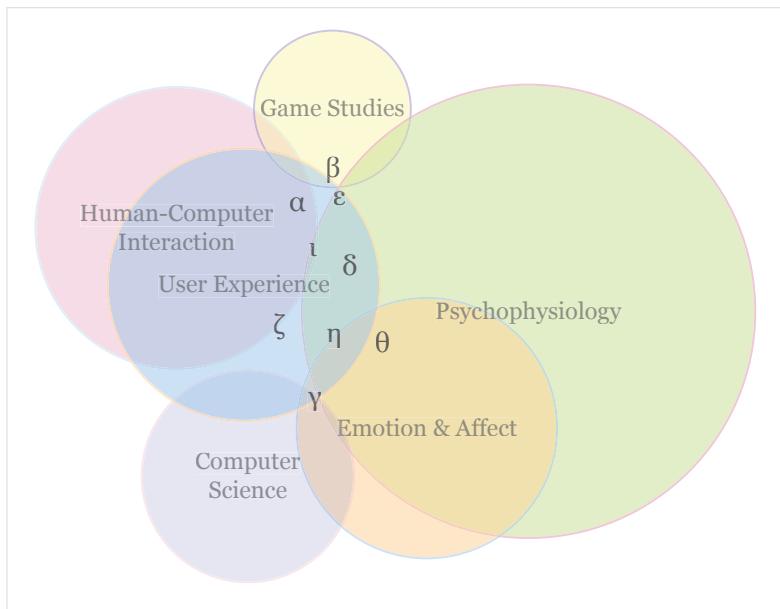


Figure 1.3: Contributions of the different papers in this thesis and how they relate to research areas.

**Paper  $\delta$**  shows how the impact different level designs have on subjective and objective (i.e., physiologically measurable) player responses. It draws from both, psychophysiological and UX research.

**Paper  $\epsilon$**  presents a preliminary investigation of the impact of sound and music on the audio UX and psychophysiological measurements and discusses the findings in light of game studies literature.

**Paper  $\zeta$**  takes a different look at measuring affective user experience with survey measures for an elderly target group and investigates the effect of game form and age on user experience when playing a brain-training game. It contributes to UX and HCI research areas.

**Paper  $\eta$**  consists of an in-depth analysis of tonic responses to game sound and music, showing a number of interesting interaction effects between sound, music, gender, and age. It is concerned with contributions to self-reported UX, especially audio UX, but also psychophysiological measures of emotion & affect.

**Paper  $\theta$**  looks at events in which player characters die in games and what kind of emotional responses this elicits, especially for different sound and music conditions. It presents a higher resolu-

tion view in comparison to the tonic psychophysiological measures described in previous work. In addition, the results support the tonic finding. The paper discusses the results in light of psychophysiological research on emotion & affect.

Finally, paper  $\iota$  is concerned with different interaction modes and their effects on gameplay experience, notably spatial presence, and electroencephalographic activity. The results of the affective player-game interaction are discussed in light of UX at the intersection of HCI and psychophysiological research using EEG measurement.

## 1.6 METHODOLOGY

*This thesis uses  
mainly  
empirical  
methodology*

Science can basically be approached from an empirical (i.e., data-driven, hypothesis-focused) and a theoretical (i.e., process models to identify the mechanisms and relationships explaining the data) perspective (Popper, 2002). However, the methods used in this Ph.D. project were mainly empirical. More specifically, the methodology followed in researching the questions outlined in Section 1.3 extends and further develops research approaches previously presented by Ravaja (2004) and Mandryk & Inkpen (2004). However, the focus of the work presented here is slightly different: While Ravaja et al. (2005, 2008) have mainly focused on *phasic* responses to specific events in a game, the studies presented in this thesis mainly represent *tonic* (i.e., long-term) physiological impact of level (paper  $\delta$ ), sound (paper  $\epsilon$  and paper  $\eta$ ), and interaction design (paper  $\iota$ ) considerations (paper  $\delta$  with its focus on death events being an exception). It also extends the work of Mandryk & Inkpen (2004), who also investigated correlations between subjective reports and physiological responses by using more sensors and adding tonic EEG results to this correlation. Furthermore, while both Mandryk et al. (2006) and Ravaja et al. (2006) have investigated the role of co-located opponents, the investigations conducted in this thesis focus on assessment of game design factors (as mentioned before: level, sound, interaction) of digital games.

In addition, we have extended the methodology of Ravaja (2004) toward using automated correlation of logged in-game events and psychophysiological data<sup>7</sup>, which was inspired by work from Microsoft Games User Research (Kim et al., 2008; Pagulayan et al., 2003) and our colleagues' work in eye tracking (Sennersten, 2008; Stellmach, 2007). This automated logging of game events to the psychophysiological data acquisition hardware can replace the regular event-scoring procedure with videos, which is used in psychophysiological game research (Ravaja et al., 2008), and hence

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<sup>7</sup> It was developed in paper  $\delta$  and used in the analysis in paper  $\theta$ .

speed up the analysis procedure.

In general, the methodologies used in this Ph.D. project come from the related research areas presented in Section 1.5 and were employed in combination for gaining a better understanding of gameplay experience and fun of gaming. The use of multiple methodologies was inspired by the project and internal research group focus (Lindley & Sennersten, 2008; Ravaja, 2004). Specifically, this thesis makes use of the following methodologies:

- **Psychophysiological analysis:** Two types of psychophysiological analyses were conducted in this thesis: *tonic* and *phasic*. *Tonic* measurements accumulate psychophysiological data over a time period, while *phasic* measurements allow a higher resolution view on the data (Ravaja, 2004). In general, a major challenge for phasic measurements is the automated scoring of events. For this purpose an automated logging tool was developed in **paper γ**, which has been utilized by FUGA partners conducting psychophysiological analyses and which was used for the phasic analysis conducted in **paper θ**. However, the measurement of tonic activity during gameplay yielded a number of interesting results documented in **papers δ, ε, and η**. More specifically, power estimates of different frequency bands of EEG data provide a tonic view of psychophysiological brain activity during play sessions, documented in **papers ι and δ**.
- **Qualitative interviews and surveys:** In addition to using psychophysiological equipment, other measures of subjective inquiry were used in most of the conducted studies. One of the measures developed during the FUGA project and described in Appendix B was the game experience questionnaire (IJsselsteijn et al., 2008; Poels et al., 2007), which has been used in all studies investigating gameplay experience in this Ph.D. project. For some measures, correlations between psychophysiological measures and gameplay experience dimensions were found. For other measures, questionnaires investigating usability (Sauro & Kindlund, 2005; ISO/IEC 9241-11, 1998) or spatial presence (Vorderer et al., 2004) yielded interesting results, for example in **paper ζ**.
- **Automated performance measures:** The logging of different events during gameplay has recently become popular (Tychsen, 2008; Kim et al., 2008) and a tool for facilitate automated logging is discussed in **paper γ**. However, other measures of success are commonly used in usability evaluations of products, such as error rate and the time to complete a task

*A detailed description of methodologies used in this thesis*

(ISO/IEC 9241-11, 1998; Sauro & Kindlund, 2005). Some of the measures are explored in paper  $\zeta$ .

- **Literature reviews:** An in-depth review of relevant literature in journals, books, and other publications related to user experience, immersion, and flow in gaming led to the theoretical developments presented in **paper  $\alpha$**  and **paper  $\beta$** . The purpose of this review was to gain a deeper understanding of the experiential constructs involved in playing games.

### 1.7 SUMMARY OF RESEARCH RESULTS

*How does this thesis answer the main research questions?*

While, there is still no comprehensive explanation to the question of "*What makes playing games engaging and fun?*," the papers in this thesis have gathered some empirical data for supporting some high-level conclusions about engagement in games. For example, elderly people might value brain-training games for their mental exercise (**paper  $\zeta$** ), there might be a connection between immersive level design and mental workload (**paper  $\delta$** ), music and sound might be important elements of game design with music potentially having a soothing effect for female players (**paper  $\eta$** ), player character death events in a horror FPS game might be connected with positive and negative emotions at the same time (**paper  $\theta$** ), and using physical game interaction controllers such as a Wii remote might lead to *interaction fatigue* indicated by increased EEG delta activity (**paper  $\iota$** ).

Regarding our initial question of "*How can this engaging experience of players be measured empirically?*," most of the papers included in this thesis make use of subjective and objective assessment techniques for player experience evaluation, which builds upon and extends prior work in the *affective ludology* area that was discussed in Section 1.1 and 1.2. A recommendation coming out of these measurement approaches is that psychophysiological recording together with automated in-game event logging allows for a very detailed understanding of player behavior.

In summary, all of the nine papers included in this thesis address and contribute partial answers to the research questions mentioned in Section 1.3. The individual contributions to the research questions and the individual results of the papers are as follows.

**Paper  $\alpha$**  describes the conception of a player experience framework. It reviews the current state-of-the-art of knowledge on player experience in—and the potential moderating variables of—player-game interaction. A two-dimensional, three-layer model is introduced that accounts for the dimensions *time* and *abstraction*, the

latter being subdivided into three levels ranging from concrete to abstract, which represents different stages of player experience; looking at technical, individual and social experience created by the use of games. Finally, it is discussed how these levels interact to form players' game experience and how they can be assessed with user research measurement techniques, such as psychophysiological measurement.

In **paper β** an extensive literature review is done on the subject of *flow in games* Csíkszentmihályi (1990). Several flow models and their features are presented and subsequently discussed with regard to their shortcomings and benefits. It appears that flow might either be related to high arousal emotions or to attentive processing of the brain. Four categories are proposed that can provide classifiers of flow experience in games: *effectance*, *identification*, *transportation*, and *mental workload*. A number of psychophysiological measurement techniques and their potential for assessing experience in each of the categories are described.

**Paper γ** describes a psychophysiological logging tool that automates psychophysiological data acquisition for digital games. For understanding game experience, phasic psychophysiological analysis of game events with high temporal resolution and within the game context is helpful and such an analysis is later described in **paper θ**. Nevertheless, this paper ( $\gamma$ ) presents a solution for recording in-game events with the frequency and accuracy of psychophysiological recording systems, by sending out event byte codes through a parallel port to the psychophysiological signal acquisition hardware. This enables real-time correlation of game events during psychophysiological data acquisition. By employing this system for psychophysiological game experiments, researchers are able to analyze gameplay in greater detail.

**Paper δ** highlights the challenge of researching game experience phenomena that are described by gamers but have no formal taxonomy, such as flow, immersion, boredom, excitement, challenge, and fun. The paper describes an initial research effort to provide measurable criteria for different experiential states in different level design conditions. Results from the subjective gameplay experience questionnaire support the validity of level design conditions, while emotional and arousal patterns generated from electromyography and electrodermal activity indicate that challenge-based flow gameplay generates very positive, high arousal emotions. Patterns of electroencephalographic spectral power show that the immersion level design elicits more activity in the theta band, which may indicate a relationship between sensory immersion and mental

workload.

**Paper e** presents an experiment on the immersive experience of play in a First-Person Shooter (FPS) environment under different sound and music conditions. This work was motivated by the lack of existing empirical data that explores the sonic relationship between player immersion and sound. Participants played in four conditions of two independent variables (sound: on/off × music: on/off) while measurements were taken using electroencephalography (EEG), electrocardiography (EKG), electromyography (EMG), electrodermal activity (EDA) and eye tracking equipment. In addition, participants filled out self-reports after each session. The results of a one-way analysis yielded no significant psychophysiological results, but showed some interesting variations in the subjective results.

**Paper ζ** takes a different approach to measuring game experience with a supervised field study conducted with elderly and young participants in their homes and institutions. The motivation for this study was that brain-training games target an elderly population while research investigating gameplay experience of elderly people using this game form is lacking. The experiment employs an *age group: young/old × game form: paper/Nintendo DS* mixed factorial design to investigate effects of age and game form on usability, self-assessment, and gameplay experience. In the experiment, *effectiveness* was evaluated in task completion time, *efficiency* as error rate, together with self-assessment measures consisting of (*arousal, pleasure, dominance*) and game experience questionnaire items (*challenge, flow, competence, tension, positive and negative affect*) (IJsselsteijn et al., 2008). The results suggest that age has no effect on effectiveness and efficiency, while game form does have an effect with pen-and-paper scoring higher than DS. However, the game was found to be more arousing and induce a high sense of flow in digital form than in paper form, for gamers of all ages. It was additionally concluded that logic problem solving challenges within digital games may be associated with positive feelings by the elderly, but associated with negative feelings by the young.

**Paper η** returns to the experiment outlined in paper e and reports an in-depth analysis of tonic psychophysiological responses to game sound and music. Two main effects are reported: (1) a main effect of music on electromyographic (EMG) brow and eyelid activity and (2) a main effect of sound on positive game experience (all GEQ items except *negative affect* and *tension*). Interestingly, women also showed a significant difference in electrodermal activity (EDA) between sound off, music off (high) and sound off, music on (low),

suggesting a soothing effect of music. A moderating effect of gender with music on negative affect ratings supports this hypothesis. Gender also had a moderating effect with sound and music on immersion and flow ratings, suggesting than men generally prefer to play with diegetic sound, regardless of music, while women like to play with either sound or music on, while absence of sound/music generates the lowest game experience ratings. The results support the notion that music and sound are both elementary and complex factors of an FPS gameplay experience.

**Paper θ** analyzes a different data set gathered in the experiment described in papers η and ε using the technique for automated psychophysiological event scoring developed in paper γ. During death events, changes in electromyographic (EMG) activity and skin conductance level (SCL) were recorded. Contrast tests of event-related changes during seconds following the death events revealed that neither sound nor music had an effect on *phasic* physiological responses, but show a significant quadratic trend of EMG activity. SCL shows a negative quadratic trend when sound and music is off and a linear increase when music is on and sound is off. In addition, the interaction contrasts reveal a greater linear increase in SCL when sound is off and similarly when music is on. These results contrast with prior findings reported by Ravaja et al. (2008) and may point to more complex emotions elicited during death events in violent, fast-paced FPS games.

Finally, **paper ι** reports a study on the influence of interaction modes (Playstation 2 game controller vs. Wii remote and Nunchuk) on subjective experience assessment and brain activity measured with electroencephalography (EEG). Results indicate that EEG alpha and delta power correlate with negative affect and tension when using regular game controller input. EEG beta and gamma power seem to be related to the feeling of possible action in spatial presence with a PS2 game controller. Delta as well as theta power correlate with self-location using a Wii remote and Nunchuk. The results point to *interaction fatigue*, which could come from the use of highly interactive input controllers.

## 1.8 FUTURE WORK

Many interesting paths for future work emerge from the work presented in this thesis. One example for extending the methodologies used in this thesis would be the combination of the established psychophysiological techniques (e.g., EEG, EDA, EMG) with either higher-resolution brain imaging equipment such as fMRI (Mathiak & Weber, 2006) or easier-to-deploy lightweight fNIR equipment

*Psychophysiological user interaction is a promising future area of research*

(Hirshfield et al., 2009) to study player-game interaction with a focus on mental processes (Grimes et al., 2008; Lee & Tan, 2006). This could also lead to more detailed considerations of how to use these sensors for psychophysiological user interaction or brain-computer interfacing (BCI) with games (Mason et al., 2004; Nijholt et al., 2008; Nijholt, 2008). This area is anticipated to grow as sensor technologies using physiological signals as means of user interaction become more ubiquitous, cheaper and hence be available to a larger audience.

In addition, these emerging psychophysiological interaction techniques may not only be used within a gaming context but for assessing any kind of engaging activity with novel digital media. Most interesting in this respect are social and online media domains, for which the impact of social networking sites and playful online applications might be assessed.

Another promising venture to establish an empirically-grounded game design theory is an area that could be called *neuroludology*, which aims at finding scientific correlations between playing preferences or player typology and activation in different brain areas, as suggested in the *BrainHex* model developed by Bateman (2009). The model tries to map gameplay behavior in to seven elements in the human nervous systems—the hippocampus and sensory cortices, the amygdala, epinephrine, norepinephrine, the orbito-frontal cortex, the hypothalamus, and the nucleus accumbens. The current limitation of this model is that it is only based on assumed correlations between player behavior and findings in scientific literature, such as those from Biedermann & Vessel (2006). Thus, a structured investigation of the validity of this model using psychophysiological investigation would be a promising research venture.

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Part II

THEORY, METHODOLOGY AND TOOLS



# LOGGED AND LOADED: A THEORY AND METHODOLOGICAL TAXONOMY OF GAMEPLAY EXPERIENCE MEASUREMENT

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Lennart Nacke and Anders Drachen

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## ABSTRACT

*User experience (UX) studies in games have been using various methodologies, commonly operating without an umbrella framework that classifies these methods within gameplay experience. In this paper we approach a methodological definition of gameplay experience measurement that moves beyond subjective interpretations of gameplay. We present a variety of UX models and methodologies in digital games, essentially leading us to propose the three levels of gameplay experience measurement framework: (1) game system experience, (2) individual player experience, and (3) contextual play experience. Three methodologies that operate within the presented framework are explained in case studies from industry and research. We discuss the methodological model in respect to prior research and current trends and outline future work that will combine physiological and technological logging of gameplay experience.*

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## 2.1 INTRODUCTION

Although the scientific exploration of games dates back to the work of Neumann & Morgenstern (1944) in economics, who emphasize the mathematical between strategic decision making in games as well as in economic situations. It is surprising that game studies, which was spawned by researchers from the humanities, was then called a discipline of its own in 2001 by Aarseth (2001). Fact is that the study of games is multidisciplinary and has been around for a long time, probably dating back to fundamental discussions about principles of science by Socrates and Plato (Butler, 1997). In the past decade game-focused research came largely out of the

*Early works of game research*

computer science field, especially in the areas of computer graphics and artificial intelligence. In recent years, however, we have seen an increasing interest in the emotional and affective aspects of the user experience (UX) that games provide. While in the past, the evaluation of games has been a largely informal process, the game industry is starting to adopt more formal techniques to evaluate their products. However, classic usability testing is not sufficient for game testing, since its standard metrics (e.g., effectiveness in task completion or efficiency in error rate) are not directly mappable to digital games. Desktop software is primarily created with functionality in mind. However, digital games are created with an enjoyable experience in mind. While traditional usability metrics are still relevant, they are subsidiary means that can supplement physiological and metrical assessment of digital games (Mandryk et al., 2006; Tychsen & Canossa, 2008; Nacke et al., 2008). Good evaluation methodologies for digital games must allow us to make inferences of the game's success in terms of impact on the player and for describing how successful the interaction with the game reflects the designer's intent (Isbister & Schaffer, 2008).

#### *Usability and user experience*

Since recently much effort has been put into broadening usability concepts to investigate UX (Law et al., 2008) in terms of underlying principles and action plans for improving design (Law et al., 2007, 2008), similar actions are now being taken to formalize playtesting methodology during game development (Nacke, 2009; Pagulayan et al., 2003; Sánchez et al., 2009a,b). However, there is still a lack of concrete advice for game industry and research practice about the taxonomical relationship of different methodologies for gameplay experience assessment. In addition, to our knowledge no gameplay experience framework has focused on presenting methodological advice and action plans with detailed case studies before.

#### *Goals of this research*

Thus, our motivation for this research is twofold: First, we would like to provide a formal theoretical model and taxonomical frame of the different methodologies that are being used in the development process to evaluate games iteratively. We aim at making this a broad and simplistic model and a framework taxonomy, which should include most methods already in use for game evaluation. In addition, this approach should be game-focused and not player-focused, allowing for establishing a more quantitative and technical view of gameplay experience. This is not to exclude player experience from this equation, but to focus on the received technical variables (assessment of technological and physiological metrics) that allow for behavioral inferences to understand players and games from an empirical standpoint (Tychsen, 2008; Nacke & Lindley, 2008b; Ravaja et al., 2008). Second, we want to focus

on presenting emerging methodologies that combine physiological and technological metrics in the different layers of our model that provide a technology-based, but user-centered approach to evaluating games during the development process. We will present case studies that show how these methods are being used in the digital game development process in industry and evaluation of players in research. It is our hope that by establishing emerging game evaluation methodologies and framing them in a development-focused taxonomy, this research will be useful for game developers and researchers alike, ideally making an interesting contribution to the UX community in general.

In this paper, we first discuss related work of UX and player experience models. Based on this, we propose a two-dimensional, three-layer model of gameplay experience. For each layer in the abstraction dimension, we discuss a number of measurement methodologies, thus establishing a taxonomical frame. Here, we focus on approaches that use physiological or technological metrics for evaluating UX in games. Next, we present case studies of emerging methodologies that use technological or physiological assessment of gameplay experience. These methodologies also show the efficacy of the proposed methods in action and how they help defining gameplay experience in more detail. Finally, we discuss these methods in game user testing in the game development process context.

## 2.2 RELATED WORK

### 2.2.1 *Models of User Experience*

Hassenzahl (2004) introduced a model (supplementing simpler and older models, for example Logan (1994)), which views user experience from a designer and a user perspective making a distinction between the intended and apparent character of a product. Thus, he emphasizes the fact that there is no guarantee for designers to ensure their products are used or perceived as intended. The emotional personal response to a product is based on the situational context. The process of forming an opinion about a product includes factors such as the combination of product features, individual customs or expectations, temporal memory of past product experiences and situational setting. Experience in his model is formed from the iconic value and prior memories the product triggers. Following his argumentation, a product can have pragmatic (e.g., utilitarian value) and hedonic (e.g., knowledge/skill stimulation, communication of identity, memory evocation) attributes. This model extends to games as well, since they also provide challenges, stimulation and novelty to create personal value. However,

one has to note that games are played primarily for their hedonic value in which pragmatic impact of play - if any - is often hidden underneath the sugarcoating of pleasurable experience.

Jordan (1999) proposed a hierarchical pleasure model of user needs (based on Maslow's motivational model of human needs (Maslow, 1943)). In Jordan's user needs model, pleasure follows from usability, which follows from functionality. He also distinguishes four types of pleasure: physio-pleasure (e.g., evoked tactile and olfactory stimuli), socio-pleasure (e.g., evoked by relationships, society, personal status, or indicative of social identity), psycho-pleasure (e.g., cognitive and emotional reactions), and ideo-pleasure (e.g., aesthetics and ideological value). While games are pleasure-centric products, they also need to be evaluated from sociological and technological perspectives. In general, this theoretical model does not give much direction in terms of applicable technology to evaluate pleasurable experiences.

Garrett (2003) proposed a UX design model for the web with UX elements on different layers of abstraction during the web development process. His notion of moving from an abstract strategy to a concrete aesthetic surface in product development can be adapted to game development, but needs to be refined in its details, which will be discussed in the next section.

Overall, UX has also recognized fun as an important factor for people to interact with products. More generally, three important threads for UX research have been outlined: addressing human needs beyond the instrumental, affective and emotional aspects of interaction, and the nature of the experience (Hassenzahl & Tractinsky, 2006). For the theoretical model and methodological taxonomy of gameplay evaluation that we are going to present, this discussion offered two motivations: (1) provide technological methods that enable behavioral modeling and (2) include affective measures of emotion and cognition that evaluate player-game interaction. These three directions also inspired the three layers of our methodological framework. Similar to product experience in general, gameplay experience is very complex, since player personas and profiling, game brand awareness, individual expectations based on past experiences and marketing campaigns are all factors contributing to it. This is what we will call the context of gameplay experience (and which relates to the nature of the experience mentioned above).

Another definition of UX describes it as forming from interaction with user and product in the particular context of use, including social and cultural factors (Arhippainen & Tähti, 2003). More pre-

cisely, the interaction of all these factors is seen as contributing to UX. If we were to adapt this model for our methodological gameplay evaluation model, our methodologies would mainly operate on the product and user level. The important notion of gameplay experience methodologies we focus on is that they have their main value in combining physiological (user-centered) and technological (product-centered) metrics.

One account that discusses user-centered methodologies for concept-level product design defines UX as a result of motivated action in a certain context (Kankainen, 2003). *Motivation, action, and content* all form the vertices of a triangle that subsumes present experience. Thus, *temporality* is introduced to this model, indicating that previous experiences are likely to shape present experiences, and those are again going to shape future experiences. The model is discussed in a user-centered product concept design process. It focuses on creating the product content by evaluating motivational needs (i.e., reason for the behavior of a person) and action needs (i.e., process and behavior of persons executing an action). For the design of digital games, this model can be useful; however, motivational needs of individuals are hard to assess with any kind of methodology, while action needs of a person can be evaluated during gameplay if behavior and emotional responses of players are recorded.

Few researchers have tried to explicitly model gameplay experience or in a similar vein, playability. Fernandez (2008) proposes a rather complex model of digital game experience, which has similar traits to the aforementioned temporality. The model is built around temporal influences before (i.e., antecedents), during (i.e., processing) and after (i.e., consequences) the gameplay experience. The model regards fun as the major outcome of game experience constructed from emotional and cognitive player responses and then proposes that game evaluation follows from this. If such a model has to be used in game production, this is a major shortcoming. A methodological gameplay experience framework should define experience from a developmental, production centric perspective, which allows improvement of each aspect of gameplay experience during production with a rich set of methods.

*Models of user experience for games*

Malone (1981) studied what makes things fun to learn and presented a model of intrinsically motivating instruction, which has been influential to the design of digital games as well. His model has three categories: *challenge*, *fantasy*, and *curiosity*. He hypothesized that challenge comes from having goals with uncertain outcomes. Fantasy has cognitive and emotional advantages for

design, where a distinction has to be made between intrinsic (skill-related) and extrinsic (not skill-related) fantasies. He also separates curiosity into sensory and cognitive parts, where he discusses that cognitive curiosity comes from making users believe their knowledge structures are incomplete or inconsistent. His model is useful for creating design guidelines, but not so much for explaining UX in games or for finding a methodological taxonomy to evaluate UX in games.

In a nutshell, many different UX models and approaches for mapping UX to games are around. However, none of these approaches has taken an inclusive methodological stance for describing emerging quantitative evaluation techniques, with focus on both, the player and the game.

### **2.2.2 Playability Evaluation Approaches**

*Playability evaluation as part of game testing*

A mapping of usability to playability to evaluate UX in entertainment systems by Sánchez et al. (2009a,b) introduced the notion of facets of playability, which integrates methodological approaches into the game development process. They propose a playability model usability factors effectiveness (e.g., time and resources needed to offer a player an entertaining experience), efficiency (defined as learnability being the cognitive capacity of the player to understand the game system and rules and immersion in a game as capacity of the content to be believable), and satisfaction. Satisfaction is subdivided into motivation (e.g., prompting the player to undertake actions), emotion (e.g., response to game stimuli), satisfaction (e.g., pleasure derived from playing), and socialization (e.g., game attributes that promote the social dimension). They then proceed to define six facets of playability: intrinsic, mechanical, interactive, artistic, intrapersonal/personal, and interpersonal/social playability. While being derived from concepts of usability makes this model quite interesting, it has a few major limitations. First, it is not described clearly what process was used to derive the game playability concepts from the desktop usability definitions. In addition, each of the fuzzy concepts of playability is defined by using other fuzzy conceptual descriptions. This is also true for the facets of playability derived from the initial descriptions. None of these descriptions can be used for empirical evaluation, nor does it provide recommendations of how to measure it. Thus, while providing an interesting theory, the model is short of methodological recommendations for empirical gameplay assessment. This essentially presents a research gap that we aim to fill with our methodological framework.

A preliminary game usability model that has focused on description of playtesting in game development classifies game usability into evaluations of technology (i.e., system quality), player (i.e., gameplay quality), and community (i.e., social quality) (Nacke, 2009). Analysis of the technology is supposed to be handled by a quality assurance team, player analysis is evaluated a UX team, and community analysis is done in sociological studies. The model comes close to Garret's description of web UX (Garrett, 2003) and is organized in similar layers as other approaches in UX that we have described above, essentially providing a basis for the methodological framework, we propose and evaluate in this paper.

Qualitative playability evaluation in other research studies provides criteria with which a product's gameplay or interaction can be evaluated (Järvinen et al., 2002). Four components of playability were initially discussed: (1) functional, (2) structural, (3) audiovisual, and (4) social playability, each relating to formal aspects (i.e., functional) and informal aspects (i.e., UX) of games. Functional playability is concerned with the mapping of input mechanics to in-game mechanics; structural playability evaluates game structure and rules, player skills and actions; audiovisual playability is the sensory quality of game aesthetics (aural and graphical); social playability is evaluating the context of use. The problem of qualitative playability evaluation with these categories is that most of them rely on expert evaluation and require a great amount of expertise. Quantitative methodologies that can be automated could improve playability analysis and help to gain valuable insights in player and game in a relatively short time.

Another common approach to playability evaluation is the use of a set of heuristics, a few of which have been defined for use in digital games. Desurvire et al. (2004) discussed four game heuristic categories: game play, game story, game mechanics, game usability. Game play evaluates functional aspects of gaming; game story aims at evaluating the narrative in a game; game mechanics evaluate interface and programming rules; game usability is concerned with sensory (i.e., audiovisual) and functional quality of game. Korhonen & Koivisto (2006, 2007) presented playability heuristics modules for game usability, mobility and gameplay. Their heuristics for game usability are similar to the aforementioned; gameplay heuristics evaluate the structural and rule-based content of a game. The limitation of the heuristics approach is that it again relies on experience of the evaluator and is lacking quantifiability. On the other hand, heuristics can help to get a fine-grained understanding of the conceptual and individual factors determining gameplay.

*Heuristics and playability*

Another approach investigating playability has been making use of grounded theory to create a qualitative model of player experience, which looks at players' opinions to determine the playability of digital games (Fabricatore et al., 2002). Based on those opinions, design guidelines are created, which conceptualize individual playing preferences. In addition to this, much work from the game research community has been going into conceptualizing and analyzing theoretical constructs, which are likely part the gameplay experience, such as flow, immersion, presence, frustration, enjoyment and many more. Since our focus is on a quantitative methodological proposal for gameplay experience evaluation, a discussion of all these constructs is beyond the scope of this article.

In summary, many approaches have focused on evaluating playability with more or less complete models. From the discussion of this work, we derive the following major requirements for our methodological framework of UX assessment in games: (1) The framework must provide broad and inclusive layers that focus on player and game evaluation; (2) each of the layers should include at least one emerging methodology for game evaluation; (3) the model should be applicable to stages of the development process of digital games, ideally allowing for each layer to be tested at the same time but in an iterative manner. In the broader theoretical model, these layers of abstraction should be put in a temporal context.

### 2.3 THE GAMEPLAY EXPERIENCE MODEL

*Abstraction  
and time are  
the dimensions  
of this  
gameplay  
experience  
model*

In the previously discussed models of experience for games, we have seen that time (Fernandez, 2008; Kankainen, 2003) and abstraction (Garrett, 2003; Nacke, 2009) are used as taxonomical dimensions when talking about GX. With the model that we present in this section it is our intention to synthesize both time and abstraction as important descriptors for gameplay experience. We begin by looking at abstraction in more detail, where we define three layers of abstraction in gameplay experience (context, player, system) and how they interact. Then, move on to put this abstraction in a temporal context, where we examine the progression of each experience layer over time. This leads to a presentation of the full model of processed, individual, and technical experience in different temporal stages. Finally, we make a brief recommendation how this model could be employed in practice to frame UX methodologies in game development.

### 2.3.1 Three Layers of Abstraction in Gameplay Experience

It has been argued previously that GX in a practical context can be seen in three different layers of abstraction (Nacke, 2009). These three layers progress from very concretely graspable and technical game system experience (1) to the experience that influences and is influenced by the perceptive and operational actions of the player (2), culminating in the abstract experience levels that is shaped by interactions with other players, games, technologies, etc. (i.e., the context) in a certain segment of time (3). Figure 2.1 illustrates these

*The abstraction dimension explained*

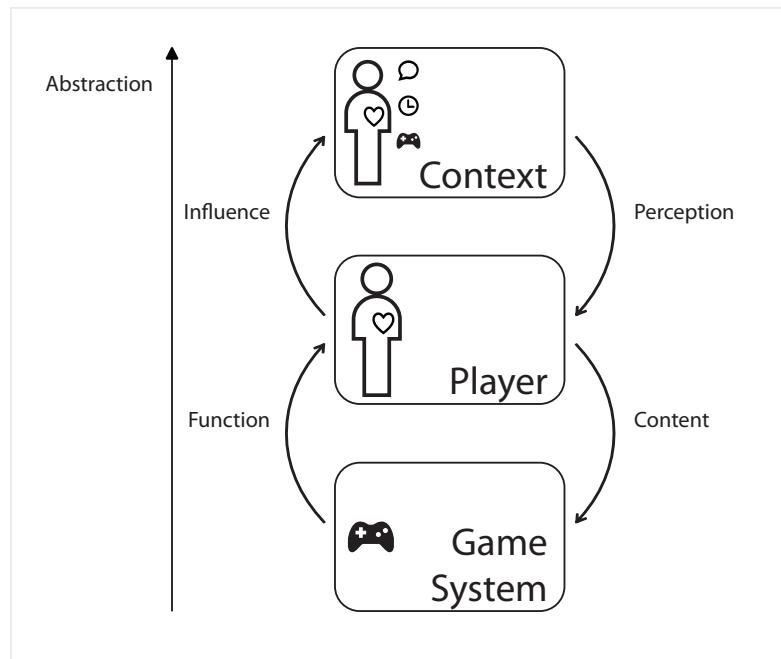


Figure 2.1: Different Layers of abstraction in gameplay experience (GX).  
Each layer demarks an actor component, which itself consists of a subset of unknown processes. The influence on GX emerges from the interactions between the actor components.

three levels of experience from concrete to abstract forms of GX.

Each of the layers of the models is a taxonomical framing device to describe an actor, which itself is a set of processes, influencing GX. On the bottom layer, the technological game system is an actor that exerts influence on player experience by its functionality, rules, mechanics, and other means. On the other hand the player is an actor able to provide content and essentially data that will shape the behavior and content of the game system itself. We do not need to know the internal processes that each, player and game system

actor, consist off, but we need to consider the input and output of these processes that shape the interaction between those actors from which the experience occurs. An example for creating game system experience are possibilities to modify digital games, such as editing levels or changing textures or even by only adjusting a number of variables that influence how the game system behaves. Games like Spore (Electronic Arts, 2008) or Little Big Planet (Sony Computer Entertainment Europe, 2008) provide an increasing number of so-called user-generated content to create a rich and aesthetic game system experience that can be adjusted to individual preferences by creating and sharing content between users.

The next interaction taking place in the three-layer abstraction dimension of GX is between the player and context actors, which can be other players, other games, memories and affection toward a certain game or genre. Again, we take the context actor basically as a black box of processes executed in the context of playing, which interact with the player in some way. By playing a game, a player directly influences this context on an individual level, such as creating knowledge on how to progress through the game world or on a social level, such as discussing the game content with friends. This context then again shapes how the player perceives the game individually. An example for this could be a bad review making the game less enjoyable or memories of a game series making the new episode more enjoyable. In summary, three actor components influence with their mutual interaction how GX shapes within a certain segment of time. Nevertheless, each of these layers or actors may be influenced individually or comprehensively by past experiences and will itself influence the shape of future experiences. This will be explained in the next section.

### *2.3.2 Temporal Progression of Gameplay Experience*

*The temporal dimension explained*

Following the notion that the temporal context is important (Fernandez, 2008; Lindley, 2004b) for understanding the experience during playing a game, we have to synthesize the actors from the previous section with the temporal changes they undergo, depicted in Figure 2.2. First, we have to consider that the interactions between more concrete and more abstract actors happen during a certain segment or slice of time. As this interaction of system, player, and context progresses, the nature of each actor may change and thus create a new and different experience. A game system is not likely to change smoothly over time, but is usually altered in technological steps. For example, systems like gaming consoles do not change gradually, but incrementally after a given fixed time period, when

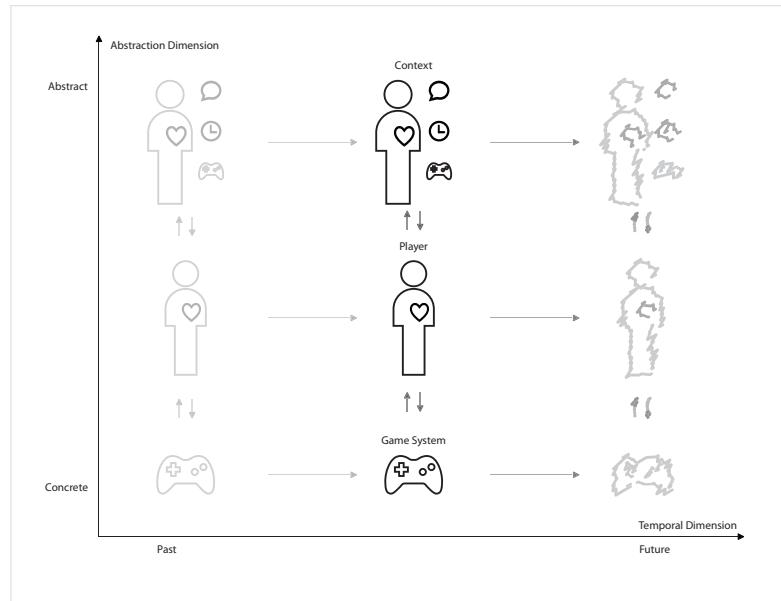


Figure 2.2: Abstraction and temporality dimensions of GX show the interactions of the actors on the abstraction dimension progressing over time.

new technology has been invented and the market is deemed ready to invest into a new console system. In contrast, for systems such as a personal computer this process is more gradual, because of their open architecture and flexibility. However, a game system may also refer to the software that builds the core of digital game, for example a game engine. These engines are constantly being developed or even patched over time, which makes it possible to create a different game system experience for the same game over the lifetime of the game<sup>1</sup>. However, while a game system may be altered individually over time (thus only altering the game system actor). New GX only emerges once this system starts interacting with the player actor for a certain time segment.

Next, players as human beings are more gradual in their change over time, since humans and animals are made up of certain psychological and physiological processes that quickly adapt to change and form our reactions and behavior accordingly (Pellis & Iwaniuk, 2004). Thus, even with the game system remaining consistent over a period of time, the experience may change as the player may be

<sup>1</sup> A good example of this is StarCraft (Blizzard Entertainment, 1998), which has been patched over 10 years fundamentally improving its original game mechanics and thus altering the experience between the original game and recent game with the newest software patch applied

influenced by context or by individual intrinsic changes of time. For example, when a player has developed blisters on a thumb after playing with a game controller, the experience has changed due to internal changes of the player as a biological system. The change becomes only apparent in the interaction with the game system as the altered experience emerges when the player starts using the controller to interact with the game. Finally, the context surrounding the player will change over time based on the sociological, economic, or political changes that influence the life of players. Temporal context changes can happen rapidly and thus influence the player's perception of and interaction with a game. For example, for children the restrictions made by their parents as to what time they are allowed to play will change over time as the children grow up. This also indicates how complex game experience is, since all three GX actors will change their interactions over time and individually, shaping the interactions between them and thus shaping the gameplay experience. We argue therefore that GX can only be assessed for a certain point in time and is likely to change as time goes by. However, assessing each actor of GX should enable us to improve GX to shape how the levels interact in the future. While we can build upon previous experiences although they may not be clearly defined in terms of their abstraction dimension, we cannot clearly determine future experiences and therefore have to treat them as a black box of consequences that follow from the actions that we exerted at the point of time we are currently operating in (see Figure 2.3). GX can therefore be only assessed in the slice of time we are currently in.

In a nutshell, gameplay experience can be assessed at three levels: context, player, and game system, which all change over time shaping the interactions between the levels over time and thus shaping GX in general. The assessment of each layer of GX may be most beneficial at time segments during the game development process, thus we will proceed with a suggestion of how to deploy the GX model in game development.

### *2.3.3 Applying the Gameplay Experience Model in Practice*

*Methodological suggestions for using the model in practice*

During game development, much concern is given to creating the game system according to certain design intentions and thus shaping primarily the game system experience. Since we have seen product designers starting to look at the emotional and affective impact of their products on users during the development process of the product (usually termed user-centered design) (Jordan, 1999; Norman, 2004), the same process is currently being adopted in the

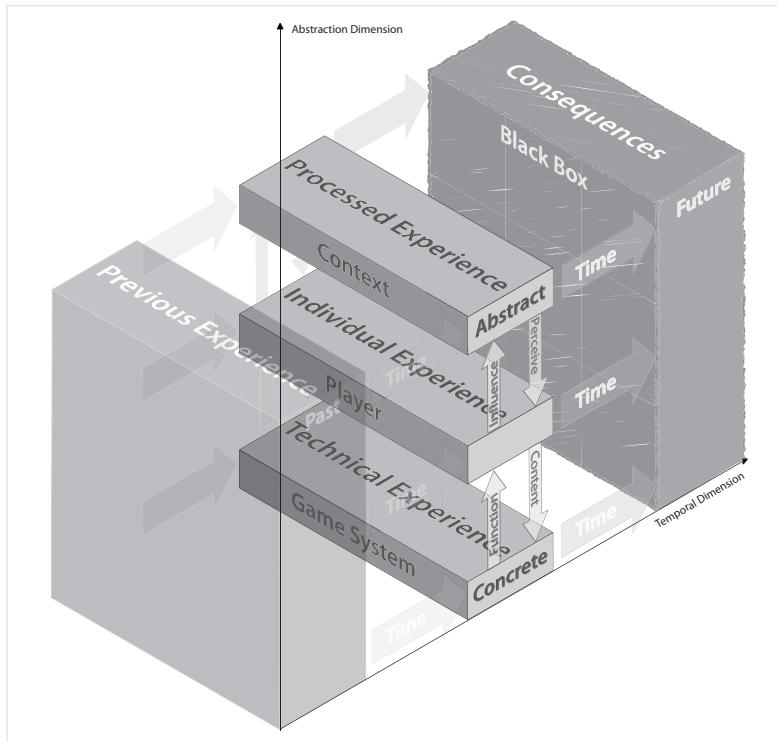


Figure 2.3: The final model of Gameplay experience accounting for time and abstraction as taxonomical dimensions.

game industry (Pagulayan et al., 2003). Using our GX model, we can classify different approaches of testing into the three levels of GX and by looking the interactions between each level or actor we can start designing for GX.

For example, if we are testing regular components of the software system or the game engine that is used for the digital game, we are operating on the game system experience layer. Hence, a programmer testing an engine component with unit testing or compatibility testing for different hardware is then exerting a change in the game system. To assess how this change will influence GX, game developers have to assess the interaction between player and game system looking at technological variables describing the game system (e.g., game metrics) and at physiological or psychological variables describing the player (e.g., psychometrics, physiological metrics). Understanding the interaction between player and game system will shape the interaction between designers or developers and the game system, potentially improving the game system to shape the player experience (see Figure 2.4).

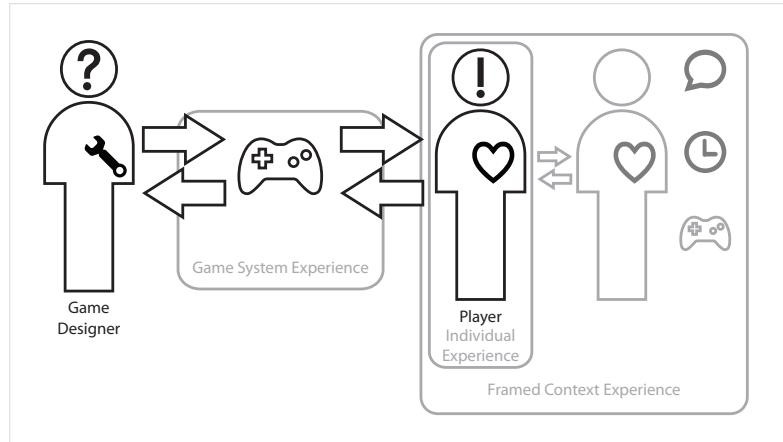


Figure 2.4: Three methodological frames of gameplay experience in the game development process. For example, game system experience methods are concerned with functional testing of the game; player experience methods ideally use sensor technology to assess player emotion and logging metrics methods enable assessing game context experience.

In a similar way, the assessment of the interaction between players and their context will help designers to understand this influence on GX. While certain methodologies are available for assessing the playing context (e.g., qualitative investigations and interviews), it is harder to design for this, since the developer only has a direct influence to shaping the player experience toward the interaction of the player with the game system (as shown in Figure 2.4). While this form of experience from player-context interaction is accounted for in our GX model, it is of limited use for developers. However, by actively assessing player-game and player-context interaction, we are approaching a more comprehensive design process of digital games that does not look at the software as an individual design artifact, but more as a communication tool for designers to shape and create experiences that grow and evolve over time.

To sum up, the GX model can help developers to understand how experience is shaped in player-game and player-context interaction and what methods can be ideal to evaluate this interaction. The focus in game development is on designing for player-game interaction by creating a game with its impact on the player and the context in mind. The model has established a foundation on which we can now try to understand how GX unfolds. We will discuss the impact of our model on our understanding of GX in light of the current literature and its implications for the game industry.

## 2.4 METHODOLOGICAL FRAMING WITH THE GAMEPLAY EXPERIENCE MODEL

The digital game development process is usually iterative and product-focused. Thus, testing of game systems has classically been carried out by quality assurance groups with a focus on finding bugs in the software and has been synonymous with assuring technical quality of the digital game. Playtesting with user-focus on the player of a game has long been neglected or been performed with a high degree of informalism (e.g. recruiting testers from within the game development studio). Only recently have we seen more work to develop inclusive player-game evaluation instrumentation (Kim et al., 2008).

There are basically three methodological categories for experiences that surround digital games: (1) the quality of the product (game system experience), (2) the quality of human-product interaction (individual player experience), and (3) the quality of this interaction in a given social, temporal, spatial or other context. All of these qualities will determine different layers of gameplay experience and all of them can be assessed during the game development process. Figure 2.4 showed how these methodological gameplay experience layers interact in game development.

*Categories of methods*

Game developers currently have primarily influence on game system experience by refining and testing the game software and by balancing the game system variables. Systematic balancing of gameplay requires either a very good knowledge of the preferences of a targeted user base or the application of scientific methods to evaluate user preferences, emotions, and behavior. This affects the layer of individual player experience, which models the reception and effects, the game mechanics, dynamics, and aesthetics have on a player. Thus, game developers can only indirectly influence this layer of game experience, for example by player modeling in the game system (Drachen et al., 2009). This is also the layer where affective studies allow a prominent assessment of player emotion and cognition using psychophysiological methodology. Finally, the individual experience is also affected by the context in which playing happens. This can for example relate to playing in a social context that might amplify emotions, it might also relate to the temporal change of experience if a game is played more than one time and affection becomes intertwined with the experiential memory of playing a certain part or sequence in the game and the actual experience, which is elicited when the game is played again. The experience is then framed in a context. This context can only be marginally influenced by game developers through providing

additional tie-in experiences<sup>2</sup>. In the following sections, we will look at methodologies that operate on the three different levels of the framework inside the GX model.

#### 2.4.1 Assessing Game System Experience

Methodologies for assessing game system experience come largely from regular software and game testing. They are often explicitly included in the game development process (at least by larger companies) and make sure the functional level on which the game system operates is correct. Most of these methodological examples come from regular software testing. A novel approach is the use of event-logging data to help balancing the gaming system, which we will discuss in more detail in a case study:

- **Unit testing.** Automated testing of the program code.
- **Load or stress testing.** Testing of software or hardware limitations.
- **Soak testing.** Sustained stress testing.
- **Compatibility testing.** Testing on different platforms.
- **Regression testing.** Iterative software bug testing.
- **Localization testing.** Correct interpretation, adaptation and translation of content in different languages.
- **Bug tracking.** Playtesting for software bugs, which are entered into a tracking system.
- **Open beta-testing.** Combination of bug/load/soak testing in massively multiplayer game production.
- **Gameplay metrics.** Event- and location-based metrics allow the tracking of user behavior in-game, which can then feed-back into the design process to balance out a certain level based on statistical data. We will focus on this method in the first case study.

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<sup>2</sup> For example, the Xbox Live Pub Games of Fable II are a tie-in to the full game. They provide people that like the casual experiences of these games with a different experience than playing the full game, potentially evoking curiosity for the full game.

### 2.4.2 Assessing Individual Player Experience

An important issue preventing successful evaluation of digital games is the inability to successfully cater to individual emotions. New sensor technology and behavioral tracking enable us to model and assess player cognition and emotion during gameplay. Some examples of novel methodologies used here include:

- **Psychophysiological player testing.** These are controlled measures of gameplay experience usually deployed in a laboratory with the benefit of covertly assessing physical reactions of players.
  - **Electromyography (EMG)** is a measurement technology for recording the electrical activation of muscles. Basic emotions are well-reflected in facial expressions. This allows a mapping of emotions in the valence dimensions of the circumflex model of affect (Russell, 1980; Mandryk & Inkpen, 2004; Ravaja et al., 2008).
  - Measurement of **electrodermal activity (EDA)** is one of the easiest and therefore most commonly used psychophysiological methods. The measured increased sweat gland activity is directly related to physical arousal.
  - **Electroencephalography (EEG)** requires the participant to wear scalp electrodes. Brain waves are usually described in terms of frequency bands, such as alpha (e.g., 8–14 Hz).
  - Functional magnetic resonance imaging (**fMRI**), positron emission tomography (**PET**) and functional near-infrared spectroscopy (**fNIR**) are **other non-invasive techniques** for measuring brain activation. The former two have major limitations in deployment and are hardly used in HCI research, while fNIR has recently received more attention from the HCI community (Hirshfield et al., 2009).
- **Eye Tracking.** Eye Trackers measure the saccades (fast movements) and fixations (dwell times) of human gaze (Duchowski, 2007). Due to the relationship between eye fixations and attentional focus, we are able to infer cognitive processes in virtual environment exploration (Sennersten, 2008).
- **Persona Modeling.** *Play-personas* are partly data-driven and traditionally constructed. Persona models can be compared with user behavior metrics and prompt changes in the game design (Tychsen & Canossa, 2008).
- **Game Metrics In-Game Behavior Assessment.** Instrumentation data ideally log any action the player takes while playing,

such as input commands, location, events, interaction with in-game entities (Tychsen, 2008; Tychsen & Canossa, 2008; Kim et al., 2008). As an analysis tool, gameplay metrics supplement existing methods of games-based user research by offering insights into how people are actually playing the games under examination.

- **Player Modeling.** Research based on AI is using neural networks and cognitive theories to model and react to player behavior, with the goal to develop adaptive games. Models of players based on behavior and responses to different in-game situations, form the basis for how the game should adapt in real time (Drachen et al., 2009; Yannakakis & Hallam, 2006; Yannakakis et al., 2008).
- **Qualitative interviews and questionnaires.** Semi-quantitative and qualitative approaches traditionally form the basis for user-feedback gathering in game development. Surveys have been focused on the enjoyment-aspects of UX in games, but recent developments have included dimensions such as tension, frustration or negative affect (IJsselsteijn et al., 2008; Poels et al., 2007). Using surveys during natural breaks in the gameplay action is usually the preferred method of deployment.
- **RITE Testing.** Rapid Iterative Testing and Evaluation was developed by Microsoft Game User Research (Medlock et al., 2002). The approach specifies data analysis after each participant or at the end of the testing day with changes to the interface or the game design being made rapidly after a solution is found. This allows iterative improvement of game designs during the development process.

#### *2.4.3 Assessing Play Context Experience*

Playing context is not often evaluated by game development studios, but has been the focus of research efforts, mainly from empirical and sociological perspectives. This is especially common in testing mobile games, where the context of the game has a large influence on how the game is perceived (Korhonen & Koivisto, 2006). Examples of methodologies used here include:

- **Ethnography.** Ethnographic methods attempt to record practices of a certain population acknowledging the impossibility for the researcher to be a transparent observer but instead treasure the impact that the act of observing has on the studied population.

- **Cultural debugging.** Testing conducted to assess how and if culturally arbitrary conventions are understood in different contexts. For example in Deus Ex 3, a receptionist was not perceived as such outside of the US because of cultural conventions.
- **Playability Heuristics.** Playability heuristics can be implemented quickly and cheaply into the game development process. There are a few sets of specialized heuristics for use in game development (Desurvire et al., 2004; Korhonen & Koivisto, 2006; Malone, 1980). Expert reviews with heuristics have been presented for action games, based on technical game review scores, and for game-based learning applications. The main benefits of heuristic methods are that they are time and cost efficient.
- **Qualitative interviews and questionnaires.** Used to assess context and social impact on individual player experience in a similar capacity as in the UX assessment at the individual player experience level.
- **Multiplayer game metrics.** Similar as for player experience, the social experience can be modeled using gameplay metrics to study the interaction of several players depicted in the interaction log.

In brief, UX evaluation of gameplay can be categorized in three frames. Game system experience methods work on the functional level of assessing the functional capacity of the game or providing game engine or level data to balance the game design. Player experience methods evaluate the emotional or cognitive impact that a game or certain events or entities in a game have on a player, ideally by using quantifiable, objective, and physiological methods. Finally, context experience methods are suited for studying the interaction of player in a co-located or co-present game environment, taking into account the sociological impact of game mechanics and player behavior. Ideally, those methods allow balancing and tuning of the game during and after game development to improve the experience and contextual or personal value that a game can provide to its players.

## 2.5 CASE STUDIES

The approaches towards measuring UX in games at the different levels of the model presented above are used in practice in the game industry and in research environments. In this section, we will focus on three case studies that present novel methodologies from each layer of the methodological framework in the GX model to show

how quantitative UX methodologies can inform game development. Each case is focused on logging and examining player death events in Shooter games.

### 2.5.1 Game System Experience Evaluation with Metrics

One of the key system design concerns in the development of games is game balance. Game balance is both focused on ensuring that the game provides a degree of challenge suitable for the player, as well as for avoiding giving specific players unfair advantages over other players in multi-player games. As mentioned in the above, gameplay metrics are instrumentation data logged from player-game interaction, tracking the behavior and actions of the player in the game environment (Tychsen, 2008; Tychsen & Canossa, 2008). Gameplay metrics permit the recreation of the play-sessions, via tracking the second-by-second interaction between the player and the game.

#### Methodology

In this example, a participant was asked to play through a level of the commercial game title *Kane & Lynch*. The total playing time was 10 minutes. Via a tracking system, the position of the player character for each second and its health at the time was logged. Health was divided into five categories. The location data was super-imposed on a level map (area of the game), as point-data, with each point colored according to the health status of the character, using the ArcGIS application suite (see Figure 2.5). Sections where the player is at the lowest level of health are marked with orange crosses. The data were logged using a custom application developed by the *EIDOS* Online Development Team, which streams information logged from the game engine itself to a central server for extraction and analysis (Drachen et al., 2009).

#### Results

The results of the process show where the participant encounters serious problems in the game level (cf., Figure 2.5). During two of the many encounters with AI-controlled enemies in the game level, the participant's game character is near death, while the other sections of the level provide minimal challenge. The player experiences this pattern as two cycles of challenge and non-challenge. Using the *EIDOS* software and *ArcGIS*, thousands of player paths can be plotted in the same visualization. This provides a means for analyzing the difficulty of games. In this case, the player did not die, but was duly challenged in two situations. An open question is whether the non-challenging sections were experienced as being



Figure 2.5: Player health in the game *Kane & Lynch*. Point-data are spaced one second of playtime apart. Color signifies character health (five categories). Locations of lowest possible health (right before death) have been marked with orange crosses.

boring, or if they provided the necessary *downtime* to restitute following the challenging sections. Supplementing game metrics with physiological data would answer this question.

### 2.5.2 Individual Player Experience Evaluation with EMG

Player character death events likely have a large emotional impact on gameplay. An emotional profile of death events in a game can thus help to understand player emotion. We designed a small case study to assess in-game death events and their psychophysiological emotional reaction in the laboratory. A level was designed in *Half-Life 2* with a high focus on gradual combat challenges, the level stretched across three rooms, each individually filled with different enemies that had to be eliminated, before the player was able to progress in the next room. Upon virtual death, players respawned at the beginning of the level. The game mod was also altered to output game instrumentation data to the psychophysiological data acquisition hardware following suggestions from the literature (Nacke et al., 2008).

Essentially, the connection of event metrics with emotional indicators such as EMG gives us a more complete picture of player experience. Individuals were invited to the laboratory, where ex-

periments ran in two-hour sessions. After a brief description of the experimental procedure, each participant had to give informed consent before the experiment started. Individuals were then seated in a comfortable chair, the electrodes were attached and a resting period followed. During this resting period of 3–5 minutes, individual physiological baselines were recorded. After playing the level, individual received a small incentive for participation.

### *Methodology*

Data were recorded from 36 undergraduate students (7 female) and University employees. Their age ranged between 18 and 41 ( $M = 24$ ,  $SD = 4.9$ ). All participants played digital games regularly. Facial EMG was used to record the activity from left *orbicularis oculi* (OO), *corrugator supercilii* (CS), and *zygomaticus major* (ZM) muscle regions (Fridlund & Cacioppo, 1986), using BioSemi flat-type active electrodes with sintered silver/silver chloride electrode pellets. The electrodes were filled with electrode gel. The raw EMG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz and using ActiView acquisition software, and afterwards filtered using a low cutoff filter (30 Hz) and a high cutoff filter (400 Hz). Noisy data was excluded from analysis.

### *Results*

The physiological data were condensed to seven 1-s means, one second before (baseline; Second 1) and six seconds after the event (virtual player death event; Seconds 2–7). EMG data was normalized with a natural logarithm and analyzed using linear mixed models in SPSS.

There was a significant quadratic trend across seconds 1 to 7 for ZM,  $t(457.74) = 5.63$ ,  $p < .001$ , OO,  $t(462.36) = 5.79$ ,  $p < .001$ , and CS,  $t(469.79) = 4.36$ ,  $p < .001$ , which is visible in by the inverted U-shape of the EMG activity curves. Figure 2.6 reveals the activation of all three facial muscles after the death event, with higher activity in muscle areas indexing positive valence (OO, ZM) and lower activity in muscle areas indexing negative valence (CS).

This case study thus shows us the complexity of an emotional response profile that can be generated for a given game and a given event. The more sensors are used to generate such a response profile (e.g., adding EEG and EDA data), the more complex this player profile becomes and the more difficult it is to interpret such a response in terms of game design implications or UX. For our case study, we might conclude that dying in this game is not an

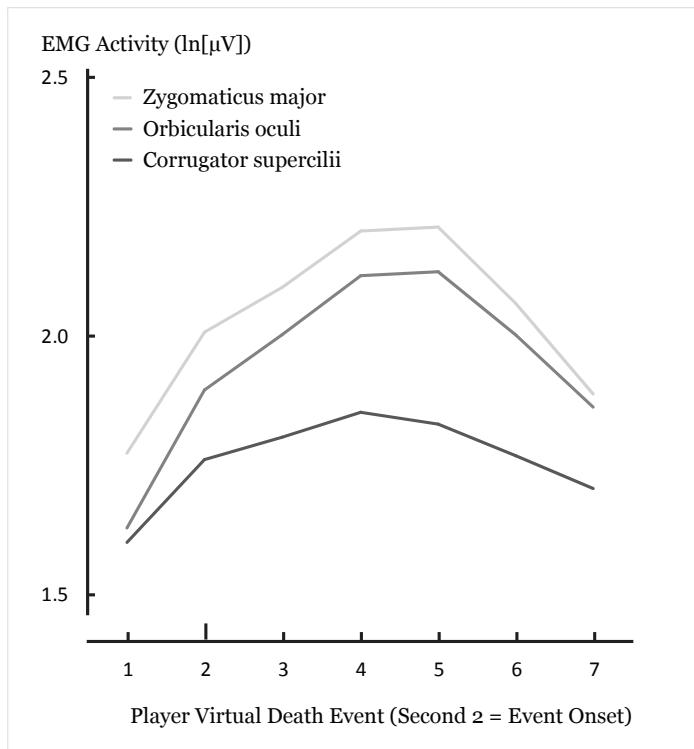


Figure 2.6: The emotional response profile (EMG data) triggered by an event, where the player dies (virtually) in the digital game.

entirely positive affair, but rather a complex interplay of positive and negative emotions.

### 2.5.3 Context Experience Evaluation in a Multi-Player Shooter

In the multi-player game *Fragile Alliance*, published by *IO Interactive* in 2008, the players form two teams of mercenaries and police respectively. The mercenary team has to perform heists, breaking into for example a bank vault and escaping with the loot. The police team is there to stop them, and is at the beginning of the game augmented by AI-controlled agents. The game has a twist: Mercenaries can eliminate other mercenaries, stealing their loot. Police officers can eliminate other police officers, becoming *dirty cops* and effectively siding with the mercenaries. A central element of the game design is creating a balance between the attractions of trying to steal the loot of others, versus the need to work as a team to complete the mission. If you die as a mercenary, you respawn as a police officer. The idea of this design was to apply a steadily increasing pressure on the mercenary team - the more time that

elapses, the stronger the police team becomes. The aim of the case study was to evaluate if the intentions of the design manifested in the interaction between the players.

### *Methodology*

At *IO Interactive*, *Fragile Alliance* was playtested intensely during production, using in-house testers as well as volunteer external participants in series of user-research tests (all above 18 years of age). During the playtests, participants played the game naturally for the purpose of enjoyment alone (i.e., without any directions). Gameplay metrics data were collected from the playtests, showing the places where players die, what role they played when they died, and who killed them. The dataset used here comprise about 5800 death events, all occurring in one specific level (section of the 3D virtual game world). *Fragile Alliance* features a mission time, typically from 240–540 seconds, after which the game round ends.

### *Results*

The gameplay metrics data were subjected to simple counts-based analysis (see Figure 2.7), dividing the player roles at death and the roles of their killers into percentages, based on a series of time slices (15 second intervals).

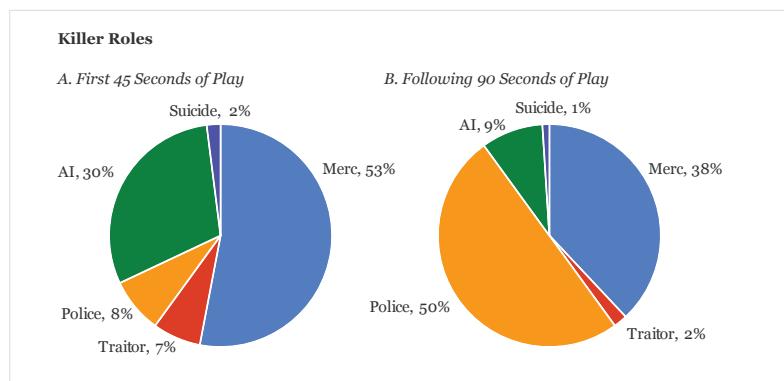


Figure 2.7: Evaluating killer roles in *Fragile Alliance*. Dataset drawn from game testing sessions across multiple levels. (A) Only data from the first 45 seconds of play have been included. (B) The roles of killers after 90 seconds of gameplay.

The analysis shows a notable shift in the roles of the killers between 45 to 90 seconds of play. During this period, Mercenary players and AI bots go from being the major causes of player death, to the police being the primary cause (this happens at the 60 second

mark). As the AI bots get eliminated, they become gradually less important in the interaction between the player teams. At the same time, the role of the players at death changes, from the police players holding a small fraction (12%) to being more common among those eliminated (40%), which corresponds well to the presence of more police players in the game. The role of traitors is relatively minor compared to the other roles.

The case study highlights how gameplay metrics can be used to evaluate the interaction context between players from within the game itself. Combining instrumentation data with attitudinal data allows the evaluation of whether the interaction was positive or detrimental to the game UX, and which elements elicited the most positive effects.

To sum up, we have present three case studies using novel, empirical, and quantifiable approaches to studying player experience in an industry and an academic context. We aim at providing more of these studies in the future and to refine the model from this initial methodology focus to a more comprehensive theory of gameplay experience that is rooted in the empirical analysis of such experience.

## 2.6 DISCUSSION AND FUTURE WORK

In this paper, we have discussed approaches to measuring UX in games and concluded that no comprehensive model exists based on empirical assessment of game UX. Therefore we have presented a theoretical GX model that includes a methodological framework providing a taxonomy for talking about assessing gameplay experience. We have also presented three case studies showing different approaches to studying certain kinds of player-triggered events within our methodological framework of the GX model (in this case: death events). The case studies also indicate that instrumentation methods can help get insights into the complex realm of gameplay experience, not by measuring it directly, but by enabling user-research specialists to locate for example areas of a game world or level where players are pressed too hard or conversely making progress too easily. Ideally, finding such situations and correlating them with physiologically measured emotional and cognitive responses, a so-called physiotechnological approach could provide a very accurate account of gameplay experience and has to be investigated in the future.

The suggested structural model formally organizes a wide array of non-homogeneous testing methods ranging from qualitative

ethnographic accounts to quantitative methods based on instrumentation on physiological measures. The model also provides indications on the pertinence of each method according to the purpose of the test and the involved stakeholders (generally game developers). For example, to assess social interaction between players in a co-located racing game it makes no sense to use player modeling techniques.

*Strengths and weaknesses of measurement techniques*

Approaches for measuring UX in player-game interaction directly have different strengths and weaknesses. For example, physiological methods provide an assessment of affective UX as expressed by the physical reactions of the human body provide detailed and objective data. However, psychophysiology currently does not provide the same amount of nuanced feedback we get from qualitative inquiry. Additionally, physiological methods are easiest to deploy for single player evaluation because of the cumbersome experimental setup of a full psychophysiology study. The exception is heart-rate or EDA, which both require no extensive preparation or setup. If there is one conclusion that we can draw from the more than 250 publications focusing on theoretical and empirical aspects of gameplay experience, it is that the process by which gameplay experiences are created, is complex and associated with a number of variables that contribute to greater or minor extent. The GX model presented here is meant as groundwork for future studies into player experience and can hopefully be refined as the evaluation of gameplay experiences with novel methodologies continues.

Regardless of what layer of game UX measurement is of interest, combining methods (such as surveys and physiological data) appears to provide the most comprehensive results. At the layers of player experience and context experience, combining physiological, behavioral and neurological measures with qualitative measures appears to be the most promising approach toward measuring game experience. It is, however, challenging to obtain accurate and clear data - in an unobtrusive manner - about the actual behavior of players within the virtual worlds of digital games.

In the current state of the art it is not possible to comprehensively model how gameplay experience is created and experienced in detail - the sheer number of variables that potentially impact on it is too big to lead to any kind of functional model of UX in games. This difficulty should not prevent future research from developing various methodologies to measure UX in games. To proceed with the development of methodologies in the assessment of UX in games, we recommend looking into related fields, such as neurology or mathematics to find new quantifiable and accurate methods

to model parts of either system, player or context experience. Moreover, we have not discussed here the vast amount of experiential concepts that seem to be related to gameplay and each warrant a field of study on their own (e.g., presence or flow).

One design implication for game software system design drawn from our observation and testing of UX methodologies for games is that the game engine code should already provide classes or functions, which are geared to the recording of metrical properties of in-game entities, ideally working toward a plug-and-play solution that integrates the software logging directly into psychophysiological recording hardware (or providing APIs for rapid implementation of logging functionality). Such approaches could also be used for general software design and evaluation, potentially allowing the detailed empirical study of all kinds of user interactions with software systems.

In conclusion, we have presented a methodological GX model for gameplay experience measurement in which we have accumulated traditional and novel game UX evaluation approaches. Finally, we have discussed some novel UX evaluation methodologies that operate within the presented model in case studies from industry and research. In the future, we hope to see more research that combines technological and physiological for physiotechnological logging of players' behavior and emotion.



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# 3

## MODELS OF FLOW EXPERIENCE IN GAMEPLAY: A REVIEW AND SUGGESTIONS FOR MEASUREMENT

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Lennart Nacke

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### ABSTRACT

*This chapter will list, review and critique prominent theories of flow in gaming for understanding gameplay and discussing their cognitive and emotional components. The different flow models will be synthesized into four categories of effectance, identification, transportation, and mental workload. The categories are aimed to provide a foundation for empirical study of gameplay experiences. Suggestions for measuring factors of gameplay experiences scientifically are discussed and evaluated in light of the developed categories and a general understanding of flow.*

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### 3.1 INTRODUCTION

Game design, much like regular product design should be concerned with creating pleasurable products that fulfill their purpose as well as have an appealing value (Jordan, 2000). Games are special products in the sense that their internal purpose is to create a fun and entertaining experiences for the user/player of the game. The review in this Chapter is driven by curiosity about two factors inherent to the design process of digital games: (1) What is the interplay of emotion, cognition and other psychological factors in players' *flow* experience (Csíkszentmihályi, 1990; Nakamura & Csíkszentmihályi, 2002) and can we find new experiences incorporated in flow based on these factors? (2) How can we scientifically measure the factors that create pleasurable game experience?

In game studies, some very loosely defined constructs are common for describing experience of players, such as immersion (Douglas & Hargadon, 2000; Ermi & Mäyrä, 2005; Jennett et al., 2008;

*Gameplay  
experience  
constructs*

Murray, 1995), presence (Lombard & Ditton, 1997; Zahorik & Jenison, 1998), and flow (Csíkszentmihályi, 1990; Nakamura & Csíkszentmihályi, 2002). Flow is a commonly badly understood, but often used experiential concept for describing one kind of game experience. Many examples from game studies and human-computer interaction literature try to use flow for analyzing successful game design features of games (Cowley et al., 2008; Sweetser & Wyeth, 2005).

The following Section 3.2 will present concepts of flow theory and their application to gaming. These concepts will be framed in light of emotional and cognitive factors of gameplay experience. Specifically, the elements and conditions for each model will be described and will be criticized with special consideration of what elements could possibly be measurable scientifically. This discussion is used to present updated categories of gameplay experiences inherent in flow. Finally, objective scientific measurements, such as psychophysiological methods will be presented and discussed in light of their suitability to provide insights into the study of flow and gameplay experiences.

### 3.2 THEORETICAL MODELS OF FLOW IN GAMING AND AN ENTERTAINMENT CONTEXT

#### 3.2.1 Csíkszentmihályi's Original Flow Concept

*Flow is experienced in intrinsically rewarding activities*

The flow concept was first introduced by Csíkszentmihályi (1975) based upon studies of intrinsically motivated behavior of artists, chess players, musicians and sports players. This group was found to be rewarded by executing actions *per se*, experiencing high enjoyment and fulfillment in the activity itself rather than goals of future achievement, etc. Csíkszentmihályi describes flow as a peak experience, the "holistic sensation that people feel when they act with total involvement" Csíkszentmihályi originally argued that flow is likely experienced, when opportunities for action are perceived to be in balance with an individual's perceived skills (see Figure 3.1). Complete mental absorption in an activity is fundamental to this concept, which ultimately makes flow an experience mainly elicited in situations with high cognitive loading accompanied by a feeling of pleasure. According to Nakamura & Csíkszentmihályi (2002) the conditions for entering an experiential state of flow include:

- A matching of challenges or action opportunities that match an individual's skill
- Clear and close goals with immediate feedback about progress

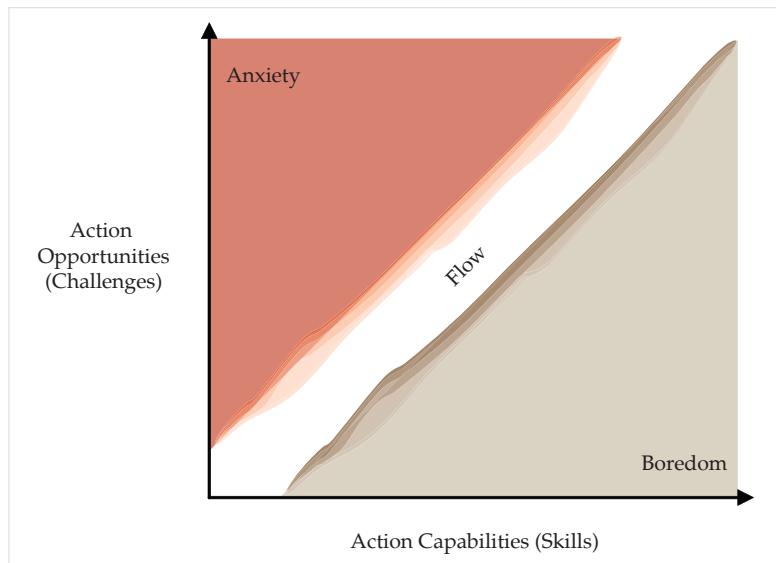


Figure 3.1: Csíkszentmihályi's original model of the *flow* state, adapted from Csíkszentmihályi (1975). Flow is experienced when challenge (perceived action opportunities) and skills (perceived action capabilities) are in balance.

It is important to note that these descriptions of prerequisites for experiencing flow have never been empirically tested and are based on a method called experience sampling, which Csíkszentmihályi used in his conception of flow. The method requires participating individuals to note their peak experiences in a diary and describe what they were doing before entering the experiential state that was later dubbed flow. These qualitative descriptions were later collected and evaluated to create the prerequisites that were stated above. Thus, the word *flow conditions*, while being often used, might not be accurate as none of these was ever empirically tested. Neither are these descriptions clear enough to design a falsifiable hypothesis around them. For example, one would need to be able to break down *challenges* into certain metrically accessible game elements. However, there is a very fine-grained level at which game elements interact to create challenges for players, such as life energy of an enemy, penetrating power of a player weapon and individual aiming skill. Accurate measurement would require us to individually assess player skill (and its development over time) as well as develop a challenge metric that incorporates the gameplay elements in the game creating this challenge.

This highlights a major caveat of the prerequisites for entering flow experience, they are currently not empirically testable and

*Caveat of the flow concept*

they themselves are based on fuzzy conceptualizations like challenge and skill. The same goes for the definition of clear goals, which begs for a measurable definition of clear. Nevertheless, this fuzzy conceptualization of flow prerequisites has not stopped them from becoming popular for describing gaming experiences, since all games provide action opportunities, rules to initiate challenges and several levels of difficulty, which make the matching of challenge difficulty to player skill easy. Generally, game designers have already balanced the fine-grained elements of the game, making challenge adjustable manually by players or automatically through dynamic adaption of the game (see for example Hunicke & Chapman (2004); Yannakakis & Hallam (2006)). To sustain interest in the game, games provide immediate clear goals, such as levels or missions, and high scores, health bars or life indicators, which always allow evaluation of individual progress. In addition, player actions directly and visibly impact the game world (e.g., pressing a button triggers shooting a weapon), a concept that has been labeled *effectance* (Klimmt, 2003; White, 1959). Games share many elements that Csíkszentmihályi (1975) considered important for entering a flow state, but if this concept is used for assessing the impact of games on players cognitive and emotional state it needs to be redefined into definitions that are falsifiable, allowing the concept to be tested empirically (Popper, 2002).

### *Csíkszentmihályi's Flow Components*

Given that an individual is in a situation where all prerequisites for flow are present, it is possible to enter flow, which is characterized by Nakamura & Csíkszentmihályi (2002) as having the following components, all of them having cognitive and emotional aspects to them, which I will try to briefly describe:

1. **Concentration focuses on present moment.** Since concentration involves focusing attention, this component largely regards a state of consciousness and cognitive focus. It is questionable whether emotions facilitate concentration and thus mediate this component.
2. **Action and consciousness merge.** This component likely refers to cognitive and motor components operating without any cognitive evaluation. This is supposed to be a seamless, unconscious process that allows individuals to feel one with their actions. Thus, it is likely to involve more emotional processes than active cognition.
3. **Self-awareness is lost.** The conscious cognitive reflection that underlies self-awareness is blocked. The absence of this kind

of cognitive processing is likely accompanied by a particular feeling of ease as the emotions connected to self-perception are suppressed.

4. **One is in full control over one's actions.** The control derives from actions being effortless. This again refers to the action being completely automated, since it is running as a cognitive script (Abelson, 1981). This control is only possible in environments where learning the interaction semantics is a self-motivated process (Malone, 1980).
5. **Temporal perception is distorted.** Subjective perception of time is known to depend on cognitive load and how much attentional resources an individual allocates to passage of time (Zakay, 1989). We can assume the temporal distortion described in flow to be related to mental workload and attentional resource allocation (i.e., being largely a cognitive feature).
6. **Doing the activity is rewarding in itself.** Rewards provide a lot of motivation to engage in an activity, for the activity to be rewarding, it is important that it is accompanied by positive emotions or that the prospect of experiencing a positive emotion is present during its execution.

Features of Csíkszentmihályi's flow theory have been criticized, especially since the theory provides no clear definition how the features are related and why they are important for motivation or how they can be measured empirically (Chen et al., 2000; Ellis et al., 1994; Malone, 1981; Novak et al., 2000). For example, if an activity is rewarding in itself, this might be a motivating factor for people to enter flow, however, a description of distorted temporal perception is rather a result of flow than a feature that motivates the experience. Numerous of the above flow features are not directly measurable, such as action-awareness merging or the loss of self-awareness, and therefore still challenge scientific researchers that want to investigate metrics for the empirical assessment of flow. Action control and consequently, perceived *efficacy* of actions (White, 1959) is a flow feature likely to manifest in pleasure and often observed in games. Here, the result—pleasure—can be observed or (as positive affect) even be measured, but the cause—likely a complex interplay between player effort and gameplay reactivity—remains difficult to assess with empirical methods. Although, advances are being made for measuring metrical game data (Nacke et al., 2008; Tychsen, 2008; Tychsen & Canossa, 2008) and correlating it with physiological user states (Mandryk et al., 2006; Nacke & Lindley, 2008b; Ravaja et al., 2008).

*Criticism of  
flow*

A helpful research that will support such efforts is the structuring of flow as a game experience into its cognitive or emotional impact in a similar manner as presented above. Many of the qualities of flow experience are of a cognitive nature. Cognitive effects of flow form complete cognitive control. This shows how the different flow qualities relate to each other, since cognitive control results from focal concentration, consciousness within action—not on self or temporal perception—and control of all actions. The awareness of this sense of control then determines a sense of pleasure or positive affect, which results in the activity being rewarding itself. Thus, one could argue that feeling control and *effectance* (Klimmt, 2003) may be the primary mediators for positive emotions resulting from flow in games. This provides an interesting basis for empirical investigations of flow in games, since control could be measured subjectively by asking individuals how well they could control the game (external, such as via input device, and internal, such as via difficulty) or objectively by recording brain waves in areas responsible for motor control and information processing.

Since the original description of flow was held very general to be applied to a number of activities, game researchers have revisited the original components and redefined them for the analysis of digital games. A few of the most prominent theories in game research will be discussed below.

### 3.2.2 Jones's Model of Flow for Game-based Learning

Jones (1998) adjusted flow theory for use in game research and, for example, uses it for understanding engaging computer-based learning environments. He discusses eight elements of flow and their manifestations in digital games:

1. **Facing a task that can be completed.** Game levels provide small sections of missions and tasks, which make up the entire task of the game.
2. **Player is able to concentrate on a single task from multiple tasks in a game.** In digital games, convincing worlds are created that draw users in.
3. **Tasks in the game have clear goals.** Clear goals can be survival, collecting or gathering objects, or solving a puzzle.
4. **Game tasks provide immediate feedback on progress.** This relates to subjectively felt immediate *effectance* in games (e.g., clicking mouse triggers a shot, which hits enemy/monster to cause damage or exterminate).

5. **Players feel deeply and effortlessly involved in the game.** Game environments are far removed from individual realities. It is interesting to note here that this description only accommodates the notion of deep involvement, but gives no indication how this should be effortless.
6. **Exercising a sense of control over the game world.** Mastering input schemas, controls of the game.
7. **Concern for self disappears during flow experience in a game session.** Representation (e.g., death in game is different from death in real life), game problem (e.g., the level of challenge), and control over game systems (e.g., mastering input schemas) collaboratively cause this.
8. **Sense of time duration is altered during play.** People stay up all night to play games.

Cowley et al. (2008) critique this mapping of flow in games in their comprehensive review of flow in video games. First, it is noted that elements (2) and (5), as well as elements (7) and (8) significantly overlap in their manifestations in games. They also present the following caveats to Jones (1998) model: Element (1), the task that can be completed, should only be restricted the amount of aspiration a player has to play a certain game, that is by a player's internal motivation to complete a game task, not by external factors like game level structure.

Digital games can feature elements of what Bateman (2009) calls *toyplay* facilitating the motivation of playing for its own sake. *Toyplay* denotes an unstructured activity of play guided by the affordances of the game world and largely of an exploratory nature (Bateman, 2009; Bateman & Boon, 2006) similar to games of emergence (Juul, 2005) and unstructured and uncontrolled play termed *paida* (Caillois, 2001). The important questions regarding game design that aims to facilitate flow is: Should tasks be provided by the game (i.e., created by the designer), should they be encouraged by the game environment or should finding the task be part of the gameplay? The latter is rather unlikely, since finding only one task at a time sequentially might frustrate players and choosing a pleasant task according to individual mood, emotional or cognitive disposition will likely provide more fun. Thus, instead of saying players need to face tasks that can be completed, it might be better design advice to provide several game tasks at the same time and design for an environment that encourages playful interaction. An environment that facilitates flow would provide opportunities for the player to alternate between playing for its own sake (i.e., setting up own tasks) and finding closure by completing a given

task. Regarding flow elements (1) and (3), *toyplay* generates its own tasks and goals to be completed and thus is not primarily guided by game rules or a sequential and narrative structure of a game.

Cowley et al. (2008) also criticize that immediate feedback in games must be suitably patterned for a player to comprehend the information presented by the game world. Thus, although effectance is certainly a driver for game enjoyment (Klimmt, 2003), as a factor of flow in games, effective feedback must be presented in a manner that accounts for cognitive, attentional capacities of players. The last point of criticism from Cowley et al. (2008) is that for feeling a sense of control a player needs to be familiar with the genre and its conventions. However, this would more accurately be described as developing gameplay competence (i.e., selection and performance of actions that support advancement in a game based on past experiences (Lindley & Sennersten, 2008)). It is therefore questionable whether this criticism is correct, since even genres and innovative games should allow for players to be able to exert a feeling of control after a reasonable amount of training time, meaning they should be able to develop gameplay competence. Thus, it would be more suitable to compare this element of flow with the ability of a player to match control and gameplay to developed schemas from a game, general media or real world interaction and cognition (Lindley & Sennersten, 2008) and through this matching process reach a feeling of control, which will likely mediate a feeling of pleasure.

### 3.2.3 Cowley et al.'s Restructured Flow Elements in Games

Cowley et al. (2008) also present an updated mapping of flow elements to gameplay elements, which should be mentioned here. Suggestions what cognitive or emotional processes these components might relate to is given.

1. **Game should feature challenging, but controllable tasks to complete.** This is meant to account for the complete gameplay experience including elements of social interaction. As mentioned above, perceived control may lead to enjoyment, suggesting both cognitive and emotional processes to be involved.
2. **Players experience full immersion in the task.** High motivation for playing is to feel immersed in a game, but immersion itself is a concept that is loosely defined and currently lacks empirical research (Jennett et al., 2008). Nevertheless, research suggests that immersion like flow is largely guided by en-

- abling or disabling cognitive processes. Immersion itself needs to be defined more clearly for this component to be useful.
3. **Players feel in full control.** Cognitive knowledge of control schemes, genre conventions and game mechanics. The positive emotion for control again follows from cognitive processes enabling control by developing gameplay competence, understanding interaction semantics, and developing a cognitive script (making the first element of this definition almost redundant).
  4. **Players have complete freedom to concentrate on task.** Freedom to concentrate encompasses an environment that facilitates the focus of attention to be on the game. Concentration on a task is nothing more than a persistent shift of attention to this task. Thus, the task must be perceptually incentive as well as providing enough characteristics to mentally load players' cognition.
  5. **Task has clear unambiguous goals.** Missions, plot, levels, quests, explicit structure, the y all allow to evaluate success of a gaming session. Again, the segmentation of a task into subtasks with simple goals is something that can come intrinsically from the player or extrinsically provided by the game. Again, this relates to the ability of the human brain to only process a limited amount of information at a given time, making this feature relate to cognitive processes more than emotional.
  6. **Game gives immediate feedback on player actions.** A game may time the delivery of suitable rewards appropriately, using player effectance in a meaningful way to operate a play session. Rewards trigger positive emotions and thus serve as motivators for continued cognitive processing of the information presented by the game.
  7. **Players are less conscious about time passing.** Games should focus on a vicarious, temporally-independent environments, enabling subjective perception of time to be altered. Temporal perception is likely influenced by a game's fantasy environment (Malone, 1981) as well as the ability of the game to provide mental workload for the player (Zakay, 1989).
  8. **Sense of identity lessens during gameplay, but is reinforced afterwards.** Identification with player characters might facilitate cognitive shifts from individual identities to in-game identities (Isbister, 2005; Tychsen et al., 2007), allowing for a transfer of empathy and emotion between the virtual identities and the player (Bessiere et al., 2007).

While the mapping of Cowley et al. (2008) is more suitable for designing games than that presented by Jones (1998), it is still a mapping that tries to adhere to Csíkszentmihályi (1975)'s original flow elements. When we look at our systematic restructuring of these elements into cognitive and emotional components, we find that cognitive elements are central to describing flow-inducing gameplay. Being able to control a challenging task is largely a cognitive effort, but may contain subtasks that can be matched to schemas known from other game or media interactions or developed by playing the game. This schema-recognition will then again be the mediator of positive affect.

*Immersion as mental and sensory loading*

The full immersion in the task is largely achieved by mental and sensory loading of a player's cognitive resources. The presence-inducing freedom to concentrate on a task at hand may be guided by a player's motivational state, his gaming environment as well as any emotional disposition that he might have developed during prior exposure to playing games. Thus, this feature element of flow is difficult to design as part of game software, but can possibly be done in a better way by modifying hardware appropriately (e.g., *Guitar Hero* or *Rock Band Controllers*) since immersion in the same way as telepresence tries to bridge the gap between players and games as smoothly as possible. For a game to provide better features of immersion, it is therefore beneficial to mimic real-world actions, allowing humans to feel that they can naturally interact with the game technology. It needs to be studied empirically, what interfaces have a better feel to them and are therefore more suitable to assist humans in their interaction with virtual game worlds. Initial evidence suggests that this immersion type of presence in virtual worlds is connected to positive emotions (Ivory & Kalyanaraman, 2007; Ravaja et al., 2006; Saari et al., 2004).

In contrast to this, the focus on clear goals is largely a game design effort to support cognitive processing of in-game information, by dividing gameplay elements into groups and clusters that can easily be mentally digested by players. Player feedback again relates to concepts of effectance (White, 1959), which is largely an emotional element as the perception of self-produced actions in the game world will likely guide player feelings (Klimmt, 2003). The temporal distortion of flow in games depends on cognitive load and the amount of attentional resources an individual allocates to passage of time (Zakay, 1989). Our brain is diverting all focus and attention to gameplay features, which results in a subjective disconnect from real-world time. Finally, the changed efficacy of players when entering and influencing a game world leads to a lessened sense of individual identity, since this is projected on the

representative identity within the game world. The exerted cognitive effort to sustain a vicarious identity is likely mediated by the positive emotion accompanying this identification, partly due to the possibility to engage in actions deviant from and likely impossible in reality. Emotion is likely to be a driver of projective identification in a game.

### 3.2.4 Sweetser and Wyeth's GameFlow

Sweetser & Wyeth (2005) have developed their own mapping of *GameFlow* criteria for player enjoyment in games, that includes: (1) concentration, (2) challenge, (3) player skills, (4) control, (5) clear goals, (6) feedback, (7) immersion and (8) social interaction. The most significant difference from the other models presented here is that it adds a dimension of social interaction, which is heavily critiqued by Cowley et al. (2008), who question whether social interaction needs to be a necessary or desirable part of every game. Many players of offline, single-player role-playing games enjoy their experience a lot and are very likely to enter states of flow during long sessions of play. In addition, the definition of an engaging and immersive experience that is provided by Douglas & Hargadon (2000) explains this experience as the recognition of familiar schemas. Familiar schemas like solitude would be excluded from flow or generally immersive experiences if social interaction were a necessary element of *GameFlow*. Nevertheless, the *GameFlow* criteria of Sweetser & Wyeth (2005) can again be clustered into cognitive and emotional components:

1. **Concentration** is largely a cognitive effort that refers to the allocation of a player's resources of attention and an increase in cognitive, perceptual and memory workload. This description is similar to the engagement phase of immersion, described in (Brown & Cairns, 2004). Again, in terms of schema recognition, this is the phase where players have to make a cognitive effort to match existing schemas to the information they are being presented in the game (Douglas & Hargadon, 2000; Lindley & Sennsteren, 2008).
2. **Challenge** is connected to both, cognitive processing to recognize challenging game problems and to an emotional reaction that accompanies challenge as it may be related to prior play experiences that are connected to certain feelings or memories of failure or success. In addition, the relief (i.e., the decline of arousal after solving a challenge) may facilitate emotions, which are subsequently cognitively stored in players' memory and will allow altering future emotions connected with this kind of challenge. This is a reason why designing balanced

challenges is such an important aspect of good level design (Pagulayan & Steury, 2004). Challenge in gameplay is central in studies of playability, where it is very important to distinguish challenges arising from bad interface and controls from challenges that are part of the game design (Desurvire & Wiberg, 2008; Pagulayan et al., 2003). Although, there has been some criticism from the game industry that interfaces can be a designed and integral part of the challenge gameplay provides.

3. **Player skills** relate to learning, development and mastery of a game-related skill set. This is a chiefly a cognitive effort, since it is likely related to the formation of gameplay schemas that are stored in memory and administered to gameplay situations governed by attentional and cognitive processes (Lindley & Sennersten, 2008). The evaluation of a successful schema is however related to emotion. Emotional processes provide a value function that classifies scripts and schemas according to their successful function to advance players in a game or not. Thus, the development of basic effective playing skills in the interaction between designed game features and player's a priori knowledge can be seen as an important precursor for flow.
4. **Control** again relates to the felt effectance of player action. Thus, while mastering control is a cognitive process, control mentioned in this context rather refers to the felt experience of control and is therefore connected to emotional evaluation of the cognitive ability to exert game control. This kind of control must then relate to both internal game-challenge oriented control and user-interaction related control, which has been described as interaction mechanics and gameplay competence (Lindley & Sennersten, 2008).
5. **Clear goals** is connected to a player's ability to always have enough mental resources for cognitively processing and clustering the presented missions, levels, quests or game sections, so that his progress in the game is always apparent.
6. **Feedback** should be handled by the game to appropriately inform players at all time about progress. This makes this element largely overlapping with the prior *clear goals* and if we relate this to cognitive capacities of the player, a statement like "avoid cognitive overloading of players" would suffice to encompass both concepts.
7. **Immersion** is a principally fuzzy concept (Jennett et al., 2008), however here it refers to a game's capability to cognitively

absorb players by stressing their mental processing in a way that is still enjoyable. Thus, immersion in this context is cognitive immersion, again governed by an emotional evaluation that decides how much processing of game information is still pleasant. Ermi & Mäyrä (2005) would label this type of immersion as challenge-based immersion, since it is not taking perceptual (sensory) and imaginative properties of game software and hardware into account.

8. **Social interaction** is labeled by Sweetser & Wyeth (2005) not as an element of flow, but as a strong element of game enjoyment, which makes the inclusion of this concept in their *GameFlow* model questionable. However, social components are crucial for experience, if we remember Lewin's equation, which represents behavior or any kind of mental event as a function of a person and his environment (Lewin, 2007). In line with this assumption, a social component might largely relate to player's emotional experience of playing as co-presence of other player may facilitate pleasant game experiences (Gajadhar et al., 2008).

In overview, the *GameFlow* model does not add many new elements to the prior discussions of flow in games, most notably it explicitly includes the concept of immersion as a component of flow (i.e., challenge-based immersion), but is inconsequential in its explanation of why social interaction should necessarily be a part of flow. As Cowley et al. (2008) note, Csíkszentmihályi's original flow studies already included chess players, so that social interaction may have already been a part of their flow experience, but not necessarily, since the flow concept was trying to account for a large array of individual experiences. It is questionable whether co-located opponents have any influence at all on a player's flow experience and empirical research on this is needed in the future.

### 3.2.5 *Flow as a Concept of Cognitive Effortlessness*

Most of the discussed research from game studies is concerned with facilitators of flow experience in games, since they might be used as game design elements or simply inform and enhance the normal game design process. Game designers value flow experience for its attributed feature that it fosters intrinsic engagement and game-based educators value that it may lead to improved performance, because the state is so desirable that an individual is willing to exert high effort for reaching it (Egbert, 2003). Flow in this sense serves as a motivator to enter an activity, for example a learning activity. The most interesting thing to note here is that flow need

not *per se* be a pleasurable experience, although it is a desirable mental state associated with information processing. Flow might just be the state leading to positive emotion, because flow itself might not so much be an emotional experience, but more a state of cognitive effortlessness in a way that actions and environment facilitate cognitive processing at an ideal level. In this sense, flow is probably not the salvation experience, it was being hailed to be in the past and not necessarily be the desired experience for every type of game. Some game dynamics and mechanics might be perfect for flow others might provide exciting experiences evoking all kinds of different emotional responses from players but not flow. That being said, a microscopic view at the mechanics of game design would maybe inform the creation of self-motivating learning environments (Malone, 1981), which foster enduring concentration and appropriate cognitive processing. This is why flow has been influential in theories of learning with digital games (Jones, 1998; Malone, 1980; Pillay, 2002).

#### *Neurological exploration of flow*

If we accept the notion that flow is primarily a state of consciousness, it is imperative to analyze it in relation to brain mechanisms, which cognitively enable players to enter flow. A first approach in this direction was undertaken by Dietrich (2004), who identifies flow as "a period during which highly practiced skill that is represented in the implicit system's knowledge base is implemented without interference from the explicit system." The human brain can differentiate between emotional and cognitive knowledge and process information to acquire, represent and memorize this knowledge in two systems (Damasio, 1994). The explicit system is tied to rule-based processing and conscious awareness, whereas the implicit system is based on skill or experiences and expressed through task performance (Dienes & Perner, 1999; Dietrich, 2004). We could argue that explicit system of the brain is primarily concerned with appropriate cognitive processing of information and consciousness, thus it would account for any cognitive function (e.g., understanding, framing) of game content, while the implicit system would be concerned with recalling motor schemas from memory or emotionally evaluating a performed task. This brings us back to the interplay of cognition and emotion during gameplay. Cognition, if largely attributed to explicit brain systems, would then be a framing device for the flow experience in gameplay, while the emotional, subconscious factors would be the drivers of flow experience. If we argue in line with Dietrich (2004), a temporary suppression of the explicit system and its conscious capacities would enable flow experiences to happen. Thus, it remains for future research to explore whether emotions contribute to flow at all and whether this

is possible to be measured using psychophysiological techniques (Kivikangas, 2006).

### 3.3 CATEGORICAL SUMMARY OF FLOW MODELS

Table 3.1 shows a comprehensive taxonomical synthesis of the models of flow that have been discussed into categories that represent different experiences that seem to occur as part of flow. A main goal of this synthesis is to move away from a fixed definition of flow in games. This is an attempt to identify experiences that have been described as part of flow in games, but can also be seen as separate experiences that together with additional experiences—which are not mentioned in this context—are likely to form gameplay experience.

This new clustering of game experiences provides a foundation on which a more complex definition of gameplay experience can be built. This could lead to measurable items of gameplay experience that will be assessable from players. This could be done via subjective questionnaires and objective psychophysiological measurements or from games via metrical data gathering and analysis. The categories of game experiences related or inherent in flow are the following:

1. **Effectance:** Possibly a very important driver of enjoyment in digital games (Klimmt, 2003), effectance describes the feeling of empowerment rising in players' when they can witness the impact of their actions. This can be experienced when challenge of the game match the player's skills, feedback provides immediate information about progress in terms of goals, the interaction semantics of the game system can be mastered and gameplay competence can be acquired. A possibly more complicated mapping is that of action-awareness merging to effectance, but acquisition of gameplay competence can lead to this merging. This is motivated retrospectively by effectance. Thus, effectance might be self-motivating and evolving in an iterative repetition cycle.
2. **Identification:** The changed perception of identity was noted as important for flow experience, but it might also be related to concepts of escapism (i.e., escaping into a vicarious identity, and identifying with a character in a game world (Bessiere et al., 2007; Isbister, 2005)).

FLOW ELEMENTS	EFFECTANCE	IDENTIFICATION
Nakamura & Csíkszentmihályi (2002)	Action-awareness merging (2), control (4)	Self-awareness lost (3)
Jones (1998)	Clear goals (3), feedback (4), control (6)	Self-concern lost (7)
Cowley et al. (2008)	Challenge/ skills for task (1), control (3), clear goals (5), feedback (6)	Identity/ self-awareness weakened (8)
Sweetser & Wyeth (2005)	Challenge (2), skills (3), control (4), clear goals (5), feedback (6)	
TRANSPORTATION	MENTAL WORKLOAD	
Nakamura & Csíkszentmihályi (2002)		Concentration/ focused attention (1), action-awareness merging (2), temporal distortion (5)
Jones (1998)	Effortless involvement (5)	Task completion (1), focused attention (2), temporal distortion (8)
Cowley et al. (2008)	Immersion (2)	Challenge/ skills for task (1), focused attention (4), less temporal perception (7)
Sweetser & Wyeth (2005)	Immersion (7)	Concentration/ focus (1), challenge (2), skills (3)

Table 3.1: Comprehensive synthesis of flow models according to their main components into four categories, which serves as a fundament for exploring factors of gameplay experience empirically.

The ability to test out other identities in a game might lead to the reinforced return to the own identity after a play session, described as the reinforced sense of identity (Cowley et al., 2008).

3. **Transportation:** This is described mainly as the feeling of immersion in games (Cowley et al., 2008; Sweetser & Wyeth, 2005). However, since immersion itself is lacking a clear definition and has been described as a *progression* (Jennett et al., 2008) rather than a *state* (potentially leading to the state of presence), a more general description of transportation will be used here. Transportation can account for immersion as the process of transporting the player's mind and for presence as the state of the player's mind as being inside the virtual world.
4. **Mental workload:** Many elements of flow contribute to or result from mental workload of players. The distortion of temporal perception that is witness in flow is likely a result from the loading of players' attentional resources in a continuous manner during gameplay. The concentration of attention initiates the loading of players' cognitive information processing. Resulting from this intense concentration is the creation of cognitive scripts for developing skills necessary to overcome present challenges.

These four gameplay components omit the items social interaction (Sweetser & Wyeth, 2005) and self-motivation (Nakamura & Csíkszentmihályi, 2002). The latter can be a result from experiencing either of the experiences described above, while social interaction might have an impact on identification and transportation, since mental workload and effectance are concepts primarily resulting from the direct interaction of a player with a game system. While this categorization presents a first step toward understanding game experience in more detail, the categories in their current refinement do not account for objectively measurable phenomena like psychophysiological indicator of player emotion and cognition. A research effort for the future must be to refine the categories, so that their underlying independent variables can be identified and may be used for empirical game research.

### 3.4 PROPOSALS FOR PSYCHOPHYSIOLOGICAL MEASUREMENT OF FLOW

#### 3.4.1 Experimental Measurement of Flow in Games

Experimenting with variations in game design can provide new insights into player behavior. However, a few methodological prob-

lems need to be mentioned when discussing the application of psychophysiological techniques in a laboratory. It may be difficult to create natural play situations, such as ensuring controlled, but ecologically valid gaming settings. Players who participate in experiments play in less naturalistic conditions and for participating in an experiment, which might not be for their own pleasure (i.e., they are not intrinsically motivated). However, this can easily be addressed by selecting only participating that would like to play the game under investigation in any case. In a lab environment

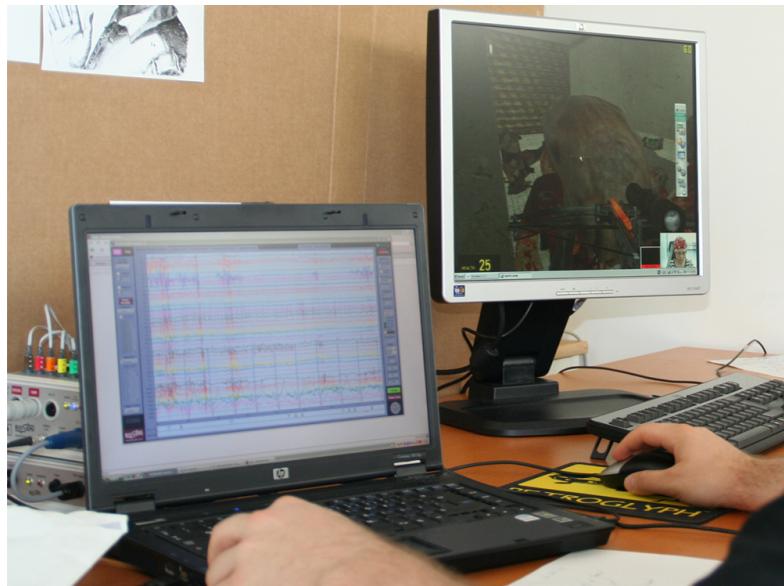


Figure 3.2: Example of a multimodal measurement researcher workstation for gameplay experience observation with psychophysiology and eye tracking recording hardware and analysis software.

*Example of a biometric testing lab*

(see Figure 3.2), player experience can be assessed ideally using multimodal empirical measurement techniques from psychological, sociological, psychophysiological, computer science and human-computer interaction research.

Empirical measurements of player cognition and emotion can be done in two ways, either (1) measuring it as objective, context-dependent experience with physiological measures (usually electrodes) of how a player's body reacts to a game stimulus or (2) assessing it as subjective, interpreted experience with psychological measures (usually questionnaires) of how a player understands and interprets their own emotion. If subjective assessments are used, the gaming sessions is likely intercepted by an interview or a questionnaire, which might make subsequent assessment more difficult as interception might be factored into succeeding responses.

However, when using objective measurement methods, for example psychophysiological measurement equipment, ecological validity can be hard to establish because of the sensor equipment. Nevertheless, many participants easily forget about the electrodes they are being measured with. In the following, a set of psychophysiological measurements is introduced with a discussion how these measurements can possibly allow us to gain new insights into flow in gaming.

### 3.4.2 Measuring Emotions with Electromyography and Electrodermal Activity

Emotional classification in dimensional models has a lengthy history in psychology (Schlosberg, 1952). A rather modern approach is the two-dimensional model of emotional affect and arousal suggested by Russell (1980) first tested to classify affect words. The mapping of emotions to the two dimensions of valence and arousal was later elaborately developed and used in numerous studies (Lang, 1995; Posner et al., 2005; Watson & Tellegen, 1985). Setting the fundamental cornerstone of modern emotion research, Ekman (1992) found that basic emotions are reflected in facial expressions after studying hundreds of pictures of facial expressions. This insight was fundamental for subsequent studies investigating physiological responses of facial muscles using a method called electromyography (EMG), which measures subtle reactions of muscles in the human body. For example, *corrugator supercilii* muscle activity (responsible for lowering the eye brow) was found to increase when a person is in a bad mood (Larsen et al., 2003). In contrast to this, *zygomaticus major* muscle activity (on the cheek, associated with smiling) increases when a person is in a positive mood. In addition, a higher *obicularis oculi* muscle activity (responsible for closing the eyelid) is associated with high arousal positive emotions (Cacioppo et al., 2007a). Even though facial expressions can be evaluated by both physiological measurement and visual observation, a major advantage of physiological assessment is that it can assess covert activity of facial muscles with great sensitivity to subtle reactions (Ravaja, 2004). Classifying emotions in the two-dimensional model of emotional valence and arousal is now possible even when playing games according to the physiological activity of brow, cheek and eyelid muscle (Mandryk, 2008; Mandryk & Atkins, 2007; Mandryk et al., 2006; Nacke & Lindley, 2008b; Ravaja et al., 2008).

For the correct assessment of arousal, additional measurement of a person's electrodermal activity (EDA) is necessary (Lykken & Venables, 1971), which is either measured from *palmar* sties (*thenar/hypothenar eminences* of the hand) or *plantar* sites (e.g., above

*abductor hallucis muscle* and midway between the proximal *phalanx* of the big toe) (Boucsein, 1992). The conductance of the skin is directly related to the production of sweat in the *eccrine* sweat glands, which is entirely controlled by a human's sympathetic nervous system. Increased sweat gland activity is related to electrical skin conductance. Heart-rate is also an index of emotional arousal and stress, but since it was shown to be influenced by both parasympathetic and sympathetic nervous systems (Papillo & Shapiro, 1990), EDA is a more objective measure of arousal.

### 3.4.3 Measuring Emotional Game Experiences and Flow

With EMG measurements of facial muscles that reliably measure basic emotions and EDA measurements that indicate a person's arousal, we can correlate emotional states of users to specific game events or even game sessions (Nacke et al., 2008; Ravaja et al., 2008). Since there are no established psychophysiological indices of flow experience, we currently have to rely on additional subjective assessment tools to establish psychophysiological factors of flow in gaming (e.g., (Hsu & Lu, 2004; IJsselsteijn et al., 2008; Jackson & Marsh, 1996; Komulainen et al., 2008; Novak et al., 2000)).

Psychophysiological measurement of emotional valence to investigate flow may be very difficult as previous studies have been inconclusive (Kivikangas, 2006; Nacke & Lindley, 2008b). Nevertheless, the effect of interaction semantics on player emotion could likely provide a good basis for a study that supports the concept of effectance. Similarly, identification with a player character could lead to strong feelings for that character, something which could experimentally be assessed by measuring psychophysiological player valence, when a well-developed player character is destroyed, which hypothetically would result in a burst of strong emotions. Transportation and mental workload are probably better assessed with other psychophysiological methodology.

We have established that flow is not only an emotional state, but also largely relies on the absence of a certain kind of mental processing (Dietrich, 2004), so we also need to access cognitive functioning, which can be done for example with functional magnetic resonance imaging (fMRI), positron-emission tomography (PET) or electroencephalography (EEG). We will present the EEG measurement methodology, since it currently represents the best compromise between objective measurement, affordability and intrusiveness in experiments.

### 3.4.4 Measuring Cognition and Emotion with Electroencephalography (EEG)

Typically, an electroencephalogram represents the voltage recorded between two electrodes on the scalp. Electrodes are placed in standard positions distributed over the head, usually aligned using a headcap (see Figure 3.3). Each electrode is color- and letter-coded

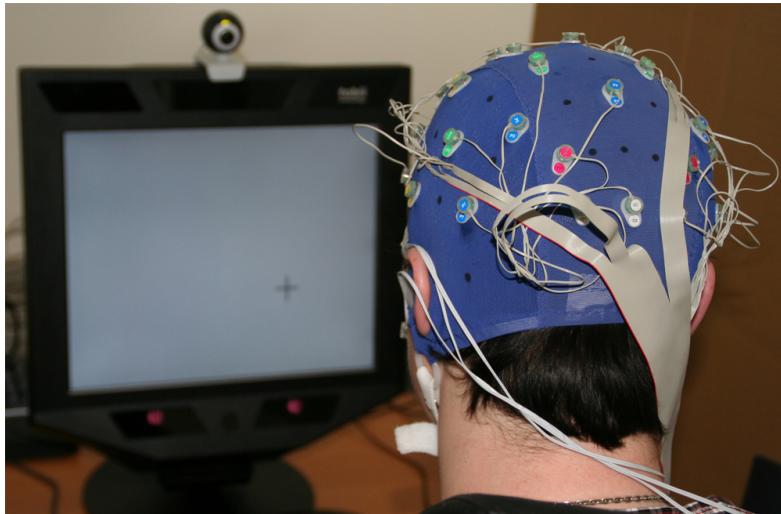


Figure 3.3: A typical cap used for EEG measurement. This particular example is a Biosemi large-size cap for 32 pin-type electrodes (i.e., they can be easily plugged into the cap).

to indicate its positioning (frontal (F), parietal (P), temporal (T), occipital (O), central (C)). Brain waves are usually described in terms of frequency bands, like alpha (e.g., 8–13 Hz), beta (14–30 Hz), theta (4–7 Hz), delta (< 4 Hz), and sometimes gamma (> 36 Hz). Alpha power increases have been associated with cortical inactivity and mental idleness (Pfurtscheller et al., 1998) as well as attentional demand (Ray & Cole, 1985). Alpha waves denote a state of neither particular arousal nor demanding mental activities like problem solving, thus it is also often correlated with meditative activities. Beta activity is most evident in the frontal cortex and relates to a state of attention and alertness, which is connected to cognitive processes, decision making, problem solving and information processing (Ray & Cole, 1985). Theta activity seems to be connected to daydreaming, creativity, intuition, memory recall, emotions and sensations (Aftanas & Golocheikine, 2001). Delta waves are most prominent during deep sleep and could be associated with unconscious processes, such as trance (Cacioppo et al., 2007a).

*Results from previous studies*

A previous study noted that it would be interesting to see a correlation between central low alpha wave power asymmetries and motor processes (Salminen & Ravaja, 2008), which might give new insight into the interplay of mental workload (Pellouchoud et al., 1999) and effectance(White, 1959). If we again adopt the hypothesis that flow suppresses certain cognitive and analytical capacities of the brain (Dietrich, 2004), it would yield new insights into flow research to correlate alpha activity with questionnaire results indicating a state of flow. At the current state of research, a thorough cross-correlation of additional subjective assessment tools to establish psychophysiological factors of flow in gaming is still necessary for EEG data as well.

### 3.5 CONCLUDING SUMMARY

This paper discussed the main elements of flow experience and categorized different flow models into gameplay experience categories. Finally, a number of psychophysiological measures were presented to can aid in our understanding of flow and other gameplay experience. The suggestions for measurement and categorization of flow and gameplay experiences can be seen as a foundation on which future empirical studies can be based. These studies are needed in game research to support or refute the claims made in this paper and develop a scientifically grounded understanding of gameplay experience.

For example, in game development, *flow* could act as a mediating layer between game designers and players governed by emotional and cognitive processes resulting in *effectance*, *identification*, *transportation* or *mental workload*. Flow in gaming is largely about control of a gaming situation, this effortless control allows for other perceptive factors (losing time and self-perception) to occur. It is also responsible for the sense of pleasure generated, since optimal control of a game is also an experience of effectance, which is a basis for game enjoyment (Klimmt, 2003) and results in the activity being rewarding in itself. Identification and transportation allow for vicarious experiences that are also like to drive game enjoyment. Finally, mental workload explains flow effects with the attentional demands of gaming situations and provides a link to applying schema theory to games (Lindley & Sennersten, 2008).

Finally, if we are able to find neurocognitive correlates of brain mechanisms driving flow, we will be able to distinguish more precisely, which elements of flow in gaming are related to emotion or cognition. For this purpose, several psychophysiological mea-

surement methodologies were introduced, which can be applied to studying games in an experimental laboratory setting. While much of this research applies to understanding flow in gaming, some of it might also prove useful for investigations of flow in other related media areas and it is hoped that the research methodologies presented in this chapter prove useful for these investigations.



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## LOG WHO'S PLAYING: PSYCHOPHYSIOLOGICAL GAME ANALYSIS MADE EASY THROUGH EVENT LOGGING

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Lennart Nacke, Craig A. Lindley, and Sophie Stellmach

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**Keywords:** *psychophysiology, digital games, interactive techniques, game-play analysis, usability*

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### ABSTRACT

*Modern psychophysiological game research faces the problem that for understanding the computer game experience, it needs to analyze game events with high temporal resolution and within the game context. This is the only way to achieve greater understanding of gameplay and the player experience with the use of psychophysiological instrumentation. This paper presents a solution to recording in-game events with the frequency and accuracy of psychophysiological recording systems, by sending out event byte codes through a parallel port to the psychophysiological signal acquisition hardware. Thus, psychophysiological data can immediately be correlated with in-game data. By employing this system for psychophysiological game experiments, researchers will be able to analyze gameplay in greater detail in future studies.*

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### 4.1 INTRODUCTION

The automatic logging of events to better understand user behavior within an interactive system has a long history in psychology and usability (Hilbert & Redmiles, 2000). Historical automated logging solutions (e.g., Skinner's *operant conditioning chamber*) kept track of animal interactions (e.g., pedals pressed by a rat) to study their behavior (Skinner, 1938). By analyzing the response rate logs, Skinner was able to create his theory of schedules of reinforcement. The idea of automated logging has survived until today. In recent human-

*The history of behavioral instrumentation and psychological observation.*

computer interaction (HCI) history, behavioral observation logs are a common analysis tool. They also provide a basis for a detailed analysis of usability (Pagulayan et al., 2003), fun (Wiberg, 2003) and game experience (Poels et al., 2007), which benefits greatly from employing classic usability metrics (e.g., time to complete a task, accuracy of input, user satisfaction) along with survey and observation measurements (Nielsen, 1993; Sauro & Kindlund, 2005; Bernhaupt et al., 2007).

Kim et al. (2008) give a great overview of classic HCI instruments and discuss their shortcomings. They note that the amount of low-level event data recorded (e.g., number of keystrokes) is growing enormously with the complexity of modern systems. A possible solution for reducing data is to cluster them with contextual information, so that not all low-level data need to be reported. The system presented by Kim et al. (2008) combines the advantages from different research approaches, such as the collection of user evaluation data, qualitative survey data and behavioral data. These event-related data sets can also be accompanied by video recordings to provide contextual information.

*Data aggregation systems and tools become more important with growing data complexity and hardware storage capacities*

The approach of combining different methodologies to provide a coherent view of the game experience is sound. However, we find that it could be greatly improved by adding one important facet of recent game experience research: human physiological responses (as an objective context for interpreting subjective survey data). The connection of system events with human behavioral responses is gaining importance as researchers want to analyze game events with high temporal resolution (Kivikangas, 2006; Ravaja et al., 2008; Salminen & Ravaja, 2008; Ravaja et al., 2005).

To overcome the limitations that self-report measures of emotional responses in games have, it is of great value to assess specific game events in more detail, since some game events may trigger different or contradictory emotional physiological responses (Ravaja et al., 2006, 2008). In comparison to studies investigating only tonic measures, our objective was to create a system that allows reporting of phasic psychophysiological responses at game events.

*Automated logging systems reduce the time needed for psychophysiological analysis*

Using such a system, it is then for example possible to report emotional valence and arousal elicited by a certain game event (at a time resolution limited only by the capacities of a game engine and the psychophysiological recording hardware). In addition to eliminating the time needed for scoring game events manually using video, another key advantage of an automated logging system is its accuracy. While manual scoring might introduce errors in

the log, automated scoring of game events is almost fail-safe. Integrating game events and physiological responses with eye tracker recordings and survey data can provide an almost comprehensive overview of game experience.

This work focuses on an integrated logging framework for psycho-physiological systems (like the Biosemi ActiveTwo acquisition hardware) because of the desire to correlate game events and psycho-physiological data. A comprehensive framework containing various possibilities for handling different psychophysiological measurements (e.g., Biosemi ActiveTwo and Tobii 1750 eye tracker) was created as part of an internship at the BTH Game and Media Arts Laboratory (Stellmach, 2007).

- In Section 4.2, we introduce the design concept behind the framework. As part of the design, we investigated the requirements underlying the framework.
- Next, we present the implementation of automated event logging in detail in Section 4.3. This includes a look at the transmission component and the event component. It also introduces the concept of a logging entity for graphical use within a level editor.
- We end with a discussion and an outlook using our software for psychophysiological game experiments in Section 4.4.

*Ideally automated psychophysiological and behavioral logging is combined in a software.*

## 4.2 A CONCEPTUAL DESIGN

Psychophysiological researchers are interested in questions about the relationship between mind and brain or the ability to control one's well-being with your thoughts (Cacioppo et al., 2007a,b). It is the curiosity about how the relation of pure feelings and thinking manifests to bodily responses that drives the research field. Andreassi (2000) defines the field as exploring the "relations between psychological manipulations and resulting physiological responses, measured in the living organism, to promote understanding of the relation between mental and bodily processes".

### 4.2.1 Requirements Analysis

To gather meaningful data for further analysis, psychophysiological researchers have to record precise markers during data acquisition to manually score the recordings for further analysis, which is a serious time investment. A logging system that operates at the run-time speed of a game engine and sends out game-related events with the same temporal resolution is greatly beneficial for

researchers that want to study player experience in detail. The recording of such events with the help of the same hardware that is used to record biofeedback would enable a researcher to perform an instant correlation and analysis of game experience.

*Events of different types  
can be witnessed in  
Human-Computer Interaction with games.*

In digital games one has the possibility of interacting within a virtual environment and directly influences the occurring events. For a common understanding of the types of events that occur within an experimental gaming context, we differentiate the following events:

- *In-game events* (e.g., player picks up a reward)
- *Real-world events* (e.g., shouting at the computer in anger, moving nervously on the chair)

The definition of in-game events in the source code has the advantage of logging them automatically to a file. For the examination of real-world events other methods have to be used (e.g., sensors measuring physiological responses, positional sensors, accelerometers). In our case, events need to be automatically written to a file and to the psychophysiological recording hardware via a serial cable. The semantic clustering of game events is something that deserves more thorough investigation for future studies. Nevertheless, we considered the following example events most meaningful within a first-person shooter environment (e.g., *Half-Life 2*):

- Player fires a gun
- Player gets hurt
- Player dies

The event must be reported to the parallel port at game runtime and simultaneously to a log file. Information in the log files needs to contain an event description and the related timestamp. The ability to log data in two different ways allows researchers without a psychophysiological recording device (that collects trigger data from a parallel port) to receive automatic output from their experiments in form of log files. In addition, the log files come in handy for debugging the functionality of the port logging.

Each event, which is reported to the parallel port, has to be transmitted for a predefined minimal time amount. If the signal is not sent long enough, older psychophysiological hardware with a lower frequency resolution might not be able to correctly register the event. Therefore, we agreed on a minimum transmission time of 200 milliseconds.

### 4.3 AUTOMATED GAME EVENT LOGGING

When planning the design of experimental game stimuli, we used the Source SDK that ships with the game *Half-Life 2* (Valve Corporation, 2004a,b). Game development tools such as the Hammer editor and access to the source code made our preference for this solution. The fact that the Source SDK was used successfully in research contexts before (Arango et al., 2007; McQuiggan et al., 2006), including the development of serious games (Mac Namee et al., 2006; Swartout & Lent, 2003) also influenced our decision. Level designers should be able to easily integrate logging inside existing levels, so the logging system was designed as two modular components for *Half-Life 2*:

- Transmission Component
- Event Component

The transmission component is responsible for receiving signals and to communicate these to the parallel port and the log file. This is the base component on which the second module depends, because the event component will catch events anywhere in the code and report them to the transmission component.

#### 4.3.1 *Transmission Component*

This module is a static C++ class, which has to be accessible from all other files in the project to enable the possibility for firing events from any given class. For the implementation of the port logging, functionality of the InpOut32 library for communicating with the parallel port was used (Logix4U, 2007). The basic structure for this communication shall be presented, describing the main steps as executed in the source code:

1. Load library file
2. Determine function's address
3. Send event code to port
4. Free library memory

These steps are the basis for communicating with the parallel port and have been integrated within the transmission component to enable the writing of event codes to the parallel port. The process of logging to a regular text file is using an output stream. Text, represented as the datatype `string` or as an array of characters, is transmitted to the method `logMsg`.

*The Valve Corporation provides a set of useful modding tools with their games.*

*A system should be integrated in the game code to run fully automated together with the game engine.*

### 4.3.2 Event Component

The event component is responsible for managing predefined events and reports them to the transmission component. However, different kinds of events exist, which have to be handled in their certain ways. First, we have in-game events that need to be distinguished before they are reported. Some events are applicable in a general manner, whereas others are just convenient for particular scenarios. Therefore, we should differentiate between common level-independent events (e.g., player is damaged or enemy is killed) and unique level-dependent events (e.g., player enters a certain area or encounters a certain NPC<sup>1</sup> type).

In the specific case of *Half-Life 2*, the damage of a whole NPC class can be referred to as a general event. In contrast, the action by a particular NPC from this class can sincerely lead to a unique event. For the design of the event component this means that the ability to dynamically assign additional unique events within the level editing tool (*Hammer Editor*) would be desirable. Thus, one central entity called `logging_entity` was created, which provides the possibility to choose from a list of common events, but also to refer to this entity by other instances for defining unique events.

Figure 4.1 illustrates the general structure of the logging entity. It derives from the `CBaseEntity` class, which is, as the name suggests, the base class for all entities contained in the Source Engine. As shown there, the members of this class can be broken down in member variables, input functions and output functions. Available

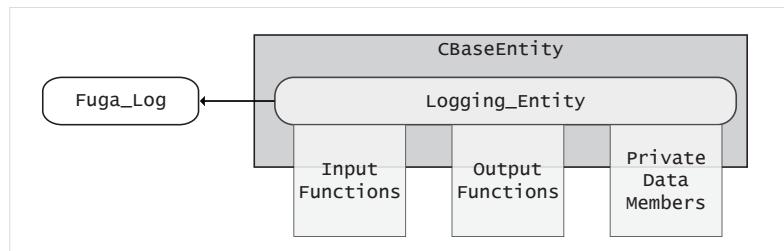


Figure 4.1: Structural overview of the class `logging_entity` and its functions

events, which can be fired by the logging entity, are indicated by its output functions. In addition, when an event is fired (not only by this but also by other entities) the mentioned input functions can be explicitly called. This means that also events by other entities can

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<sup>1</sup> Non-player character: NPCs in *Half-Life 2* can be either friendly or hostile.

trigger the `SetEventCode`<sup>2</sup> function as long as the logging entity has been given a name.

An example for calling the `SetEventCode` input function from another entity could be as follows. A level consists of different areas, which are sequentially playable. Every area has its distinct characteristics and it is desired to automatically log when the player moves on to a new area. A simple trigger can be created, which fires an `OnTrigger` output function (event), when the player passes through and sends a predefined event code to the logging class.

The work, however, is not done just by creating the class `logging_entity` as presented, because the output functions may be initialized, but they will not fire the desired output yet, because the exact spot in the source code, when the desired event takes place, still has to be determined. In a huge project as the Source SDK this becomes a complex and time-consuming task. But once the suitable point in the source code has been found, the approach for firing an event is always the same.

Due to the various events contained in the logging entity, working in several different source files is necessary. Thus, access to the logging entity has to be provided on a higher user level. All entities, which have been added to a certain level in the *Hammer Editor*, are listed in `gEntList`. If the logging entity is not found in this list, then nothing will happen and no error will occur. Otherwise, the event defined in the logging entity will be fired and, depending on the settings of the particular level, an input function will be called.

In order to find the entity in `gEntList`, the logging entity has to be given a specific debug name within the *Hammer Editor* (e.g., `FugaLog`, see Figure 4.2). When adding other events the same procedure has to be followed. However, playtesting revealed that events concerning the player (e.g., `Player gets hurt`) had to be distinguished from other events. Some events would, otherwise, not be logged. This had to do with the fact that closely related events would be sent simultaneously.

Designing the event component as an independent entity in the *Half-Life 2* level editor (*Hammer*) provides several helpful features for the user:

- **Existing event codes can easily be changed during level editing.** The user is able to adapt event codes within a well

*Benefits of the  
created logging  
system*

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<sup>2</sup> `SetEventCode` is an input function contained in `logging_entity` for saving a given event code to the member variable `currentEventCode`. With the output function `SendToPort`, this value will then be sent to the parallel port.

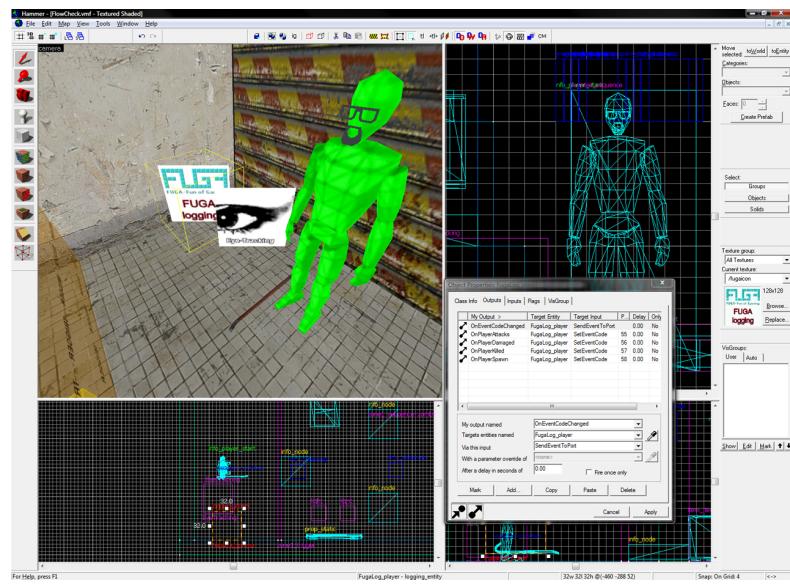


Figure 4.2: Screenshot showing the logging entities and manually defined output codes inside the Hammer editing environment of the Source SDK (Valve Corporation, 2004a)

arranged menu within the Hammer Editor. Otherwise one would have to go through thousands of lines of code in order to find the specific spot where a certain event code would be sent. Something which is impossible for ordinary users.

- **It is possible to define event codes for unique events.** Events closely related to a certain scenario can easily be added by defining them within the Hammer Editor. In case of the occurrence of this event, it can refer to `logging_entity` and send a predefined event code.
- **Logging entity exceeds simple logging functionality.** The logging entity can be used for more than just logging events. Output functions defined in this entity can trigger other entities. For example, if the player is damaged, a health kit should be created. This can be done by calling the function `Spawn health kit` at the event `Player is damaged`.

#### 4.4 CONCLUSION AND FUTURE WORK

We presented a system that writes game events to a text file and sends them simultaneously as a byte code to the port of psychophysiological recording hardware, thus making it possible to index phasic psychophysiological responses precisely at the occurrence of game events. We focused in this paper on describing the details

of the implementation of this tool.

The application of the tool within empirical studies investigating game experience remains to be presented in future studies, which we have already conducted. The created logging framework presented in this study has also been used within the EC FP6 NEST FUGA project for studying the fun of gaming. Although, this paper only presents the portion of the software concerned with logging of general events, it is planned to extend the tool to visualize and cross-correlate several streams of physiological data, eye tracker data, and usability data. Thus, it will enable even more detailed analysis of player behavior.



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Part III

EXPERIMENTS, MEASUREMENTS AND  
RESULTS



BOREDOM, IMMERSION, FLOW:  
PSYCHOPHYSIOLOGICAL ASSESSMENT OF  
AFFECTIVE LEVEL DESIGNS IN A  
FIRST-PERSON SHOOTER GAME

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Lennart Nacke and Craig A. Lindley

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**ABSTRACT**

*In this paper, we present the methodology and results from a pilot study on affective ludology, which investigates the impact of game design on player experience, measured with psychophysiological apparatus and questionnaires. The goals of this research were twofold: establish a methodology for investigating affective ludology and identify whether level design decisions can have empirically assessable impact on player experience. For this purpose we first developed the methodology for assessing gameplay experience with subjective and objective measures. Second, we report the impact of three different level design conditions (boredom, immersion and flow) on psychophysiological and subjective indicators of gameplay experience. Results from the subjective gameplay experience questionnaire support the validity of our level design conditions, while emotional and arousal patterns generated from electromyography (EMG) and electrodermal activity (EDA) indicate that challenge-based flow gameplay generates very positive, high arousal emotions. Patterns of electroencephalographic (EEG) spectral power show that the immersion level design elicits more activity in the theta band, which may indicate a relationship between sensory immersion and mental processing workload. Our research shows that facets of gameplay experience can be assessed with measures of affective ludology, such as psychophysiology, in which emotional and cognitive patterns emerge from different level designs.*

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### 5.1 INTRODUCTION

Digital games have grown to be among the favorite leisure activities of billions of people around the world. Today, digital gaming competes for a share of people's individual leisure time with other more traditional activities such as reading books, watching movies, listening to music, surfing the internet or doing sports. Games as a form of entertainment have matured from their early forms and focus on a young player demographic to now being played by many adults as well around the world. However, the scientific exploration of games has only been a discipline of its own since 2001, according to Aarseth (2001). Nevertheless, scientific studies of games have been around for much longer than the inception of the field called *ludology* (Frasca, 1999), which is broadly understood by *as the study of games*. While the term itself was popularized by the work of Frasca (1999), it has been traced back by Juul (2005) to an abstract from Csíkszentmihályi (1982).

Game studies or rather game science has only recently started to attract attention from researchers in the human-computer interaction (Barr et al., 2007; Fabricatore et al., 2002; Mandryk & Atkins, 2007), user research (Isbister & Schaffer, 2008; Pagulayan & Steury, 2004), and psychophysiology communities (Ravaja et al., 2006, 2005, 2008). With this comes an interesting shift in ludology, which has in the past been focused primarily on analyzing games (Tychsen et al., 2006; Juul, 2005) or establishing a design vocabulary (Church, 1999; Costikyan, 2002; Hunicke & Chapman, 2004; Koster, 2005), taxonomies (Lindley, 2003) and ontologies (Zagal et al., 2005) toward an *affective ludology*. Affective ludology must investigate cognition, emotion, and goal-oriented behavior of players from a scientific perspective by establishing more rigorous methodologies (e.g., psychological investigation or physiological response analysis) (Lindley & Sennersten, 2008; Lindley et al., 2007).

The improvement of scientific methodologies for studying players and games will not only help us understand the aesthetics of digital games better, but also the underlying processes involved in creating individual play experiences. Establishing methods that allow gathering insights into how players play games will allow for game designs to be evaluated and to be mapped to emotional and cognitive responses of players, thus largely improving and validating the formal design process of digital games. In design research, we see a call for moving beyond the limitations of subjective interpretations of emotion and design. This requires us to focus on multi-modal methods for evaluating the human experience triggered by design aesthetics. Currently, we are witnessing more

and more studies that apply neurological and affective methods to evaluating human experience (Jenkins et al., 2009; Chanel et al., 2009).

Many researchers have studied the experience of gameplay as a part of certain psychological mind-sets: For example, immersion (Brown & Cairns, 2004; Ermi & Mäyrä, 2005), frustration (Gilleade & Dix, 2004), presence (Huang & Alessi, 1999; Takatalo et al., 2006; Slater, 2002), and flow (Chen, 2006; Kivikangas, 2006; Polaine, 2005; Sherry, 2004; Sweetser & Wyeth, 2005). These terms currently lack well-accepted common definitions, but more importantly game designers have no testable features of constructs such as immersion, flow, or even boredom. For example, in a First-Person Shooter (FPS) game a player virtually turns into the game character, enacting interactions with the digital game world from an ego perspective, possibly enhancing gameplay experience like sensory immersion (Ermi & Mäyrä, 2005; Ivory & Kalyanaraman, 2007). The study of FPS games may simplify the investigation of gameplay experiences by removing character-identification issues (Isbister, 2005). The study presented in this paper will investigate the impact of level design conditions (boredom, immersion, flow) on psychophysiological and subjective responses from players in an FPS game modification (mod) of *Half-Life 2*. Thus, we pursued two goals with this research: (1) establish a methodology for investigating affective ludology and (2) identify whether level design conditions (LDC) can have empirically assessable impact on player experience. We will first discuss related literature relevant for designing levels focused on the experiential constructs immersion, flow, and boredom, then we proceed to present level design features derived from the related literature (the immersion and boredom levels were designed as part of an undergraduate work, see also Stellmach (2007)). Following this, we will give a quick overview of psychophysiological methodology. Next, we present the method and results of our exploratory pilot study investigating the impact of these level design conditions. Finally, we conclude with a discussion of the results and challenges for affective ludology.

*Gameplay from  
a psychological  
perspective*

## 5.2 DESIGNING LEVELS FOR IMMERSION, FLOW AND BOREDOM

### 5.2.1 Immersion

Jennett et al. (2008) give an extensive conceptual overview of immersion such that it can be differentiated from other concepts of engaging experiences like flow (Csíkszentmihályi, 1990), cognitive absorption (Agarwal & Karahanna, 2000) and presence (Lombard & Ditton, 1997; Zahorik & Jenison, 1998). They define immersion

as a gradual, time-based, progressive experience that includes the suppression of all surroundings (spatial, audiovisual, and temporal perception), together with attention and involvement within the sense of being in a virtual world. Thus, immersion is likely to share at least some properties with flow, such as a distorted perception of time and contextual surroundings, as well as being engaged in a task that provides challenge to a person. Another account describes three gradual phases of immersion: engagement, engrossment, and total immersion, where total immersion is a fleeting experience of total disconnection with the outside world (Brown & Cairns, 2004). This definition overlaps with flow and potentially presence and points to the problem of no clear boundaries between constructs of gameplay experience. Immersion could in our opinion also be an *umbrella* experience, which in its different stages could incorporate notions of presence and flow.

Ermí & Mäyrä (2005) provide another model of immersion, which subdivides immersive game experiences into sensory, challenge-based and imaginative immersion based on qualitative player surveys. Sensory immersion can be enhanced by amplifying a game's audiovisual components, for example using a larger screen or a surround-sound speaker system. Imaginative immersion describes absorption in the narrative of a game or identification with a character, which is understood to be synonymous with feelings of empathy and atmosphere. The dimension of challenge-based immersion conforms closely with the description of flow (Nakamura & Csíkszentmihályi, 2002). More precisely, challenge-based immersion describes the emergent gameplay experience of players balancing their abilities against challenges of the game. The construct we found most distinct in these accounts is sensory immersion and we will later discuss what a design for sensory immersion could feature.

#### Designing for sensory immersion

#### *Immersion Level Design*

The goal for the player in this level is reaching the target destination, which is a church. The path to the church is linear meaning that there are no multiple paths of getting to the church. To reach the target, the player has to make his way through several indoor areas (see Figure 5.1). As such the level features a good mix of indoor and outdoor areas. Estimated playing time for this level was 10 minutes (depending on the skills and FPS experience of the player). The explorative setting of the outside environment resembles the *Half-Life 2* level *Ravenholm*. The areas in this level were designed for an ebb and flow of enemies with various strengths, where in the early parts of the level, the player engages in combat with

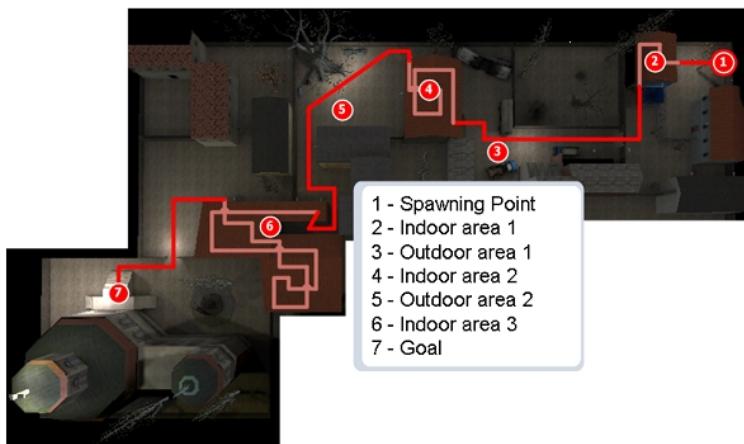


Figure 5.1: Overview of the Immersion LDC. The level features an explorative design with many indoor and outdoor areas alternating. See also Stellmach (2007).

weak enemies and in the later parts, the player has to face stronger enemies. The design idea behind this level was to evoke a feeling of sensory immersion in the player because of the tense horror settings, lush environments, balanced combat challenges and the scattered areas of reward and relief, where the player could power up before the next combat encounter. In summary, the level design criteria applied to this level are:

- A complex and exploratory environment (i.e., the player has to explore the area to find the way through the level)
- A number of different opponent types (i.e., aesthetic representation and strength of opponents should be varied and increase in number towards the end of the level)
- Fitting sensory, aesthetic effects (i.e., fires, lighting, scripted animations, sounds, etc.)
- Variety of models, textures and dynamic lights to establish a mood and scenery
- New weapons are usually found after a fight as a reward; so is Ammo and Health
- Narrative framing (ideally this would add to immersion, in our design it is however left out due to time limitations)

*Designing for combat challenges to induce flow*

### 5.2.2 Flow

The flow concept was first introduced by Csíkszentmihályi (1975) based on studies of intrinsically motivated behavior of artists, chess players, musicians and sports players. This group was found to be rewarded by executing actions per se, experiencing high enjoyment and fulfillment in the activity itself. Csíkszentmihályi (1975) describes flow as a peak experience, the "holistic sensation that people feel when they act with total involvement". Thus, complete mental absorption in an activity is fundamental to this concept, which ultimately makes flow an experience mainly elicit in situations with high cognitive loading accompanied by a feeling of pleasure. According to a more recent description from Nakamura & Csíkszentmihályi (2002) the *conditions* for entering an experiential state of flow include:

- A matching of challenges or action opportunities that match an individual's skill
- Clear and close goals with immediate feedback about progress

It is important to note that these descriptions of prerequisites for experiencing flow have to our knowledge not been empirically tested and are based on a qualitative method called experience sampling, which Csíkszentmihályi used in his conception of flow. Thus, the word flow conditions, while being often used, might not be accurate as none of these was ever empirically tested. Neither are these descriptions clear enough to design a falsifiable hypothesis around them. For example, one would need to be able to break down *challenges* into certain metrically accessible game elements. In combat games like FPS, these could consist of firepower, armor strength, health or other variables. However, these game elements interact at a very fine-grained level to create challenges individually for players, such as personal aiming skill. Accurate measurement would require us to individually assess player skill (and its development over time) as well as to develop a challenge metric that incorporates the gameplay elements in the game creating this challenge. This highlights a major caveat of the prerequisites for entering flow experience, they are in their current definition not empirically testable and they themselves are based on fuzzy conceptualizations like challenge and skill. The same goes for the definition of clear goals, which begs for a measurable definition of what *clear* actually means. Defining the balance of skills and challenges is often challenging for game designers, which led Chen (2006) to propose different *flow zones* for hardcore and novice players and an optimal intersection, within which the experience converges towards an optimal match of challenges and abilities.

Another caveat of approaching flow from a level design perspective is the different definitions that are around, since a study by Novak et al. (2000) shows, there are many different concepts used for studying flow. In their meta-review, they report 16 flow studies between 1977 and 1996, which all use different concepts and definitions of flow. The only commonly used questionnaire, the flow state scale (Jackson & Marsh, 1996), was designed for sports research. The best we can do for designing a game level for flow is to try to approximate challenge levels of opponents and their placement in a level.

### *Flow Level Design*

In this level, the player has to overcome a series of combat challenges within three rooms in order to reach a final door in the last room that ends the level. All rooms are connected with doors that only open after the player has killed all enemies in each room. The first room features slow melee type of enemies that pose not much of a challenge for experience FPS players (see Figure 5.2). The

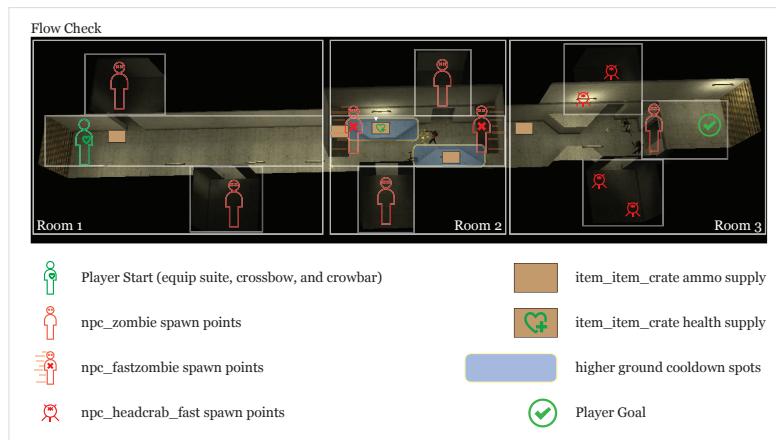


Figure 5.2: Overview of the Flow LDC. The level features an ebb and flow of enemies subdivided into three subsequent rooms, each marking an area that only opens once the enemies in one area have been defeated.

second room features both, fast and slow enemies, which constantly pressure the player into combat. The third and final room has many small and fast enemies that are difficult to attack and avoid. Thus, the only way to survive this last room is for the player to evade the attacks by climbing up a ladder to an exit door. For an extra challenge, the player has only a melee (*Half-Life 2* crowbar) and a slowly reloading sniper weapon (*Half-Life 2* crossbow) with limited ammunition. The ammunition is scattered across the rooms. Not

enough ammunition is available to shoot every enemy with an arrow. We wanted to explore how players reacted to the gradual challenges in this level. The design guidelines that we used for the implementation are:

- Specific weapon mechanics can be used as a design focus and challenges are then designed around that weapon. (In our case, the crossbow was used, which has a slow reload time that makes for an interesting combat game mechanic)
- Start with easy combat. (Weak enemies are put in the start area with a moderate spawn time, resulting in persistent but less challenging combat)
- Increase combat difficulty gradually. (Combat becomes more difficult throughout the level as the number of opponents, attack pace and strength increases, while the spawn time decreases)
- Allow for brief *cooldown* spots. Between the areas of combat, we used cooldown or rest spots, where players can find a sparse amount of health and ammo items

### 5.2.3 Boredom

Fisher (1993) defines boredom as an unpleasant, transient affective state in which the individual feels a lack of interest in and difficulty concentrating on the current activity. Relating to Csíkszentmihályi's flow concept (Csíkszentmihályi, 1975), boredom is a state when skills are much higher than the challenge provided by an activity. In his early flow model, it is opposite to what he defines as anxiety, where challenges are too difficult and cannot be matched with the current skill. Boredom in level design could thus be achieved by providing a linear spatial layout. In addition, Chanel et al. (2008) have argued that repetitive challenges at the same level of difficulty elicit boredom. Although they used the game Tetris (Alexey Pajitnov, 1984), we argue that similarly by facing the same type of enemies in combat in an FPS boredom will arise. In a nutshell, boredom in a game context can be seen as the counterpart to engagement (as supposedly elicited by the immersion and flow designs).

#### *Boredom Level Design*

##### *Designing for boredom*

This level was designed to evoke a feeling of boredom in reasonably skilled FPS players. The goal for the player was as in the immersion level described above to reach the target destination: A church (see Figure 5.3). The general playing time for this level is a bit shorter, amounting roughly to 6 minutes (again dependent on the skill

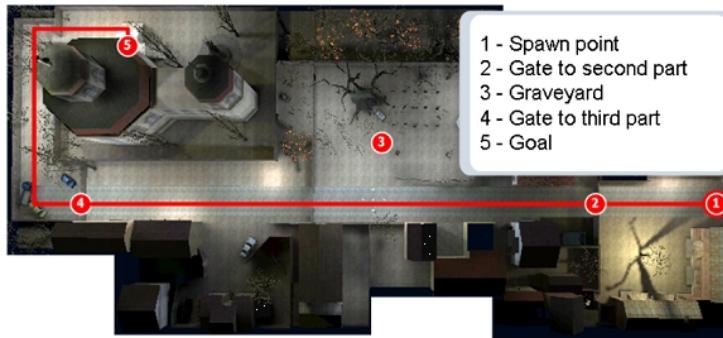


Figure 5.3: Overview of the Boredom LDC. The level features a strictly linear design with almost weak enemies and not less space to explore. See also Stellmach (2007).

of the player). The level features solely an outdoor area with a setting similar to the *Ravenholm* level of *Half-Life 2*, but in this level the enemies are mostly of the same type (i.e., slow melee attack zombies), causing less damage to the player with each attack. We expected the combat encounters to elicit boredom in the player, although these encounter have a slightly higher frequency at the end of the level. Seeing boredom as a relative experience at the lower end of a scale of engagement, we propose the following design criteria for a less engaging experience:

- Linear level (straight path)
- Weak enemies (only two different types)
- Repeating textures and models
- Damped sounds, less focus on aesthetics
- No real winning condition (after reaching the end of a level, the church, the player can continue to walk around)
- Limited choice of weapons
- High amount of health and ammo supplies throughout the level
- No surprises (no gameplay information should be concealed)

### 5.3 PRIMER OF PSYCHOPHYSIOLOGICAL MEASUREMENT

Emotions are a vital part of the game experience, motivating the cognitive decisions made during gameplay. In a psychophysiology, the circumplex emotional model suggested by Russell (1980) is

commonly used for assessing emotions. In this model, all emotions are based on dimensions of valence (i.e., pleasant to unpleasant) and arousal (i.e., more or less excitement) (Lang, 1995). In dimensional theory of emotion, emotional categories found in everyday language (e.g., happiness, joy, depression, anger) can be interpreted as correlating with different ratios of valence and arousal, hence being mappable within a two-dimensional space defined by orthogonal axes representing degrees of valence and arousal, respectively.

A method called facial electromyography (EMG) is commonly used in psychophysiological emotion research for indexing valence of physiological responses. It measures subtle electrical activation involved in facial muscle contractions at sites on the human face (Cacioppo et al., 2004). Empirical studies support the hypothesis that processing pleasant emotions is associated with increased activity in the zygomaticus major (ZM, cheek) muscle, whereas processing unpleasant emotions is associated with increased activity in the corrugator supercilii (CS, brow) muscle (Bradley et al., 2001; Bradley & Lang, 2000, 2007; Simons et al., 1999). Furthermore, orbicularis oculi (OO, eyelid) muscle has been shown to be associated with high arousal positive emotions (Bradley et al., 2001; Hawk et al., 1992), and it has been proposed to differentiate between genuine pleasure and faked smiles (Duchenne, 1990; Ekman et al., 1990) during co-activation with ZM muscle activity.

Measurement of electrodermal activity (EDA) or skin conductance level (SCL, sometimes called galvanic skin response) is one of the simplest and therefore most commonly used psychophysiological methods (Lykken & Venables, 1971). It is either measured from palmar (thenar/hypothenar eminences of the hand) or plantar sites (e.g., above abductor hallucis muscle and midway between the proximal phalanx of the big toe) (Boucsein, 1992). Sweat production in the eccrine sweat glands is what regulates EDA, which is entirely controlled by the sympathetic nervous system. Thus, increased sweat gland activity is related to electrical skin conductance. It is considered to have a strong association with arousal (Dawson et al., 2007; Lang et al., 1993).

Typically, an electroencephalogram (EEG) measures the voltage recorded between electrodes on the scalp. Electrodes are placed in standard positions distributed over the head, usually aligned with a cap (see Figure 5.4). Each electrode is color- and letter-coded to indicate its positioning (frontal (F), parietal (P), temporal (T), occipital (O), central (C)). We recorded brain activity using 32 BioSemi pin-type active electrodes and did not use a ground electrode, because the BioSemi Common Mode Sense (CMS) active electrode



Figure 5.4: Application of EEG, EMG and EDA electrodes to a participant. The EEG electrodes are placed on scalp locations with a cap.

and Driven Right Leg (DRL) passive electrode replace the ground electrodes used in conventional systems. Thus, EEG activity from the BioSemi system is generally average referenced (i.e., not using a specific reference electrode, but the average electrical activity as a reference). Brain waves are usually described in terms of frequency bands, such as Delta (1–4 Hz), Theta (4–8 Hz), Alpha (8–14 Hz), Beta (10–30 Hz), and sometimes Gamma (30–50 Hz).

Alpha power increases have been associated with cortical inactivity and mental idleness (Pfurtscheller et al., 1998) as well as attentional demand (Ray & Cole, 1985). Beta activity is most evident in the frontal cortex and is connected to cognitive processes, decision making, problem solving and information processing (Ray & Cole, 1985). Theta activity seems to be connected to daydreaming, creativity, intuition, memory recall, emotions and sensations (Aftanas & Golocheikine, 2001). Delta waves are most prominent during deep sleep and could be associated with unconscious processes, such as trance (Cacioppo et al., 2007a).

The often described many-to-one relation between psychological processing and physiological response (Cacioppo et al., 2007a) allows for psychophysiological measures to be linked to a num-

ber of psychological structures (e.g., attention, emotion, cognitive demand, information processing). Using a response profile for a set of physiological variables enables scientists to go into more detail with their analysis and allows a better correlation of response profile and psychological event. The central concern for affective ludologists is the link of patterns of measurement characteristics for a set of different measures taken when playing different games with subjective characterizations of experience such as emotion and feelings (e.g., immersion in gameplay). The pilot study reported here will investigate whether different affective level designs can be linked to patterns of emotions or cortical activity.

#### 5.4 METHOD

##### 5.4.1 *Participants*

Data were recorded from 25 male University students, aged between 19 and 38 ( $M = 23.48$ ,  $SD = 4.76$ ). As part of the experimental setup, demographic data were collected with special respect to the suggestions made by Appelman (2007). Of the participants 88% were right-handed. All the participants owned a personal computer (PC) and 96% rated this as their favorite gaming platform. All participants play games at least twice a week, while 60% play every day, 84% played between two and four hours per day. The preferred mode of play was console single player (44%) or PC multiplayer (36%), while eight percent rated PC single player as their preferred play mode. 36% rated First-Person Shooters (FPS) as their favorite game type. Of the participants 44% started to play digital games when they were younger than six years and 40% started between six and eight years old. This leaves only 16% that started to play between eight and twelve years. So, all the participants started playing digital games before twelve years.

##### 5.4.2 *Design*

We employed a simple one-way design using level design conditions (LDC: boredom, immersion, flow) as a three-level within-subject factor for dependent variables. Dependent variables were EMG, EDA, EEG spectral power estimates, and subjective GEQ responses.

##### 5.4.3 *Procedure*

We conducted all experiments on weekdays with the first time slot beginning at 10:00h and the last ending at 20:00h. General time

for one experimental session was 2 hours with setup and cleanup. All participants were invited to a laboratory. After a brief description of the experimental procedure, each participant filled out two forms. The first one was a compulsory *informed consent* form (with a request not to take part in the experiment when suffering from epileptic seizures or game addiction). The next one was an optional photographic release form, which most of the participants signed as well. The participants were led to a notebook computer, where they filled out the initial game demographic questionnaire. Participants were then seated in a comfortable office chair, which was adjusted according to their individual height. The electrodes were attached and participants were asked to relax. During this resting period of approximately 5 minutes, baseline recordings were taken. Then, the participants played the game levels described above. Each game session was set to 10 minutes, but in general participants could finish all game levels before this. After each level, participants filled out a paper version of the game experience questionnaire (GEQ) to rate their experience. After completion of the experiment, all electrodes were removed. The participants were debriefed and escorted out of the lab. None of the individuals received any compensation for their participation in the experiment.

#### 5.4.4 Materials and Measures

##### Facial EMG

We recorded the activity from left *orbicularis oculi* (OO), *corrugator supercilii* (CS), and *zygomaticus major* (ZM) muscle regions (Fridlund & Cacioppo, 1986), using BioSemi flat-type active electrodes (11mm width, 17mm length, 4.5mm height) electrodes with sintered Ag-AgCl (silver/silver chloride) electrode pellets having a contact area 4 mm in diameter. The electrodes were filled with low impedance highly conductive Signa electrode gel. The raw EMG signal was recorded with the ActiveTwo AD-box at a sampling rate of 2 kHz and using ActiView acquisition software. EMG was filtered in BESA software using a low cutoff filter (30 Hz, Type: forward, Slope: 6 dB/oct) and a high cutoff filter (400 Hz, Type: zero phase, Slope: 48dB/oct). If data remained noisy, they were excluded from further analysis. Tonic EMG data were rectified and exported together with tonic EDA data at a sampling interval of 0.49 ms to SPSS software for further statistical analysis. EMG data was transformed with a natural logarithm to reduce skew.

*Psychophysiological measurement included EMG, EDA, and EEG*

##### EDA

Electrodermal activity was measured using two passive Ag-AgCl (silver/silver chloride) Nihon Kohden electrodes (1 $\mu$ A, 512 Hz).

The electrode pellets were filled with TD-246 skin conductance electrode paste and attached to the thenar and hypothenar eminences of a participant's left hand (Boucsein, 1992). EDA data was log-transformed for normalization.

### EEG

We recorded brain activity using 32 BioSemi scalp Ag/AgCl (silver/silver chloride), pin-type active electrodes and with Common Mode Sense (CMS) active electrode and Driven Right Leg (DRL) passive electrode as equivalent to ground, allowing for interference-free, extremely low-noise recordings, with the ActiveTwo AD-box at a sampling rate of 2 kHz and using ActiView acquisition software. The 32 electrodes were placed on the scalp via a cap adhering to the extended 10-20 system (Chatrian et al., 1988; Jasper, 1958), known as the 10% system. The raw data was processed in brain-electrical source analysis software BESA. A low cutoff filter of 1 Hz (type: forward, slope: 6dB/oct), a high cutoff filter of 40 Hz (type: zero phase, slope: 48 dB/oct), and a notch filter of 50 Hz (with 2 Hz width) were applied. Since the BioSemi system uses no ground electrodes, the signal was average referenced in BESA and first filtered using a semi-automatic artifact correction with  $\pm 85 \mu\text{V}$  electrooculography (EOG) thresholds. Ten minute epochs were selected and visually inspected for artifacts contamination. Those containing artifacts were rejected for all channels. Average power estimates ( $\mu\text{V}^2$ ) were calculated using Fast-Fourier Transformation (FFT), which was conducted on artifact-free epochs using two-second blocks (4096 points per block) for averaging. The power estimates were calculated for the following frequency bands: Delta (1–4 Hz), Theta (4–8 Hz), Alpha (8–14 Hz), Beta (10–30 Hz), and Gamma (30–50 Hz). Spectral power estimates were then averaged over all electrodes for each frequency band and finally transformed using a natural logarithm ( $5 + \ln$ ) to normalize the data distribution and eliminate negative numbers.

### Game Experience Questionnaire

*In addition to psychophysiological measures, the GEQ was used*

Different components of game experience were measured using the game experience questionnaire (IJsselsteijn et al., 2008). It combines several game-related subjective measurement dimensions: immersion, tension, competence, flow, negative affect, positive affect and challenge. Each of these seven components consists of 5–6 question items (e.g., "I was deeply concentrated in the game" is a flow component item). Each question item consists of a statement on a five-point scale ranging from 0 (not agreeing with the statement) to 4 (completely agreeing with the statement). The questionnaire was

developed based on focus group research (Poels et al., 2007) and subsequent survey studies.

## 5.5 RESULTS

### 5.5.1 Results of EMG

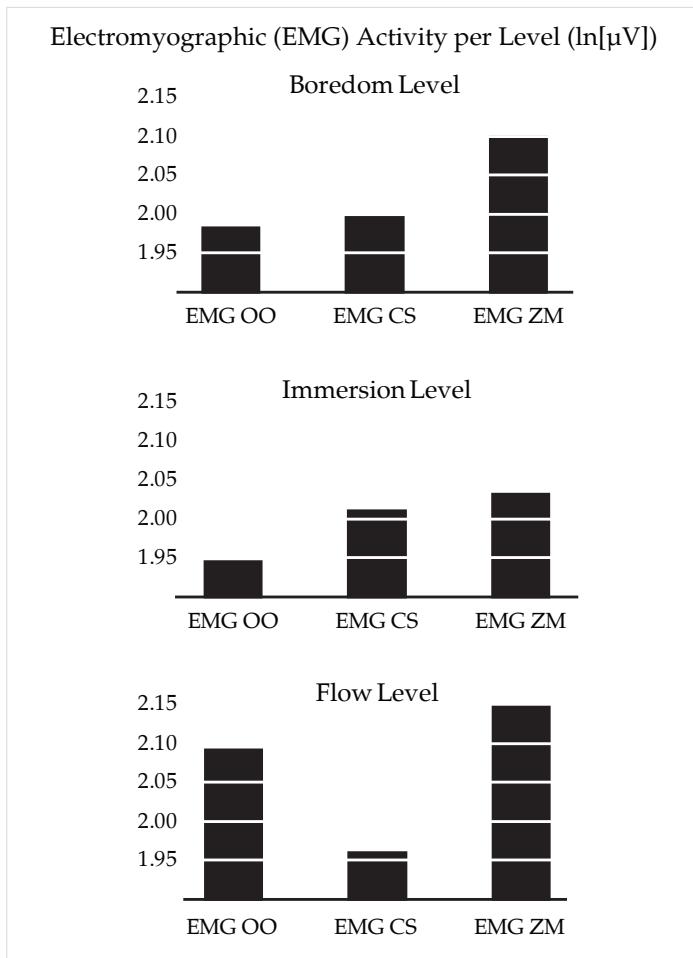


Figure 5.5: EMG activity for each level design condition (LDC) that was tested. EMG activity is displayed in  $\ln[\mu\text{V}]$ .

A one-way repeated-measures analysis of variance (ANOVA) was conducted using level design conditions (LDC: boredom, immersion, flow) as a three-level within-subject factor for dependent variables OO, CS and ZM EMG activity ( $\ln[\mu\text{V}]$ ). Multivariate tests showed a significant impact of LDC on EMG activity,  $F(6, 10) = 8.08, p < .01, \eta_p^2 = .83$ . However, CS EMG activity showed no significant difference in

the LDC, OO EMG activity was only marginally significant,  $F(2, 30) = 3.09, p = .06, \eta_p^2 = .17$ , but ZM EMG activity was significantly affected by the LDC,  $F(2, 30) = 6.65, p < .01, \eta_p^2 = .31$ . Polynomial contrasts showed a significant quadratic trend for OO EMG activity,  $F(1, 15) = 6.11, p < .05, \eta_p^2 = .29$ , and ZM EMG activity,  $F(1, 15) = 11.12, p < .01, \eta_p^2 = .43$ . A follow-up test with repeated contrasts revealed a significant difference in OO EMG activity between boredom LDC and flow LDC,  $F(1, 15) = 6.05, p < .05, \eta_p^2 = .29$ , as well as significant differences in ZM EMG activity between boredom LDC and flow LDC,  $F(1, 15) = 8.90, p < .01, \eta_p^2 = .37$ , and flow LDC and immersion LDC,  $F(1, 15) = 9.27, p < .01, \eta_p^2 = .38$ . Figure 5.5 shows the EMG profiles for each LDC. Interestingly, ZM elicits most activity compared to the other muscles, but is lowest in the immersive LDC and highest in the flow LDC.

### 5.5.2 Results of EDA

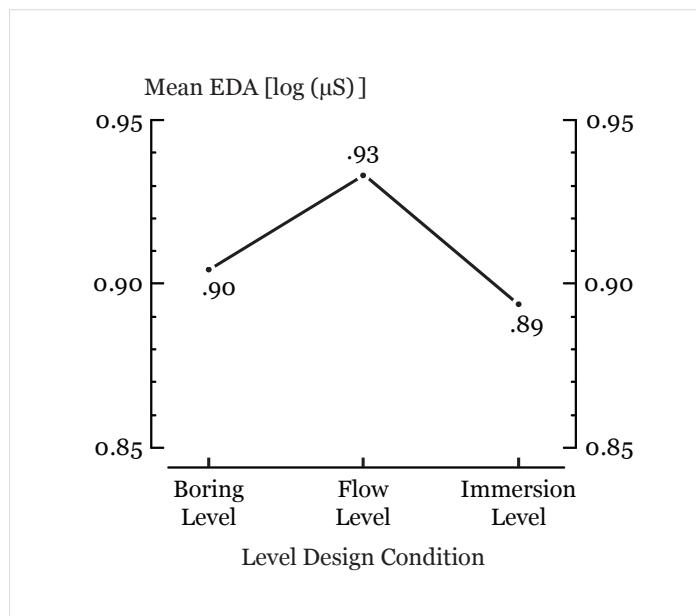


Figure 5.6: EDA for each level design condition (LDC) that was tested. EDA activity is displayed in log[ $\mu$ S].

A one-way repeated-measures ANOVA was conducted on the log-transformed electrodermal activity data (log[ $\mu$ S]). For these data, sphericity was violated ( $\chi^2(2) = 10.14, p < .05$ ) and corrected using Greenhouse-Geisser estimates ( $\epsilon = .66$ ). Following this, a significant impact of LDC on EDA could be found,  $F(1.32, 19.80) = 4.34, p < .05, \eta_p^2 = .22$ . Polynomial tests of within-subjects contrasts showed a

significant quadratic trend,  $F(1, 15) = 6.94, p < .05, \eta_p^2 = .32$ , which was followed up with repeated contrasts revealing a significant difference between boredom LDC and flow LDC,  $F(1, 15) = 12.09, p < .01, \eta_p^2 = .45$ . While EDA was almost equal for boredom LDC and immersion LDC (see Figure 5.6), it was significantly increased during the flow LDC. Thus, the flow LDC was physically more arousing to play than the other LDCs.

### 5.5.3 Results of EEG

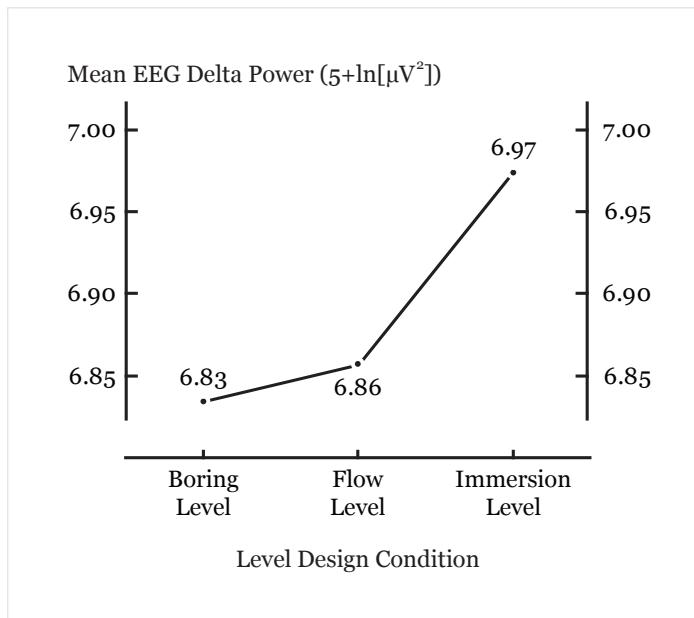


Figure 5.7: EEG delta power mean values ( $5 + \ln[\mu\text{V}^2]$ ) for each level design condition (LDC) that was tested.

A one-way repeated-measures ANOVA was conducted using LDC as within-subject factor for dependent variables delta [1–4 Hz], theta [4–8 Hz], alpha [8–14 Hz], beta [10–30 Hz], and Gamma [30–50 Hz] ( $5 + \ln[\mu\text{V}^2]$ ). Multivariate tests showed a significant impact of LDC on EEG activity,  $F(10, 9) = 6.29, p < .01, \eta_p^2 = .87$ . Univariate tests indicated this to be a significant difference for delta power estimates during the different LDCs,  $F(1.5, 26.97) = 4.10, p < .05, \eta_p^2 = .19$ . For delta power, sphericity was violated ( $\chi^2(2) = 6.93, p < .05$ ) and corrected using Greenhouse-Geisser estimates ( $\epsilon = .75$ ). A follow up test of repeated within-subject contrasts revealed that LDCs had a different impact on delta and theta power estimates. Delta power was significantly increased during the immersion LDC in comparison to the flow LDC,  $F(1, 18) = 4.96, p < .05, \eta_p^2 = .22$  (see

Figure 5.7). Theta power was also significantly increased during

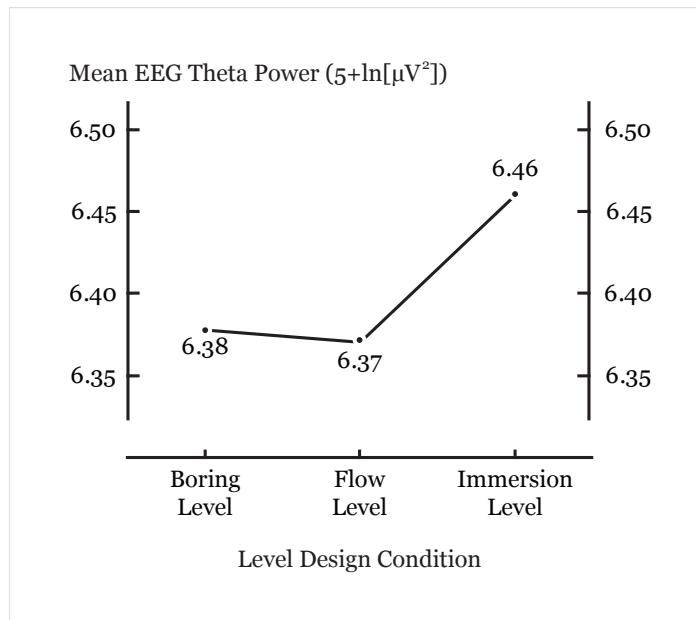


Figure 5.8: EEG theta power mean values ( $5 + \ln[\mu\text{V}^2]$ ) for each level design condition (LDC) that was tested.

the immersion LDC in comparison to the flow LDC,  $F(1, 18) = 5.12$ ,  $p < .05$ ,  $\eta_p^2 = .22$  (see Figure 5.8). This indicates that delta and theta power does not differ a lot between the boredom LDC and the flow LDC, while the immersion LDC elicited increased delta and theta power estimates. The descriptive results of the remaining EEG power estimates (*Alpha*, *Beta* and *Gamma*) are shown in Table 5.1.

Simple contrast analyses also indicated a significant difference between flow LDC and immersion LDC for delta and theta power averages (see Table 5.2). Interestingly, these contrasts also indicated a significant difference between boredom and immersion LDC for beta power averages. This means that beta power was significantly higher in the immersion level compared to the boredom level.

#### 5.5.4 Results of the GEQ

A one-way repeated-measures ANOVA was conducted using LDC as within-subject factor for dependent GEQ variables sensory immersion, tension, competence, flow, negative affect, positive affect. The GEQ dimensions challenge,  $F(2, 40) = 32.54$ ,  $p < .001$ ,  $\eta_p^2 = .62$ , and tension,  $F(2, 40) = 7.98$ ,  $p < .01$ ,  $\eta_p^2 = .29$ , were significantly different in all three LDCs. According to the expectation from the

EEG BAND	LDC	MEAN	STANDARD ERROR
Alpha	Boredom	5.21	0.10
	Flow	5.19	0.11
	Immersion	5.27	0.10
Beta	Boredom	6.58	0.09
	Flow	6.62	0.10
	Immersion	6.67	0.08
Gamma	Boredom	4.77	0.12
	Flow	4.91	0.12
	Immersion	4.87	0.11

Table 5.1: Average EEG Spectral Power ( $5 + \ln[\mu\text{V}^2]$ ) and standard errors for Alpha (8–14 Hz), Beta (10–30 Hz) and Gamma(30–50 Hz) frequencies in the different level design conditions (LDC).

level design, challenge was most pronounced in the flow LDC, less in the immersion LDC and least in the boredom LDC (see Figure 5.9). This lends support to our intended focus on challenge in the

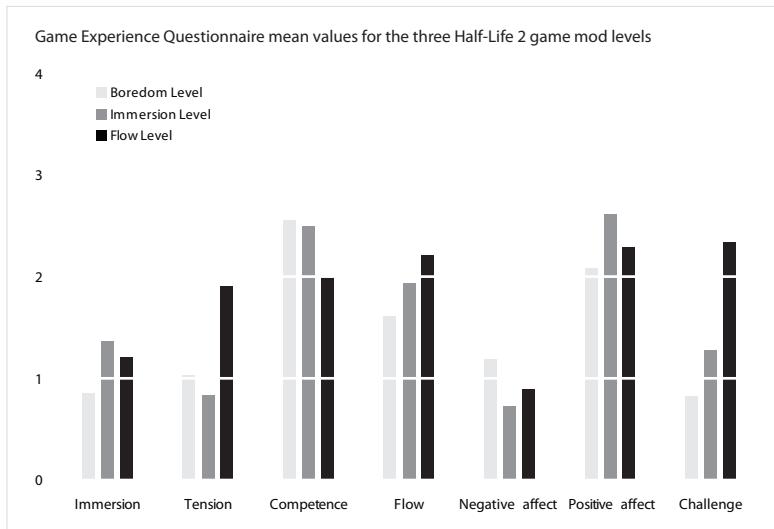


Figure 5.9: Mean scores for GEQ components in each level (for more detailed statistics refer to Nacke & Lindley (2008a,b))

flow level as being perceived truly challenging (but in a positive way as the *positive affect* ratings show). However, tension was also rated highest in the flow LDC compared to the other LDCs. It was rated lowest in the immersion LDC. A follow up test of repeated contrasts revealed a significant difference in sensory immersion

EEG BAND	LDC COMPARISON	F	p < x	$\eta_p^2$
Delta	Boredom vs. Immersion	14.40	0.00	0.44
	Flow vs. Immersion	4.96	0.04	0.22
Theta	Boredom vs. Immersion	5.58	0.03	0.24
	Flow vs. Immersion	5.12	0.04	0.22
Alpha	Boredom vs. Immersion	2.53	0.13	0.12
	Flow vs. Immersion	3.50	0.08	0.16
Beta	Boredom vs. Immersion	6.70	0.02	0.27
	Flow vs. Immersion	1.06	0.32	0.06
Gamma	Boredom vs. Immersion	2.11	0.16	0.10
	Flow vs. Immersion	0.28	0.61	0.02

Table 5.2: Simple within-subject contrast analysis for Delta (1–4 Hz), Theta (4–8 Hz), Alpha (8–14 Hz), Beta (10–30 Hz) and Gamma (30–50 Hz) spectral power estimates.

between boredom LDC and immersion LDC,  $F(1, 20) = 4.58, p < .05, \eta_p^2 = .19$ , supporting the assumption that our intended immersion level design was actually really rated higher in immersion than the boring level design. This validates the design intent for the immersion level. Interestingly the contrast analysis also pointed to a significant difference in tension between immersion LDC and flow LDC,  $F(1, 20) = 13.74, p < .01, \eta_p^2 = .41$ , but not boredom LDC and immersion LDC. For challenge, main ANOVA result was supported, indicating significant contrasts between boredom LDC and immersion LDC,  $F(1, 20) = 6.71, p < .05, \eta_p^2 = .25$ , and immersion LDC and flow LDC,  $F(1, 20) = 33.21, p < .001, \eta_p^2 = .62$ .

## 5.6 DISCUSSION AND FUTURE WORK

*Discussion of GEQ results*

We have design three different levels with focus on creating different affective experiences: boredom, immersion and flow. Results from the GEQ supported the assumption that our level design conditions were perceived as intended. The boredom LDC was dominated by subjective feelings of high competence and negative affect, the impression of challenge and immersion was low. Thus we could argue that the absence of enough challenge leaves the players in a negative emotional state, while more challenge (flow LDC) provides a much better experience in general, rating high on positive affect and flow. The immersion LDC was rated highest in immersion and positive affect and lowest on negative affect and tension. The flow LDC was dominated by feelings of flow, challenge and tension. This

may also be associated with an unusual aspect of the level design, compared to regular *Half-Life 2* gameplay, which concentrates much on fighting and managing resources (ammunition). The flow LDC reduced general *Half-Life 2* gameplay to the minimal aspect of mastering different forms of combat. The amount of ammunition was counted to be just enough if the player shot each enemy with one arrow. Of course, this did not happen often because of the frequency of attacks. If ammunition was out, the players had to fall back to the melee weapon, the crowbar, and jump around or seek a safe spot while trying to fight off the enemies. The attack frequency was raised throughout the level, which would naturally also raise the challenge level.

Results of facial EMG elucidate the different emotional responses in these LDCs. ZM and OO activity was most pronounced during the flow LDC, while CS activity was least pronounced there, indicating that this level although featuring a less aesthetic level design, elicits higher positive emotions than the immersion LDC. Interestingly, in this level ZM and CS activity are almost equal, indicating that our immersive LDC might have elicited a number of negative and positive feelings. Finally, the boredom LDC elicits a ZM response indicating general passive happiness, together with OO and CS activity, which both are equally low. Results of EDA indicate that the flow LDC was most arousing, thus letting us assume that levels with a high amount of combat challenges are likely perceived to be more exciting. When taking the EMG data into account, we can see that this is likely positive excitement. Interestingly, the immersion LDC scores as low as the boredom LDC, which might indicate that our sensory immersion focus on an exploratory environment was not very exciting for the players and the equally large size of combat and restorative areas might be one factor responsible for this lack of player arousal.

*Discussion of  
EMG and EDA  
results*

Results of EEG show that while the immersion LDC might now have been emotionally stimulating or arousing, here delta, theta and beta power are highly pronounced. This could mean that in parts of this level, the participants were drowsy (delta power), in parts they had to make more decisions than in the other levels (which had a linear design). For example, they would need to decide which area to explore and how to move through the indoor areas (beta power). This becomes especially visible in the significant contrast to the flow LDC, where other factors like combat were almost equal to the immersion level, but the spatial design was less aesthetic and linear. The high theta power lends support to the aesthetic traits of the immersion LDC, potentially being a sign of sensational impact

*Discussion of  
EEG results*

of the level design.

Since this was a pilot study into the area of affective ludology, the limitations are apparently that there is not established methodology for examining the impact of level design of players. We have seen studies before on the impact of games on EMG (Ravaja et al., 2005, 2008) and on EEG (Pellouchoud et al., 1999; Salminen et al., 2009; Schier, 2000; Stickel et al., 2007). However, the focus here was mostly to assess game events or tasks for their emotional impact (i.e., violence or aggression) on players. With affective ludology, we want to study the impact of game design on the player and thus be able to improve the design for a more engaging experience. Ideally, with more research in this area, we will be able to construct a number of different emotional patterns generated by different designs, which might allow us to understand not only the process of game design more thoroughly, but also help in creating more meaningful games that impact the lives of people for the better.

### 5.6.1 Conclusion

In this paper, we have presented a methodology for studying affective ludology, which addresses the impact of games on players' physiological and psychological responses in relation to game design. We have also demonstrated the significant impact of level design conditions on player responses and found psychophysiological indicators for boring, immersive and flow gameplay experiences. We hope to see more researchers study games from an affective ludology perspective in the future to be able to make game design a more scientific process with a detailed understanding of player-game interaction.

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## SOUND AND IMMERSION IN THE FIRST-PERSON SHOOTER: MIXED MEASUREMENT OF THE PLAYER'S SONIC EXPERIENCE

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Mark Grimshaw, Craig A. Lindley, and Lennart Nacke

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### ABSTRACT

*Player immersion is the holy grail of computer game designers particularly in environments such as those found in first-person shooters. However, little is understood about the processes of immersion and much is assumed. This is certainly the case with sound and its immersive potential. Some theoretical work explores this sonic relationship but little experimental data exist to either confirm or invalidate existing theories and assumptions. This paper summarizes and reports on the results of a preliminary psychophysiological experiment to measure human arousal and valence in the context of sound and immersion in first-person shooter computer games. It is conducted in the context of a larger set of psychophysiological investigations assessing the nature of the player experience and is the first in a series of systematic experiments investigating the player's relationship to sound in the genre. In addition to answering questionnaires, participants were required to play a bespoke Half-Life 2 level whilst being measured with electroencephalography (EEG), electrocardiography (EKG), electromyography (EMG), electrodermal activity (EDA) and eye tracking equipment. We hypothesize that subjective responses correlated with objective measurements provide a more accurate assessment of the player's physical arousal and emotional valence and that changes in these factors may be mapped to subjective states of immersion in first-person shooter computer games.*

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### 6.1 INTRODUCTION

An increasing amount of research in games studies and games technology deals with presence in virtual environments and, of more

interest for the purposes of our research, player immersion in digital game worlds. Player immersion may be said to be the holy grail of digital game design particularly in the types of game environment found in the First-Person Shooter (FPS) genre. This type of game is typically exemplified by the run 'n' gun sub-genre (games such as the *Doom* (Activision [id Software], 1993–2004), *Quake* (Activision [id Software], 1996–2005) and *Half-Life* (Electronic Arts [Valve Corporation], 1998–2004) series - even though the latter has an unusually strong focus on narrative) which is visually characterized by a hand or pair of hands holding a weapon on screen and conceptually characterized as *the hunter and the hunted*. The intention is that the player identifies with the game character whose hands, the player's virtual prostheses, are seen receding into the game environment (Grimshaw, 2008). This identification with the character, and the use of hands only, provides a first-person perspective with which it is proposed that, visually, player immersion in the game world derives from the player *becoming* the game character, in the sense of the player having the experience of acting *within* the game world. This sense of immersion is strengthened further through the player's actions having a non-trivial effect on the environment and game play (McMahan, 2003). For example, operating the game interface (the computer mouse or keyboard, for instance) may cause the image on the screen to change: the weapon may recoil and flash or an on-screen animation indicates the weapon reloading. The player perceives movement through the three-dimensional (3D) world of the game because visual artifacts rotate, magnify and diminish or appear and disappear on the screen.

#### *Immersion and game sound*

There are a variety of definitions of immersion in computer games. Kearney & Pivec (2007) claim that immersion provides the motivation or flow required for the player to be repeatedly engaged with the game while Ermi & Mäyrä (2005), paraphrasing Pine & Gilmore (1999), state that "immersion means becoming physically or virtually a part of the experience itself." They also distinguish between different forms of immersion: sensory, imaginative and challenge-based immersion. Murray (1995) suggests that immersion is a participatory activity and McMahan (2003) provides three conditions for immersion: "[T]he user's expectations of the game or environment must match the environment's conventions fairly closely [...] the user's actions must have a non-trivial impact on the environment [and] the conventions of the world must be consistent." For McMahan (2003), two factors influencing immersion are the level of social realism and the level of perceptual realism. Garcia claims that "[i]n the most immersing environments reminders of the structural level of the game are gone" (Garcia, 2006) while Carr (2006) provides two categories of immersion: perceptual (when

the participant's senses are monopolized by the experience) and psychological (an imaginative or mental absorption through which the participant becomes engrossed in the experience).

In the context of this paper, other work mentions or focuses upon the role of sound in facilitating player immersion in the game world. Laurel (1993) makes the case that the "[t]ight linkage between visual, kinaesthetic, and auditory modalities" is key to the sense of immersion. Jørgensen (2006) believes that players are immersed in an auditory world through the use of realistic audio samples, while Murphy & Pitt (2001) make similar claims for spatial sound. Autopoiesis and acoustic ecologies have been used to model player immersion through sound in FPS games (Grimshaw, 2008) and Grimshaw & Schott (2008) provide a range of conceptual tools with which to analyze the immersive functions of game sound. Some authors make a distinction between modes of immersion, particularly where immersion is enabled through the spatial qualities of the sound: Stockburger (2006) implies that the player is physically immersed in the game sound and this is amplified and explicitly stated by Grimshaw (2007). This physical sonic immersion has also been observed for film audiences and the concept transferred to the design of sound for FPS games and simulators (Shilling et al., 2002).

Most of the work cited above is theoretical and, where authors describe the immersive potential of sound in computer games, there is the assumption that sounds, more sounds, realistic sounds, spatial sounds all inexorably and incontrovertibly equate to greater player immersion. This may well be the case but the assumption lacks thorough evidence to support the various concepts of immersion outlined above. Attempts to provide evidence include Jørgensen (2006), who uses player surveys, and Shilling et al. (2002). The latter paper is of particular interest to this work because it not only explores the use of sound in an FPS game/simulation (America's Army [MOVES Institute, Naval Postgraduate School, Monterey, 2002]) but it also attempts to objectively measure the player's emotional arousal through the use of temperature, electrodermal response and heart-rate measurements. However, although the authors state that "emotional arousal has a positive impact on [the] sense of immersion in virtual environments" and that the precise conjunction of a sound and an action seen on the screen is "crucial for immersing the player", the paper is a description of their attempts to introduce, and amplify, emotion within the game environment through sound rather than an attempt to effect and measure immersion. The link between emotional arousal and immersion is assumed and so the relationship between sound and

*Experimental focus of this paper*

player immersion remains undefined in objective terms.

Emotions are a central part of the game experience, motivating the conscious cognitive judgments and decisions made during gameplay. Psychophysiological investigations suggest that at least some emotional states may be quantitatively characterized via physiological measurements. Specific types of measurement of different physiological responses (such as EDA, EMG, EKG and EEG, as described below) are not by themselves reliable indicators of well-characterized feelings (Cacioppo et al., 2007a; Bradley & Lang, 2007); a *de rigueur* cross-correlation of all measurements is crucial to identify the emotional meaning of different patterns in the responses. Moreover, the often described many-to-one relation between psychological processing and physiological response (Cacioppo et al., 2007b) allows for psychophysiological measures to be linked to a number of psychological structures (for example, attention, emotion, information processing). Using a response profile for a set of physiological variables enables researchers to go into more detail with their analysis and allows a better correlation of response profile and psychological event (Cacioppo et al., 2007a). The crucial issue here is the correlation of patterns of measurement characteristics for a set of different measures with subjective characterizations of experience such as emotion and feelings (for example, the feeling of immersion in gameplay).

Facial electromyography (EMG) is a direct measure of electrical activity involved in facial muscle contractions; EMG provides information on emotional expression via facial muscle activation (even though a facial expression may not be visually observable) and can be considered as a useful external measure for hedonic valence (that is, degree of pleasure/displeasure) (Bradley & Lang, 2007; Lang, 1995). Positive emotions are indexed by high activity at the zygomaticus major (cheek muscle) and orbicularis oculi (periocular muscle) regions. In contrast to this, negative emotions are associated with high activity at the corrugator supercilii (brow muscle) regions. This makes facial EMG suitable for mapping emotions to the valence dimension in the two-dimensional space described in Russell's dimensional theory of emotion (Russell, 1980; Lang, 1995). This dimension reflects the degree of pleasantness of an affective experience. The other dimension, the arousal dimension, depicts the activation level linked to an emotionally affective experience ranging from calmness to extreme excitement. In this kind of dimensional theory of emotion, emotional categories found in everyday language (for example, happiness, joy, depression, anger) are interpreted as correlating with different ratios of valence and arousal, hence being mappable within a space defined by orthogonal axes

representing degrees of valence and arousal, respectively. For example, depression may be represented by low valence and low arousal, while joy may be represented by high valence and high arousal.

Arousal is commonly measured using electrodermal activity (EDA), also known as skin conductance (Lykken & Venables, 1971; Boucsein, 1992). The conductance of the skin is directly related to the production of sweat in the *eccrine* sweat glands, which is entirely controlled by the human sympathetic nervous system. Increased sweat gland activity is thus directly related to electrical skin conductance. Hence, measuring both EDA and EMG provides sufficient data to provide an interpretation of the emotional state of a game player in real time, according to a phasic emotional model.

This paper describes and analyzes the results of a preliminary experiment that investigates the role of sound in enabling player immersion in the FPS game *Half-Life 2* (Valve Corporation, 2004a). The investigation is designed to provide both subjective responses (through the use of questionnaires) and objective measurements (through the use of electromyography (EMG), electrodermal activity (EDA), electroencephalography (EEG), electrocardiography (EKG) and eye tracking equipment). The overall aim of the experiment is to find external (that is, objective) measures that may be reliably correlated with subjective experiences assessed via questionnaires in order to provide more detailed descriptions of the emotional experience of game players during gameplay, both in the degree of emotions experienced and in the timescale of emotional changes and modulations. It is further hoped that this method may lead to real-time measures for states of immersion of players playing first-person shooter computer games. Finally, correlating discriminations within psychophysiological data with different categories of immersion can provide at least one method for validating those categorizations. The experiment is preliminary since the psychophysiological characterization of states of immersion is not yet well developed.

*Scope of this paper*

The study further aims to provide a psychophysiological-based answer to the assumption that sound plays a role in enabling the immersion of the player in the FPS game world. If the results of the experiment provide a positive answer, that sound does indeed play this role, it is envisaged that future experiments, using a similar methodology, will be designed to investigate more specific questions about the relationship between the player and sound in FPS games.

The experiment was conducted in May 2008 in the Game and Media Arts Laboratory at Blekinge Institute of Technology (BTH) in Sweden. The investigation of sound formed part of a larger psychophysiological investigation into the nature of the player experience in computer games. This paper is also limited to the analysis of EDA, EMG and questionnaire data. Further analysis taking into account the other data types is ongoing.

## 6.2 METHOD

Subjects played a *Half-Life 2* game mod especially designed for a short immersive playing time of maximum 10 minutes. The game mod was played four times with different sound modalities and physiological responses were measured together with questionnaires (assessing subjective responses) for each modality.

### 6.2.1 Design

The game sessions were played under four different conditions, corresponding to the permutations of sound modality as a single independent variable: playing with *diegetic* game sounds (normal sounds), playing with speakers completely turned off (no sounds, no music), playing with *diegetic* game sounds and an additional music loop (sounds and music), and playing with *diegetic* game sounds turned off and hearing only the music loop (only music). Participants played under each condition in a shifting order to eliminate repeated-measures effects (using a Latin Squares design). Physiological responses (as indicators of valence and arousal) were recorded for each session as well as questionnaire answers. Questionnaire item order was randomized for each participant using the open-source software LimeSurvey<sup>1</sup>.

### 6.2.2 Participants

Data were recorded from 36 students and employees, recruited from the three BTH University campuses and their age ranged between 18 and 41 ( $M = 24$ ,  $SD = 4.89$ ). 19.4% of all participants were female. When asked how frequently they play digital games, 50% answered that they play games every day, 22.2% play weekly, 22.2% play occasionally and only 5.6% play rarely or never. However, it should

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<sup>1</sup> LimeSurvey (v1.70). Main developer: Carsten Schmitz, available at <http://www.limesurvey.org>. Retrieved July 21, 2008.

be noted that 62.1% of all the males play on a daily basis and 20.7% play weekly. In contrast to that, most of the females enjoyed playing only on an occasional (57.1% of all females) or weekly (28.6%) basis.

Out of all participants, 47.2 % considered themselves casual gamers, 38.9% said that they belong to the hardcore gamer demographic and 13.9% could not identify themselves with any of those. Nevertheless, no female participant considered herself to be a hardcore gamer and 71.4% of all females said they were casual gamers. Male gamers were more evenly distributed among hardcore (48.3%) and casual (41.4%) gamers: the larger percentage of males considering themselves hardcore players.

91.7% of the participants were right-handed and 50% were wearing glasses or contact lenses. 94.4% believed they had full hearing capacity (5.6% stated explicitly that they lack full hearing capacity). 69.4% had a preference for playing with a music track on. 44.4% preferred playing with surround sound speakers, while 33.3% opted for playing with stereo headphones. 11.1% liked playing with stereo speakers and the final 11.1% preferred surround sound headphones. 33.3% played an instrument. 13.8% played the piano or keyboard and 8.3% played the guitar. 41.7% saw themselves as hobby musicians - some people worked with sound recording and programming but did not play instruments.

66.7% of participants were enrolled as University students. 16.7% already had a Bachelor's degree and 13.9% had a Master's degree. 61.1% of the participants had already played the digital game *Half-Life 2* before, 30.6% played it between 10 and 40 hours and 58.3% played it on a PC, leaving only one participant who played it on an *Xbox 360*.

To estimate preconceptions of sound immersion, participants were also asked how important they considered sounds, in general, for first-person shooters (FPS). The results were rated on a 5-point scale ranging from 1 (*not important*) to 5 (*very important*) (Likert, 1932). 55.6% claimed that sound was very important and 36.1% said it to be important. The term *immersive*, which was also part of the questionnaire items assessing sound immersion, was explained to participants beforehand as "the feeling of being encapsulated inside the game world and not feeling in front of a monitor anymore." This was so phrased for reasons of lay intelligibility and deemed to be a synthesis of previous definitions of game immersion noted above, particularly those of Ermi & Mäyrä (2005), Garcia (2006) and Carr (2006). This is suitable for investigating whether immersion in a very general sense may be distinguishable in psychophysiological

measurement features; if so, ongoing experiments may address the psychophysiological detection of finer distinctions within the broad category of immersion.

### 6.2.3 *Apparatus*

#### *Facial EMG*

We recorded the activity from left *orbicularis oculi*, *corrugator supercilii*, and *zygomaticus major* muscle regions, as recommended by Fridlund & Cacioppo (1986), using BioSemi flat-type active electrodes (11 mm width, 17 mm length, 4.5 mm height) electrodes with sintered Ag-AgCl (silver/silver chloride) electrode pellets having a contact area 4 mm in diameter. The electrodes were filled with low impedance highly conductive Signa electrode gel. The raw EMG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz and using ActiView acquisition software.

#### *Electrodermal activity (EDA)*

The impedance of the skin was measured using two passive Ag-AgCl (silver/silver chloride) Nihon Kohden electrodes (1  $\mu$ A, 512 Hz). The electrode pellets were filled with TD-246 skin conductance electrode paste (Med. Assoc. Inc.) and attached to the thenar and hypothenar eminences of the participant's left hand.

#### *Video recording*

A Sony DCR-SR72E video camera (handycam) PAL was put on a tripod and positioned approximately 50 cm behind and slightly over the right shoulder of the player for observation of player movement and in-game activity. In addition, the video recordings served as a validation tool when psychophysiological data were visually inspected for artifacts and recording errors.

#### *Game experience survey*

Different components of game experience were measured using the game experience questionnaire (GEQ) (IJsselsteijn et al., 2008). As shown in a previous study by Nacke & Lindley (2008a), the GEQ components can assess experiential constructs of immersion, tension, competence, flow, negative affect, positive affect and challenge with apparently good reliability.

### *Sound immersion*

Subjective player experience of sound immersion was measured using our own additional questionnaire items rated on a 5-point scale ranging from 1 (for example, not immersive) to 5 (for example, extremely immersive) for sessions where sound was audible (Likert, 1932). Specific sound questions included the following:

- How important are sounds in general for you in FPS games?
- *Diegetic Sounds:*  
How immersive were the following?
  - Background sounds
  - Sounds of opponents
  - Sounds that you produced yourself (player-produced sounds)
- How important was the sound for you in the level you just played?
- No Sound, No Music:  
How much did it bother you to play without sound?
- *Nondiegetic Music Only:*  
Did you miss the sound effects in this level? (Yes/No)



Figure 6.2: The eye-tracking screen, EMG sensors and electroencephalography array.

Other apparatus used, but not included in this analysis (the data will form the subject of a future paper), were a Biosemi 32-channel EEG system and a Tobii 1750 eye tracker (cf., Figure 6.2).

#### 6.2.4 Procedure

We conducted all experiments on weekdays in the time from 10:00 a.m. to 6:00 p.m. with each experimental session lasting approximately two hours. The experiments were advertised especially to graduate and undergraduate students. All participants were invited to the newly established Game and Media Arts Laboratory at Blekinge Institute of Technology, Sweden. After a brief description of the experimental procedure, each participant filled in two forms. The first one was a compulsory *informed-consent* form (with a request not to take part in the experiment when suffering from epileptic seizures or game addiction). The next one was an optional photographic release form. Each participant had to complete an initial demographic and psychographic assessment questionnaire prior to the experiment, which was immediately checked for completeness. Participants were then seated in a comfortable office chair, which was adjusted according to their individual height, electrodes were attached and the participant was asked to rest and focus on a black cross on a grey background on the monitor. During this resting period of 3–5 minutes, physiological baseline recordings were taken.

Next, participants were seated in front of a high-end gaming computer, which used a 5.1 surround sound system for playback (*Half-Life 2* sound quality settings on *high*), and were encouraged to get acquainted with the game controls for two minutes (using a non-stimulus game level) if they did not indicate a priori FPS experience. The participants played the same *Half-Life 2* game level four times for 10 minutes (or until completed) in a counter-balanced order to eliminate repeated-measures effects. As this was a preliminary experiment designed to produce broad subjective answers and objective measurements from which future, more refined experiments can be designed, the following broad sound on/off modalities were chosen:

- The level with all *diegetic* sounds and *nondiegetic* music audible
- The level with just *diegetic* sounds audible
- The level with just *nondiegetic* music audible
- The level with no sound or music audible

After each modality, participants were asked to report their subjective experiences using questionnaires. After completion of all modalities, participants were thanked for their participation and

paid a small participation fee before they were escorted out of the lab.

#### 6.2.5 Reduction and Analysis of Data

Recorded psychophysiological data were visually inspected using BESA (MEGIS Software GmbH, Germany) and EMG data were also filtered using a Low Cutoff Filter (30 Hz, Type: forward, Slope: 6 dB/oct) and a High Cutoff Filter (400 Hz, Type: zero phase, Slope: 48dB/oct). If data remained noisy, they were excluded from further analysis. EMG data were rectified and exported together with EDA data at a sampling interval of 0.49 ms to SPSS for further analysis.

Mean values for physiological responses were calculated for epochs of complete session times (varying between five and 10 minutes). Psychophysiological data were corrected for errors using log and ln transformations. After histogram inspection, data was assumed to be close to a normal distribution (without elimination of single outliers). Means were calculated for items of each of the seven GEQ questionnaire components (immersion, tension, competence, flow, negative affect, positive affect, and challenge).

To test statistical significance of the results, one-way repeated-measures ANOVAs were conducted in SPSS using sound modality as the within-subject factor for each of the three EMG measures (*orbicularis oculi*, *corrugator supercilii*, *zygomaticus major*), the electrodermal activity (EDA) and all GEQ components.

### 6.3 RESULTS

For each sound modality, the participants were asked a few assessment questions. This included 5-point scale ratings for the immersiveness of sounds (5 = most immersive) after they played the level with *diegetic* game sounds only. The background sounds were rated just below the median value ( $M = 2.97$ ,  $SD = 1.03$ ) and opponent-produced sounds were rated higher ( $M = 3.81$ ,  $SD = 1.06$ ) than player-produced sounds ( $M = 3.14$ ,  $SD = 1.44$ )<sup>2</sup>. The presence of sounds in this level was rated very important ( $M = 4.17$ ,  $SD = 1.03$ ). After playing without any sounds or music, most participants also claimed that it bothered them a lot ( $M = 4.06$ ,  $SD = 1.19$ ). For the *music-only* modality, it was noted as well that 75% of the participants missed the sound effects.

<sup>2</sup> Potentially supporting the theory of challenge-based immersion (Ermi & Mäyrä, 2005).

GEQ COMPONENT	SOUND & MUSIC	SOUND*
Immersion	1.53 (1.08)	1.51 (1.01)
Tension	0.97 (1.12)	1.41 (0.81)
Competence	2.18 (1.21)	2.24 (0.93)
Flow	2.10 (1.28)	2.37 (0.94)
Negative affect	0.86 (0.86)	1.06 (0.62)
Positive affect	2.06 (1.11)	2.16 (0.93)
Challenge	2.18 (1.08)	2.19 (0.69)
GEQ COMPONENT	MUSIC	NO SOUND / MUSIC
Immersion	1.13 (0.95)	0.85 (0.79)
Tension	1.94 (1.13)	1.57 (1.14)
Competence	1.88 (1.10)	1.57 (1.06)
Flow	1.72 (1.32)	1.50 (1.12)
Negative affect	1.63 (1.02)	1.71 (1.10)
Positive affect	1.61 (0.93)	1.49 (1.00)
Challenge	1.96 (0.85)	1.60 (0.81)

Table 6.2: Means (and standard deviations) of the GEQ components for the four test sound modalities ( $N = 36$ , N of items = 2(\*5), GEQ scale has values between 0 and 4 (median = 2)) (IJsselsteijn et al., 2008).

Table 6.2 shows a comparison of GEQ mean scores. A comparison of these values shows that regardless of GEQ components, people gave higher ratings (except for tension and negative affect) when sound was present. The presence of *diegetic* sound (whether combined with music or not) also seems to be an enabling factor of the subjective experience of challenge and flow - flow especially seems to be experienced more easily with *diegetic* sounds.

The complete absence of sound seems to negatively influence the subjective feeling of immersion to a significant degree as it is the lowest rated item in this modality. With missing auditory feedback, there is also a decrease in the feeling of competence among all participants. The combined presence of sound and music seems to also have a soothing effect on play as ratings for tension and negative affect are very low under this modality. It is also the modality that has the highest score for the immersion item. However, it should be noted that music also seems to be somewhat distracting from game flow since flow ratings are higher when music is omitted and only *diegetic* sounds are presented.

For GEQ components Immersion ( $\chi^2(5) = 3.49$ ), Competence ( $\chi^2(5) = 10.28$ ), Negative Affect ( $\chi^2(5) = 5.36$ ), and Flow ( $\chi^2(5) = 10.12$ ), Mauchly's test indicated that the assumption of *sphericity* had been met, but for the remaining items Tension ( $\chi^2(5) = 11.98, p < .05$ ), Positive Affect ( $\chi^2(5) = 11.56, p < .05$ ) and Challenge ( $\chi^2(5) = 23, p < .05$ ) it was violated. Therefore, degrees of freedom were corrected for the latter three using Greenhouse-Geisser estimates of sphericity ( $\epsilon = .80$ ,  $\epsilon = .84$ , and  $\epsilon = .71$ ).

Statistical significance was achieved for all components (Immersion:  $F(3, 105) = 8.20, p < .001$ ), Competence:  $F(3, 105) = 4.49, p < .01$ , Negative Affect:  $F(3, 105) = 9.75, p < .001$ , Flow:  $F(3, 105) = 9.42, p < .001$ , Tension:  $F(2.39, 83.73) = 7.85, p < .001$ , Positive Affect:  $F(2.52, 88.21) = 6.18, p < .01$ , and Challenge:  $F(2.14, 74.78) = 5.17, p < .01$ ). These results show that the subjective game experience measured with the GEQ was significantly affected by the different sound modalities.

Table 6.3 shows a comparison of the normalized physiological responses. Negatively valenced arousal would be indexed by increased EDA and corrugator supercilii activity (with decreased zygomaticus major and orbicularis oculi activity) (Ravaja et al., 2008). This is not the case for any of the accumulated measurements shown. The only notable decrease of orbicularis oculi and zygomaticus major activity is shown under the no sound condition. However, corrugator supercilii activity is also decreased and electrodermal activity is somewhat consistent across conditions.

Accordingly, Mauchly's test indicated that the assumption of *sphericity* had been violated for orbicularis oculi EMG means ( $\chi^2(5) = 25.16, p < .001$ ), corrugator supercilii EMG means ( $\chi^2(5) = 57.65, p < .001$ ), zygomaticus major EMG means ( $\chi^2(5) = 16.43, p = .006$ ) and EDA means ( $\chi^2(5) = 52.41, p < .001$ ). Hence, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity for EMG means ( $\epsilon = .63$ ,  $\epsilon = .45$ , and  $\epsilon = .76$ ) and EDA means ( $\epsilon = .47$ ).

Nevertheless, neither EMG responses (orbicularis oculi:  $F(1.90, 53.21) = 0.86, p > .40$ , corrugator supercilii:  $F(1.36, 38.02) = 0.66, p > .40$ , zygomaticus major:  $F(2.27, 63.58) = 0.61, p > .40$ ), nor EDA [ $F(1.40, 39.05) = 0.68, p > .40$ ] could achieve statistical significance for the repeated measures design. The results of the ANOVA show that tonic measurements of physiological response from an accumulated game session were not significantly affected by different sound modalities.

GEQ COMPONENT	SOUND & MUSIC	SOUND*
Orbicularis oculi (ln[ $\mu$ V])	1.85 (0.37)	1.85 (0.37)
Corrugator supercilii (ln[ $\mu$ V])	1.94 (0.25)	1.90 (0.27)
Zygomaticus major (ln[ $\mu$ V])	1.98 (0.40)	2.00 (0.38)
Electrodermal activity (log[ $\mu$ S])	0.72 (0.18)	0.73 (0.17)
GEQ COMPONENT	MUSIC	NO SOUND / MUSIC
Orbicularis oculi (ln[ $\mu$ V])	1.86 (0.42)	1.79 (0.31)
Corrugator supercilii (ln[ $\mu$ V])	1.95 (0.33)	1.89 (0.26)
Zygomaticus major (ln[ $\mu$ V])	2.00 (0.43)	1.94 (0.35)
Electrodermal activity (log[ $\mu$ S])	0.70 (0.18)	0.72 (0.17)

Table 6.3: Means (and standard deviations) for the corrected physiological measurements (EMG and EDA) under the different sound modalities.

#### 6.4 DISCUSSION AND FUTURE WORK

This paper has described and analyzed the results of a preliminary experiment to measure the effect of FPS sound and music on player valence and arousal and to detect any possible correlations between measurable valence and arousal features and self-reported subjective experience.

##### Summary of results

There are two important and related results. Firstly, the data gathered from the subjective questionnaires (see Table 6.2) shows a significant statistical difference between the four modalities over the GEQ components. This is particularly the case with Flow and Immersion, the results of which show higher scores when *diegetic* sound is present than when it is not. *Prima facie*, this would indicate that *diegetic* sound does indeed have an immersive effect in the case of FPS games. Music also appears to increase immersion, while reducing tension and negative affect, at the expense of a reduction in the experience of flow within gameplay.

Secondly, the psychophysiological data do not support the subjective results, but are instead both inconclusive and lacking statistical significance (see Table 6.3). If we maintain the assumption that physiological evidence, in these circumstances, can be used to confirm the subjective evidence, then there are several potential explanations for the lack of correlation between the two result sets. Further analysis and experimentation will be required to explain this disparity. Some initial possible explanations (assuming a valid experiment design and implementation) include:

1. The GEQ incorporates distortions derived from the retrospective *storytelling* context of the questionnaire.
2. The physiological data, gathered over 10 minutes of play, contains too much noise to produce a significant result. It must be noted that the data analyzed here was accumulated over one game session and even after inspection of histograms and logarithmic correction not all measurements were perfectly normally distributed. Even though a non-parametric statistical analysis or a range correction of physiological responses could be conducted, it is unlikely that this will show significant effects over the 10 minute timescale used. Connecting physiological response data to game events using more precise phasic measurements, as described in Nacke et al. (2008) could yield more insight into the emotional effects of sound. This level of detail can be achieved but it would need an additional method for recording subjective responses at the same event level precision to be correlated with.
3. The subjectively reported experience is a function of the modulation of emotions within a smaller time scale than that used in the analysis of psychophysiological data. This means that the emotional net effect may be the same, but the details of emotional dynamics produce different subjective experiences as reported by the GEQ. As analogy: a flat sea and a sea with big waves may have the same mean level, but one makes for much better surfing than the other. This might be detectable by derived measures from the current data set.
4. The subjectively reported results are not measurable using our equipment and methods. In particular, the source of the GEQ components reported in Table 6.2 may have a different psychological explanation than that captured by the arousal/valence model of emotion. This consideration raises the need for more thorough ongoing conceptual investigations of terms such as immersion, presence, flow, challenge and fun (as started by Lindley et al. (2007)). Based upon a

richer range of linguistic and conceptual distinctions, it may be possible to devise experiments having more discriminating power among the range of descriptive models thus created. In particular, these are complex concepts used in different ways by different authors, and it may not be the case that they have simple mappings to instantaneous emotions measured by psychophysiological techniques. Explanatory theories then need to move to higher levels in modeling the structuring of a series of measurable emotions, related to perceptions and player actions, to provide a more systemic account of the foundations of the quality of play experience, as suggested by Lindley & Sennерsten (2008).

These questions must be addressed by ongoing research. To our surprise, our research contradicts the results presented by Shilling et al. (2002), who indicated a strong correlation between sounds and physiologically elicited emotions. Unfortunately, Shilling et al. (2002) did not report direct values of their measures that would allow a direct comparison. It remains for more thorough future analysis to find greater scientific evidence for a relationship between sound and psychophysiological measures. Our future aim is to investigate this within our research.

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# BRAIN-TRAINING FOR SILVER GAMERS: EFFECTS OF AGE AND GAME FORM ON EFFECTIVENESS, EFFICIENCY, SELF-ASSESSMENT, AND GAMEPLAY EXPERIENCE

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Lennart E. Nacke, Anne Nacke, and Craig A. Lindley

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## ABSTRACT

*In recent years, an aging demographic majority in the Western world has come to the attention of the game industry. The recently released brain-training games target this population, and research investigating gameplay experience of the elderly using this game form is lacking. This study employs a  $2 \times 2$  mixed factorial design (age group: young and old  $\times$  game form: paper and Nintendo DS) to investigate effects of age and game form on usability, self-assessment, and gameplay experience in a supervised field study. Effectiveness was evaluated in task completion time, efficiency as error rate, together with self-assessment measures (arousal, pleasure, dominance) and game experience (challenge, flow, competence, tension, positive and negative affect). Results indicate players, regardless of age, are more effective and efficient using pen-and-paper than using a Nintendo DS console. However, the game is more arousing and induces a heightened sense of flow in digital form for gamers of all ages. Logic problem-solving challenges within digital games may be associated with positive feelings for the elderly but with negative feelings for the young. Thus, digital logic-training games may provide positive gameplay experience for an aging Western civilization.*

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## 7.1 INTRODUCTION

Are new ubiquitous technologies and media forms, like digital games on portable consoles, a blessing or a curse for an aging Western civilization? Recently, educational games (for example *brain-*

*How do elderly people experience educational brain/training games?*

*Do game form and age both have an effect on gameplay experience?*

*Related literature points to beneficial effects of gaming for elderly people.*

*Game form studies are inconclusive or non-existent for an elderly demographic.*

*training games) are inflating the portable console market. They are branded as successful drivers of mental health for the elderly, and researchers have argued for them to increase math skills of schoolchildren (Miller & Robertson, 2009; Pulman, 2007). However, aside from the discussion of long-term mental benefits, it is imperative to first ask whether solving logic problems on paper or within digital games makes any experiential difference at all, especially for an elderly population. This study presents an initial investigation of this first pertinent question: Do game form and age have any influence on gameplay experience and related concepts, such as arousal (Ivory & Magee, 2009) and usability (Segall et al., 2005)?*

Since the Western world's population continues to age increasingly, an older demographic becomes more interesting as players of digital games. Whitcomb (1990) reviewed pre-1990 studies, investigating how games affect the elderly. The review shows that only a limited number of computer games are enjoyable for the elderly, but there is a positive effect of games for this age group on perceptual-motor skills (Schueren, 1986), reaction times (Clark et al., 1987; Dustman et al., 1992), enhancing cognitive skills and attitude to technology (Weisman, 1983), and stimulated interest in learning (Hollander & Plummer, 1986). These studies investigate effects over long-time exposure of digital games to elderly. However, no direct investigation or online measure of gameplay experience is prominent. More recent investigations of gaming for an elderly demographic have focused on detailed game and interface design considerations (IJsselsteijn et al., 2007), brain-fitness applications (Merzenich, 2007), and the association of subjective well-being and improvement in reaction time as part of long-term game playing (Goldstein et al., 1997), but effects of game form on gameplay experience have not been studied before for this age group.

Effects of media form on usability factors were studied before, comparing effectiveness, efficiency, and satisfaction for students solving a quiz task using a personal digital assistant (PDA) or paper-and-pencil (Segall et al., 2005). Efficiency was measured as time until completion, effectiveness by student quiz scores and a mental workload questionnaire, and satisfaction with a questionnaire. Students were faster (i.e., more efficient in solving the quiz with the PDA) but no form effects on effectiveness and satisfaction were found. Another study compared an electronic PDA-based barcode entry system to a pen-based input system for participants aged above 60 years (Boissy et al., 2006). The barcode system scored higher in usability and pleasantness — the pen entry worked faster. Finally, a study with undergraduate participants investigated effects of medium (movies vs. games) and form (portable and television-

based) on physiological arousal and flow (Ivory & Magee, 2009). Consistent for games and movies, results showed portable media consoles evoke lower levels of physiological arousal and flow experience than television-based consoles. The flow experience concept was first introduced by Csíkszentmihályi, consisting of clear goals, immediate feedback, balance of challenge and personal ability, loss of self-consciousness, blurred feeling of time, and feeling of enjoyment and control in an intrinsically rewarding activity (Nakamura & Csíkszentmihályi, 2002).

Most studies of medium or form effects are focusing on usability evaluations for input devices regarding college students (Haas, 1989). Thus, there is a need to investigate how different age groups experience games using different gaming forms. Is gameplay experience for young players different from elderly players in a digital game? How does this differ when the game is played on paper? Using a basic problem-solving game mechanic on paper and on a Nintendo DS console, we investigate whether differences in gameplay experience and usability factors relate to game form or age.

### *7.1.1 Effects of Game Form or Age on Usability Factors: Efficiency and Effectiveness*

Merzenich (2007) noted that a good user experience is related to good usability, especially for elderly people. This is in line with theoretical models suggesting usability to be a fundamental contributing factor of gameplay experience (Nacke, 2009). Usability is standardized by the International Organization for Standardization (ISO) consisting of three major aspects: effectiveness, efficiency and user satisfaction (ISO/IEC 9241-11, 1998). Sauro & Kindlund (2005) suggested to measure effectiveness in completion rates and errors, efficiency in time spent on task, and satisfaction with a questionnaire. Prior studies suggest that game form will positively influence efficiency (Segall et al., 2005). Since young people are likely to be more familiar with portable game devices, they are more likely to resolve a game task efficiently on a DS than older people. Vice versa, since older people have been socialized with pen-and-paper techniques, they should thus be more efficient using this game form. This is in line with the literature, since studies suggest the elderly are faster using pen-and-paper compared to a portable PDA-like device (Boissy et al., 2006; Segall et al., 2005). We extend this assumption to account for effectiveness in addition to efficiency and hence hypothesize that:

*Our hypotheses regarding usability factors of game form for different age groups*

**H<sub>1</sub>:** Game form and player age exercise an interaction effect on task efficiency, since younger individuals will finish the game task faster on a DS than on paper, whereas elderly individuals will finish the game task faster on paper than on the DS.

**H<sub>2</sub>:** Game form and player age exercise an interaction effect on task effectiveness, since younger individuals will finish the game task with fewer errors on a DS than on paper, whereas elderly individuals will finish the game task with fewer errors on paper than on the DS.

### 7.1.2 General Effects of Game Form and Player Age on Experience

For evaluating an enjoyable gameplay experience, simple user satisfaction measures will not suffice. Since games have a stronger focus on entertainment and a pleasurable experience, player satisfaction should be measured more distinctively than user satisfaction. A study with an elderly player group observed alterations in the factors arousal, pleasure and dominance for elders who played video games regularly for an 8-week period (Riddick et al., 1987). Here, gaming increased the arousal scores, whereas pleasure scores declined, which was likely associated with frustration in learning to play. Dominance scores were not affected and remained at high levels. Thus, the three examined emotional dimensions (pleasure, arousal, dominance) seem to be suitable for evaluating game experience. We have mentioned another study before for a younger age group, which found that decreased technological sophistication evokes lower levels of arousal and flow (Ivory & Magee, 2009). Thus, we argue that playing the game in the paper condition will likely evoke less arousal and flow than on a DS.

*Game form and arousal are likely related*

**H<sub>3</sub>:** Game form will have a main effect on arousal and flow, because—regardless of age—playing on paper will elicit less arousal and less flow than playing on the DS.

*Different game forms should provide different challenges: Does this correlate with flow?*

In addition, IJsselsteijn et al. (2008) theorized immersion, tension, competence, flow, negative affect, positive affect, and challenge as important elements of gameplay experience. The concept of flow (Nakamura & Csíkszentmihályi, 2002) is linked directly to challenge, since engaging in challenges fitting to an individual's capacity is a precursor for flow experience to occur (Nacke & Lindley, 2008b). Thus, we argue that if flow is likely to be higher on the DS, then challenge will be higher on the DS as well. Moreover, flow and challenge will likely be related and depicting a positive game experience (indicating a correlation with positive affect).

**H4:** Game form will have a main effect on positive game-related challenge, because challenge will be higher on the DS than on paper, and flow will correlate with challenge and positive affect.

## 7.2 METHOD

### 7.2.1 *Design*

We employed a  $2 \times 2$  mixed factorial design (using age group as between-participants and game form within-participants independent variables), which was carried out as a supervised field study, using a counter-balanced, randomized order of stimuli exposure and a limited number of psychological questionnaires in order to keep the workload for elderly participant group low. Our main interest was in analyzing a senior demographic aged 65+, which is currently not well served by most commercial games on the market (IJsselsteijn et al., 2007). To ascertain genuine effects of age, we also tested the stimuli with a younger group (between 18 and 25 years old).

### 7.2.2 *Participants*

We collaborated with a physiotherapist who had friendly contacts with old age, mostly non-institutionalized individuals, allowing us to recruit elderly participants. Twenty-one German individuals aged between 65 and 90 years were chosen for this group. All participants were screened for mental and physical well-being. Subsequently, the physiotherapist invited them to the study. In this elderly group, 33.3% were male and 66.7% were female, having a mean age of 74.52 years ( $SD = 8.93$ ). Only 9.5% of individuals were institutionalized, the rest lived by themselves in private apartments. 47.6% of all these individuals were married. 76.2% reported full hearing, while the remaining reported using a hearing aid. 23.8% stated that they had used a computer and 14.3% that they had played a digital computer game before. All individuals were familiar with physical board and card games and played several of them. Nineteen students aged between 18 and 25 years ( $M = 21.47$ ,  $SD = 2.47$ ) were chosen for the younger comparison group. All of them had previously used a computer before and played digital games as well as card and board games. The young group consisted of 52.6% male and 47.4% female individuals.

### 7.2.3 *Stimulus Materials*

We used the popular Nintendo DS game *Dr. Kawashima's Brain Training* (Nintendo, 2006) and one of its arithmetic challenges, the 20 equations calculation game, as a test stimulus. The game requires the player to calculate 20 different random equations using the mathematical operations of addition, subtraction and multiplication, in the shortest time possible. The time taken for solving these 20 equations is used to give reward points for playing the game and to generate a high score among players. In order to compare the repeated-measures effect of form, each participant played the game in two modalities: (1) on a piece of paper and (2) using a DS. Since this study was exploratory, an investigation of the simplest game mechanics possible was chosen in order to strengthen internal validity of the experiment and to pave the way for future studies with more complex game mechanics. From observations during the experiment, all participants in both age groups considered this *simple* playful task as an entertaining and challenging game.

### 7.2.4 *Measures*

Three groups of dependent variables were observed for each participant in the different age groups in each playing condition according to our hypotheses: usability variables consisting of error rate and time-to-completion, self-assessment variables of pleasure, arousal, and dominance, and finally subjective player experience variables, consisting of flow, competence, challenge, positive affect, negative affect, and tension.

- The experimenter measured time-to-completion in seconds with a standard digital stopwatch. Error rate was measured as the number of errors made on DS and on paper. The DS automatically reports error rates; for errors on paper, the experimenters checked the correctness and a math teacher double-checked the results. To check whether error rate was related to perceived input recognition on the DS, a 5-point-scale questionnaire control item from 1 (extremely disagree) to 5 (extremely agree) was included ("The device did not correctly recognize my handwriting") (Likert, 1932).
- Pleasure, arousal, and dominance were evaluated using the self-assessment mannequin (SAM) (Lang, 1980) on a modified 9-point scale, showing five mannequins with four separator items between them. For example, the SAM pleasure scale depicts five graphic figures ranging from a happy, smiling character (9) to an unhappy, frowning character (1).

- The game experience questionnaire (GEQ) combines several game-related experiential measures (IJsselsteijn et al., 2008). The questionnaire is based on focus group research and subsequent survey investigations among frequent players. The dimensions of flow and challenge were examined with five questionnaire items for each dimension and the dimensions of competence, tension, negative affect and positive affect with two questionnaire items for each dimension. The sensory and imaginative immersion dimension was dropped, because questions were not considered suitable for investigating the arithmetic game mechanic in this study. Each item consists of a statement on a five-point scale ranging from 0 (not agreeing with the statement) to 4 (completely agreeing with the statement). Two extra items checked whether auditory clues ("The auditory feedback was motivating for me") and/or visual ("The visual feedback was motivating for me") clues on the DS were motivators for a different game experience.

#### 7.2.5 *Procedure*

All experiments were conducted at home or in institutions, where individuals lived (in the German cities of Köln, Essen, and Bremerhaven). If a trial was conducted in an institution, permission was first obtained from the local authorities. To ensure highest ecological validity and create a comfortable atmosphere, all individuals were located in a comfortable position with proper lighting conditions to fulfill the experimental tasks. After participants were welcomed, they were informed about goals and procedure of this study. Then, an informed consent form was handed out (with general information and a warning to not take part in the experiments if suffering from gambling addiction or epileptic seizures), which was mandatory to sign to proceed with the study. The experimenter briefly interviewed them about their living situation and then presented them with the pre-study demographic questionnaire. In a randomized, counter-balanced order, individuals were informed about the tasks they had to complete. The experimenter measured the time for each task. After each of the tasks, individuals filled out the post-game evaluation questionnaires. Although, the paper game was an exact reproduction of the DS game, the experimental procedure was slightly different.

For the paper game task, the participants were allowed to calculate three non-stimulus equations first, to test their correct understanding of the procedure. The experimenter answered any questions at this point and presented a piece of paper with 20 mathematical equations. All equations except for the first one were

covered with another piece of paper. The participants were instructed to only calculate one equation at a time, in sequential order, and were supervised not to go back and correct a solution that they deemed to be wrong *a posteriori* (this procedure emulates the exact procedure from the *Dr. Kawashima's Brain Training DS* game). During the calculation game, no discussion or questions to the experimenter were allowed. After completion of the paper game task, the experimenter recorded time-to-completion and collected the calculation paper, which was put into a bag to be assessed later without the participant being present.

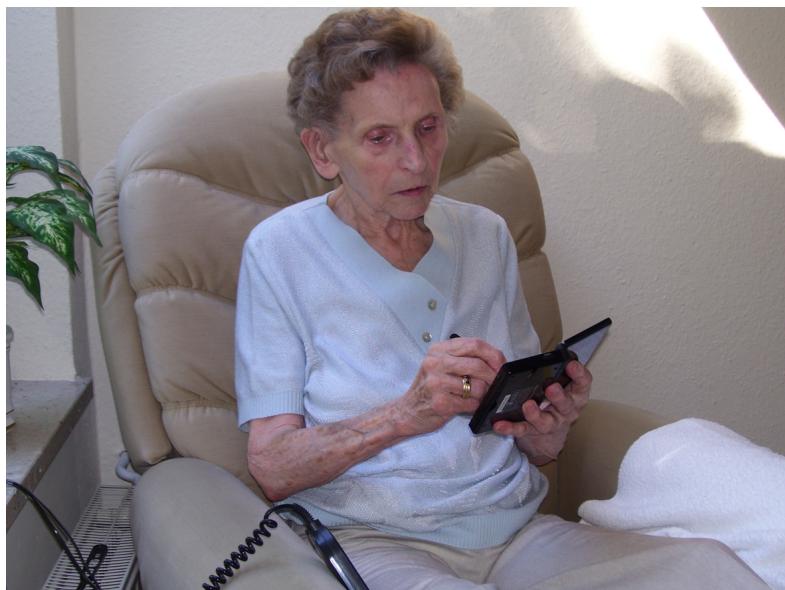


Figure 7.1: Shot from the Experiment in the Nintendo DS condition.

For the DS game task, using the digital game *Dr. Kawashima's Brain Training*, a short explanation about what the Nintendo DS device is and capabilities of its touch screen was given to the elderly participant group (all participants in the younger group knew how to use a Nintendo DS). Each elderly participant then underwent training in using the console device by writing their name in letters and several numbers on the touch screen for five minutes. The experimenter then briefly explained how to operate the DS game *Dr. Kawashima's Brain Training* and the participants were asked to calculate three non-stimulus equations using the touch screen (see Figure 7.1). Any remaining questions had to be asked at this point. After participants completed the DS game task, the experimenter recorded time-to-completion and error rate (calculated by the game) to be assessed later without the participant being present.

## 7.3 RESULTS

### 7.3.1 Usability Measures

The usability literature points to time-to-completion as a measure of efficiency and error rate as a measure of effectiveness (Sauro & Kindlund, 2005; Law et al., 2008). Our first question under investigation is whether a game task can be solved more efficiently on paper or on the DS, with prior research suggesting that young take less time on the DS and elderly take less time on paper (H<sub>1</sub>) and to see whether this hypothesis also holds for effectiveness (i.e., error rate (H<sub>2</sub>)). The time it took individuals to complete the game task was measured in seconds. Figure 7.2(a) reveals that solving the game task takes longer on the DS than on paper, regardless of age, but also that indeed elderly take longer in general to solve the task than young, regardless of game form. To test the significance of this finding, a two-way mixed *analysis of variance* (ANOVA) with age as a between-subjects factor and game form as a within-subjects factor was conducted for both dependent variables time-to-completion (H<sub>1</sub>) and error rate (H<sub>2</sub>). Multivariate analysis revealed a significant general between-subjects effect of age group,  $F(2, 37) = 22.17, p < .001, \eta_p^2 = .55$ , and a significant general within-subjects effect of form,  $F(2, 37) = 5.51, p < .05, \eta_p^2 = .20$ .

This would imply in general that solving on paper was faster than

*The game on paper was solved slightly faster and with less errors than on DS*

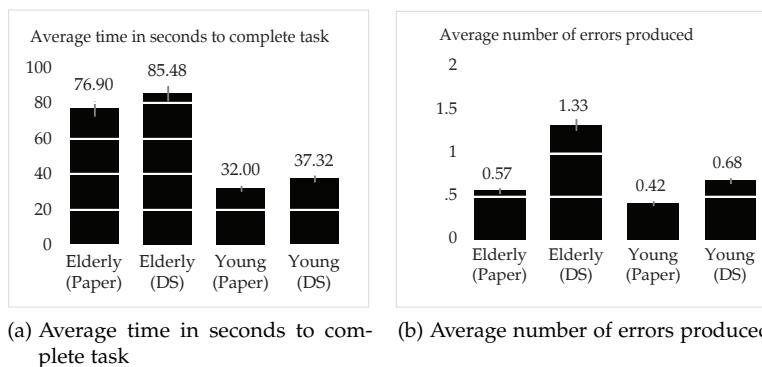


Figure 7.2: Results of usability measures: Average time to completion and errors produced as measures of efficiency and effectiveness

on DS and elderly take longer than young. In line with this assumption, univariate tests showed a significant main effect of form on time-to-completion,  $F(1, 38) = 4.52, p < .05, \eta_p^2 = .11$ . Solving on DS indeed takes longer than on paper, regardless of age. Between subjects, a significant main effect of age on time-to-completion,  $F(1, 38) = 38.93, p < .001, \eta_p^2 = .51$  was discovered, meaning that in

fact older take longer than younger, regardless of game form. No significant interaction effects between age and game form were found, however.

In summary, although we expected our younger age group to be efficient with modern technology, our hypothesis H1 that game form and player age exercise an interaction effect on task efficiency is not supported—solving the task takes longer on DS than on paper regardless of age. This means, however, that we can support our assumption that elderly take less time on paper for solving the game task and we note that elderly take longer time in general than young. This might be because elderly are more familiar with pen-and-paper than with modern gaming technology or because of the complex cognitive requirements of this technology. Given that another study using a PDA-based quiz found no effectiveness differences between pen-and-paper and PDA condition (Segall et al., 2005), we checked the correlation of error rate and time-to-completion,  $r = .51, p < .001$ , which suggested an effectiveness difference between pen-and-paper and DS.

Thus, we proceeded to check our second hypothesis that game form and player age exercise an interaction effect on task effectiveness (H2) and investigated whether we could find the same pattern for the results of error rate. Indeed, a similar pattern emerged for the average number of errors made, as shown in Figure 7.2(b). Individuals of both age groups produced less errors when playing the game on paper than on the DS. While the multivariate analysis reported above would suggest that significant differences could be found for both age and form, univariate tests only showed significant effects of form on error rate,  $F(1, 38) = 7.18, p < .05, \eta_p^2 = .16$ , but no effect of age on error rate. This is expectable in terms of our findings on efficiency, but contradicts the finding in the literature (Segall et al., 2005) and does not support our second hypothesis (H2).

The most reasonable explanation for this would be problems with the text recognition of the DS. In fact, the correlation of the input-recognition questionnaire control item with time-to-completion ( $r = .46, p < .01$ ), and error rate ( $r = .52, p < .01$ ), supports this explanation. An alternative explanation could be that younger individuals may be faster given their motor skills, but similarly effective in their cognitive ability to solve the game tasks. Finally, confounding effects of gender were checked in another mixed ANOVA with gender as additional between-subjects factor, but showed no significant main or interaction effects for time-to-completion or error rate.

### 7.3.2 Self-assessment (SAM)

In line with prior studies on form effects on physiological arousal (Ivory & Magee, 2009), we hoped to discover effects of age or form on subjective pleasure, arousal and dominance as measured with the SAM scale (Lang, 1980). Individuals in both age groups indicated an equally pleasurable experience for both game types (shown in Figure 7.3 all around a value of seven on the 9-point scale, indicating high pleasure). Significance was tested for pleasure, arousal and dominance with a two-way mixed ANOVA with age as a between-subjects factor and form as a within-subjects factor. While multivariate tests revealed a significant between-subjects effects for age,  $F(3, 36) = 6.69, p < .01, \eta_p^2 = .36$ , and significant within-subjects effects for form,  $F(3, 36) = 5.08, p < .01, \eta_p^2 = .30$ , the univariate tests showed no significant main or interaction effects on pleasure. Thus, it must be assumed neither age nor form affected the perceived pleasure when playing.

Hypothesis 3 also states that playing on DS will elicit more arousal

*Only differences in arousal were significant*

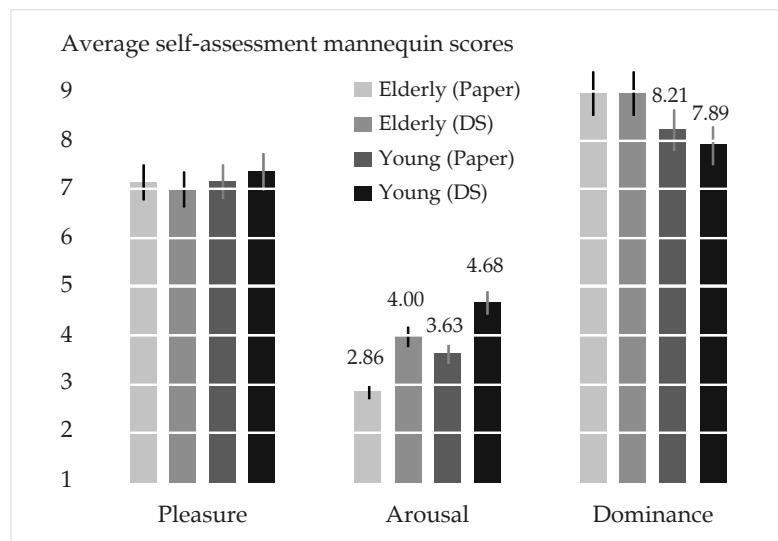


Figure 7.3: Results of Self-Assessment (SAM) scores for each of the experimental groups.

than on DS, Figure 7.3 supports this part of the hypothesis showing that arousal was in fact higher on DS than on paper. Nevertheless, SAM arousal ratings were generally below the mid-range (5) of the 9-point scale (indicating generally low arousal for the game task). This could be due to the nature of the arithmetic game, which might be less arousing than more complex game mechanics. The univariate results of the mixed ANOVA support this finding, which showed a main effect of form on arousal,  $F(1, 38) = 15.29, p <$

.001,  $\eta_p^2 = .29$ , but no main effect of age or significant interaction effects between age and arousal. Thus, the part of hypothesis H<sub>3</sub> that arousal is higher for playing on DS than on paper is supported regardless of age. The SAM dominance scale results show a difference between age groups in Figure 7.3. While elderly felt equally dominant (which is supported by long-term studies, see Riddick et al. (1987)) regardless of form, the younger age group felt less dominant, especially when playing with the DS. The univariate results of the mixed ANOVA accordingly showed a significant between-subjects effect of age on dominance,  $F(1, 38) = 18.71, p < .001, \eta_p^2 = .33$ .

This supports the literature (Riddick et al., 1987) and raises questions for future research, since the feeling of control over a game seems unaffected by game form and it would suggest that this experiential dimension could possibly be constant for elderly regardless of the independent variables employed in a study. The fact that the elderly made more errors and took longer for the game task than the young does not seem to have affected their subjective self-impression of dominance. Another mixed ANOVA ruled out effects of gender, showing no significant main effects or interactions.

*Reliability of GEQ items*

The final part of this investigation was the analysis of player age and game form effects on six gameplay experience dimensions of the GEQ: *flow, challenge, competence, tension, negative affect* and *positive affect*. A brief check of the reliability of each GEQ dimension revealed that flow (Cronbach's  $\alpha = .9$ ), positive affect (Cronbach's  $\alpha = .8$ ) and challenge (Cronbach's  $\alpha = .7$ ) were the only dimensions with an acceptable reliability for both paper and DS. For paper, tension was also barely acceptable (Cronbach's  $\alpha = .7$ ), while competence and negative affect were unreliable (Cronbach's  $\alpha < .5$ ). For DS, competence, negative affect and challenge were all reliable (Cronbach's  $\alpha \geq .8$ ), while tension was not (Cronbach's  $\alpha < .5$ ). It was argued before that the gameplay experience dimension of flow would be weaker on paper than on DS (H<sub>3</sub>). Figure 7.4 shows this was true for average scores in the flow dimension, but also in the challenge and competence dimensions. However, for the young, the opposite is true as scores in tension, negative affect and positive affect are lower in the DS condition. Both age groups have high scores (between 3 and maximum 4) for competence and positive affect, indicating that playing the game on paper and on DS kept them in a comfortable zone.

### 7.3.3 Gameplay Experience

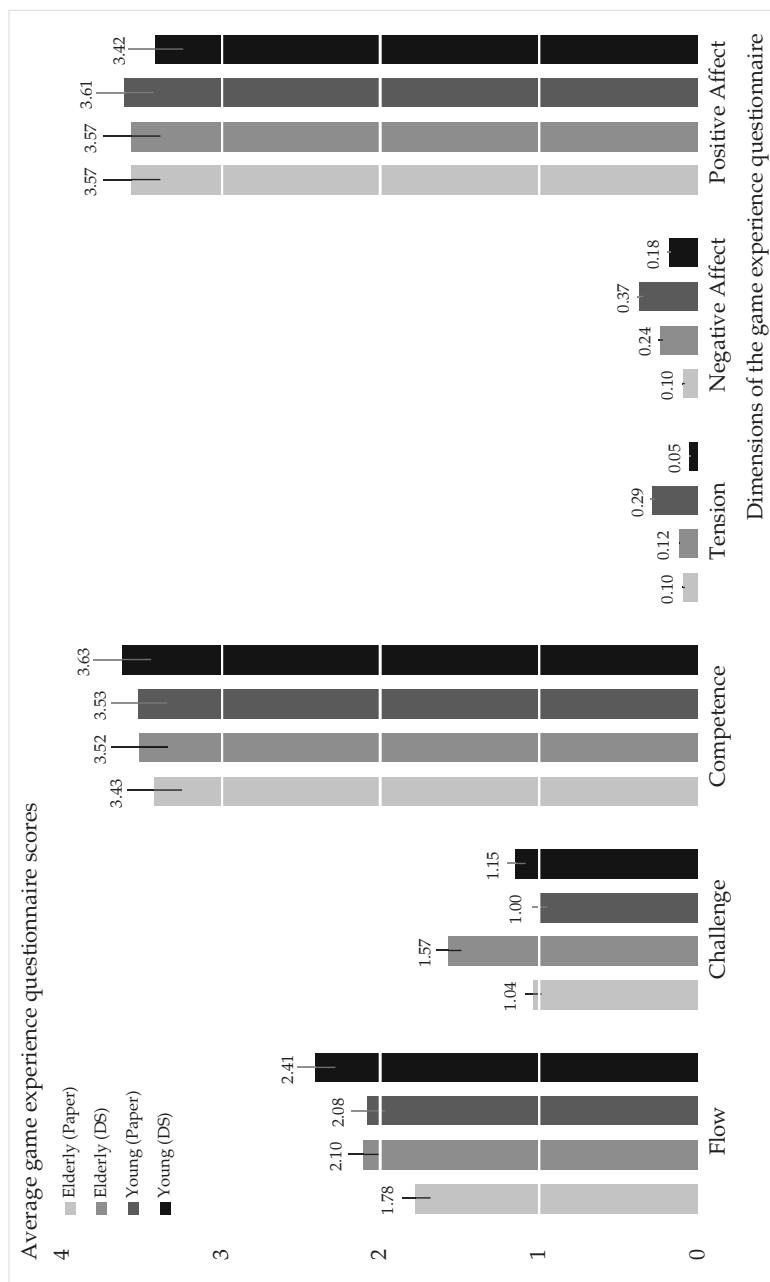


Figure 7.4: Results of game experience questionnaire (GEQ) for all experimental groups and GEQ dimensions.

*Flow and challenge were higher on DS*

More interesting is the increase from paper to DS in the dimensions flow and challenge, which indicates an effect of form on flow and possibly challenge in line with our hypotheses (H<sub>3</sub> and H<sub>4</sub>). This was checked for significance with a two-way mixed ANOVA with age as a between-subjects factor and form as a within-subjects factor for the GEQ dimensions. Multivariate results showed a significant within-subjects main effect of form,  $F(6, 33) = 3.02, p < .05, \eta_p^2 = .35$ , as well as a significant interaction effect of form and age,  $F(6, 33) = 2.78, p < .05, \eta_p^2 = .34$ . Thus, the latter would suggest that the type of form used would have a different effect depending on the age of the participants. However, the subsequent univariate analysis showed no significant interaction effects of age and form on any of the game experience dimensions. Nevertheless, significant main effects of form on flow,  $F(1, 38) = 7.24, p < .05, \eta_p^2 = .16$ , and on challenge,  $F(1, 38) = 9.24, p < .01, \eta_p^2 = .20$  were found. Thus, regardless of age, playing on DS induced more challenge and more flow. Together with the findings on the SAM arousal dimension, this now again supports our hypothesis H<sub>3</sub> that playing on DS elicits more flow and more arousal than on paper, and that this is supported regardless of age. Our last hypothesis that, while challenge scores will be higher on DS than on paper, flow will also correlate with challenge as well as positive affect (H<sub>4</sub>), is also supported. For all participants, regardless of age or game form, flow correlates with challenge,  $r = .57, p < .001$ , and flow correlates with positive affect,  $r = .41, p < .001$ , but also with pleasure,  $r = .49, p < .001$ , arousal,  $r = .34, p < .01$ , and competence,  $r = .48, p < .001$ . When correlations are split between age groups, flow for the elderly correlates with the same dimensions except arousal, but another correlation with tension,  $r = .32, p < .05$ , occurs. However, for the young, flow only correlates with challenge,  $r = .43, p < .01$ , and arousal,  $r = .42, p < .01$ . So part of our hypothesis H<sub>4</sub> that flow will correlate with positive affect has to be rejected for younger individuals.

These results suggest that different game elements may facilitate flow for different age groups. Younger individuals might find it easier to find flow through an exciting and challenging task, which does not necessarily have to be connected to a positive emotion, while elderly might prefer something that elicits positive emotion and is rather related to tense feelings than feelings of excitement. When checking for confounding effects of gender, another mixed ANOVA showed a significant within-subjects interaction effect of form  $\times$  gender  $\times$  group,  $F(6, 31) = 2.53, p < .05, \eta_p^2 = .33$ . The following univariate analyses showed significant interaction effects of form and gender on negative affect,  $F(1, 36) = 7.93, p < .01, \eta_p^2 = .18$ , and tension,  $F(1, 36) = 4.71, p < .05, \eta_p^2 = .12$ , which will not be

discussed in detail because of the lacking reliability of these GEQ dimensions.

In addition, significant interaction effects of form and age on challenge,  $F(1, 36) = 5.11, p < .05, \eta_p^2 = .12$ , and on negative affect,  $F(1, 36) = 6.75, p < .05, \eta_p^2 = .16$  were found. Again, we skip a discussion of negative affect, because of its unreliability. Instead, the observed interaction effect of form and age on challenge may explain the general interaction effect of form and age found in the previous ANOVA (which did not account for gender as a moderator). Figure 7.4 may explain this, since we can see a higher challenge score for the elderly on the DS, whereas the increase in challenge is not as prominent for the young. However, challenge is an ambiguous item and can denote either a positive or a negative gameplay experience. Therefore, correlations were tested, and in addition to a positive correlation between challenge and flow for both elderly and young, for the elderly a correlation between challenge and positive affect,  $r = .41, p < .01$ , was found. In contrast to this, for the young a correlation between challenge and negative affect,  $r = .35, p < .05$ , was found. Thus, elderly individuals might like challenge more than young individuals, suggesting that during the experiment the elderly were experiencing challenge as positive for their gameplay experience, while the young were experiencing challenge as negative for their gameplay experience.

#### 7.4 DISCUSSION

We found that for both the young and the elderly groups, time spent for solving the game task increased from paper to the game console. Thus, our hypothesis H1 that game form and player age exercise an interaction effect on task efficiency was not supported: Solving the task takes longer on DS than on paper regardless of age. Nevertheless, the assumption that elderly take less time on paper for solving the game task was supported. In general, we observed that elderly people take longer than young people for the game task. The same pattern was detected when investigating the number of errors produced during the task not lending support to our hypothesis H2 that game form and player age exercise an interaction effect on task effectiveness. However, after correlation with a control item, the most reasonable explanation for this seems that there were problems with the text recognition of the DS. Naturally, this raises another question of whether the audiovisual elements of the console provide a distraction from the basic tasks, thus eventually providing more challenge. Although, challenge did not correlate directly with those elements, this suggestion

might be supported partially for the younger age group by the correlation of flow and challenge and the correlation of visual and auditory clues as motivators for flow. Thus, the more motivating the young individuals found the audiovisual elements, the more likely they were to experience flow. However, such a scenario is doubtful to hold for the elderly age group, as audiovisual clues were found to improve a more pleasurable experience, and visual cues were found to enhance their feeling of competence. It would then also be necessary to revisit the advice of Merzenich (2007) on usability for the elderly. Since *Dr. Kawashima's Brain Training* on the Nintendo DS was designed with an elderly audience in mind, it should improve usability factors, but from our findings, it only improves positive feelings of elderly individuals when solving an arithmetical game task, but it does not improve usability factors like effectiveness and efficiency. Nevertheless, future research could add a more thorough investigation of the relationship between motor and cognitive skills, prior experience with portable game devices, and their influence of efficiency and effectiveness on game consoles.

The hypothesis H<sub>3</sub> that playing on paper will elicit less arousal and less flow than playing on the DS, regardless of age, was supported. Thus, we can confirm prior studies that decreased technological sophistication evokes lower levels of arousal and flow (Ivory & Magee, 2009) and that this is true regardless of individual age. In line with prior research (Riddick et al., 1987) was the finding of unchanged dominance for elderly people, which raises the question why the feeling of control over a game seems unaffected by game form.

While, we initially proposed that flow (Nakamura & Csíkszentmihályi, 2002) is linked directly to challenge, the type of challenge that is preferred seems to differ between young and old. While our initial hypotheses H<sub>4</sub> stated game form will have a main effect on positive game-related challenge, since challenge will be higher on the DS than on paper, and flow will correlate with challenge and positive affect, this was only partially supported. A correlation analysis showed that arousal might be an important facilitator for flow for the younger age group, while for the older age group pleasure, competence, and positive affect are all contributors to their flow experience. Prior studies have already suggested that only a limited number of games are enjoyable for elderly people (Riddick et al., 1987; Whitcomb, 1990), but we can at least say that flow achieved through feeling competent is an important part of the gaming experience for them.

#### 7.4.1 Conclusion

This study analyzed game form and age effects on usability, arousal and gameplay experience. Currently, although brain-training games are hailed as successful drivers of mental health for elderly people and researchers argue that they increase math skills of schoolchildren (Miller & Robertson, 2009), the delivery of those training games in digital form does not improve players' effectiveness or efficiency, regardless of age. However, the digital game form does make the tasks more exciting and induces a heightened sense of flow in gamers of all ages. To answer our initial question, it makes a positive experiential difference for elderly individuals when solving logic problems within digital games, and hence, this new gaming technology may indeed be a blessing for an aging Western civilization.



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## MORE THAN A FEELING: TONIC MEASUREMENT OF AUDIO USER EXPERIENCE AND PLAYER PSYCHOPHYSIOLOGY IN GAMES

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Lennart E. Nacke, Mark N. Grimshaw, and Craig A. Lindley

Submitted for journal publication.

**Keywords:** *Gameplay, user experience, play context, character, interaction, game experience*

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### ABSTRACT

*The combination of psychophysiological and psychometric methods provides reliable measurements of affective user experience (UX). Understanding the nature of affective UX in interactive entertainment, especially with focus on sonic stimuli, is an ongoing research challenge. In the user study reported here, participants played a fast-paced, immersive First-Person Shooter (FPS) game modification, in which sound (on/off) and music (on/off) were manipulated, while psychophysiological recordings of skin conductance level (SCL) and facial muscle activity (EMG) were recorded in addition to a game experience questionnaire. Two main effects were found: (1) a main effect of music on EMG brow and eyelid activity indicating positive as well as negative emotions and (2) a main effect of sound on positive game experience. Women also showed a significant difference in electrodermal activity (EDA) between sound off, music off (high EDA) and sound off, music on (low EDA), suggesting a soothing effect of music in games. A moderating effect of gender with music on negative affect ratings supports this. Gender also had a moderating effect with sound and music on immersion and flow ratings, suggesting than men generally prefer to play with sound on, while women like to play with either sound or music on. We conclude that both music and sound are elementary and complex components of FPS gameplay with gender-specific emotional impact.*

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### 8.1 INTRODUCTION

Research efforts are beginning to unravel the epistemological, ontological and methodological nature of user experience (UX) to foster a better general understanding of this concept (Law et al., 2008,

2007). While digital games have been in the focus of some of these efforts (Bernhaupt et al., 2007, 2008; Bernhaupt, 2010; Isbister & Schaffer, 2008), qualitative and quantitative studies of UX in games are still few in number. We aim at addressing this problem by contributing a user study focused on the effect of sound and music in the domain of interactive entertainment products, namely by studying a First-Person Shooter game. Insights from researching engagement with digital games may provide a better understanding of the impact and drivers of positive UX for other digital artifacts as well. Thus we anticipate our research to be beneficial to a broad range of UX researchers and practitioners alike.

*Sound and  
music are  
important for  
game user  
experience*

In the domain of digital games, an important part of UX is the conscious design of sound and music to affect aesthetics, feedback and rewards for players (Lord, 2004). Audio signals in games guide the interaction within the virtual world and can be leveraged to provide vital elements of gameplay. While the sonic UX in games may be shaped by sound and music cues, the enticing nature of these stimuli is currently understudied as is UX in digital interactive entertainment in general. Digital games currently leverage the potential of visual information for aesthetic appeal and for elements of game design more than audio information, a few exceptional examples like Silent Hill 2 (Konami, 2001) or Dead Space (Electronic Arts, 2008) excluded. The majority of user research in digital games uses qualitative approaches (IJsselsteijn et al., 2007), such as focus groups (Poels et al., 2007), heuristics (Desurvire et al., 2004; Korhonen & Koivisto, 2006; Federoff, 2002) and playtest surveys (Pagulayan et al., 2003). However, the evaluation of the emotional and cognitive experiences provided by game technology and virtual environments must be of higher value to game developers than regular performance measures. Therefore, an increasing amount of research and practice tries understanding UX in games from a psychological (Komulainen et al., 2008) and from a psychophysiological perspective (Mandryk & Atkins, 2007; Nacke & Lindley, 2008b; Ravaja et al., 2008, 2006).

Psychophysiology provides an unobtrusive measurement model for assessing emotional reactions of users covertly when engaging with interactive entertainment products (Ravaja, 2004). Facial electromyography (EMG) describes the measurement of subtle electrical activation of face muscles, which are good indicators of pleasant or unpleasant emotion (Bradley & Lang, 2007). Electrodermal activity (EDA) is a very common psychophysiological measurement method due to its very easy application (Boucsein, 1992). EDA is regulated by production of sweat in the *eccrine sweat glands*, where increased sweat gland activity is related to electrical skin conductance level

(SCL), which is associated with physical arousal (Lykken & Venables, 1971).

Arousal is likely to have a mediating effect on responses to sound, where especially the effect of environmental noise on health and performance has come under scrutiny (Glass & Singer, 1972). Noise was demonstrated to inhibit attention and lead to weak performance while showing an excess in arousal levels. However, results of psychophysiological effects of game sounds are mixed. Wolfson & Case (2000) report a study, which checked the influence of color (red/blue) and music volume (loud/quiet) on performance scores, heart-rate, and questionnaire responses. However, they found music volume alone to have little influence on the psychophysiological and survey measures, but the interaction of red color and loud music to lead to perceptions of excitement and successful playing. In another study, Grimshaw et al. (2008) analyzed the effects of sound and music on UX as well as psychophysiological measures in the First-Person Shooter (FPS) game *Half-Life 2*. The psychophysiological results were inconclusive and in need of further analysis, while the survey results pointed to differences in gameplay experience when playing on different sound and music conditions.

*Arousal and sound*

Although our research in sound and music effects in games is largely exploratory, following from the discussed literature, we have the following two broad hypotheses for our research: (H<sub>1</sub>) both sound and music have an effect on the UX in an FPS game and (H<sub>2</sub>) if H<sub>1</sub> is correct, then sound and music, either singly or in combination, will have different effects moderated by individual variables. Our experiment uses definitions of diegetic sound and non-diegetic music as defined in various studies of sound in games (Grimshaw & Schott, 2008), and mirrors the practice of separate user volume controls for sound and music typically found in the console interfaces for the genre of games studied here. The user study reported here was designed to record both subjective (i.e., questionnaires) and objective (i.e., psychophysiological sensors) responses. We used electromyography (EMG) and electrodermal activity (EDA) to account for valence and arousal dimensions of affect (Bradley & Lang, 2007; Lang, 1995; Russell, 1980). Another goal with this research was to investigate what affective activity EMG and EDA measures could reliably indicate regarding game sound and music. Finally, it has to be noted that this experiment was exploratory, providing a reference for further studies in this area.

## 8.2 METHOD

### 8.2.1 Participants

Data were recorded from 36 undergraduate students (66.7%) and university employees. Their age ranged between 18 and 41 ( $M = 24$ ,  $SD = 4.9$ ). Gender was not evenly distributed, since 19.4% of all participants were female. All participants played digital games regularly, 50% answered that they even play games every day.

### 8.2.2 Materials

The game used in this study was a specially designed mod for *Half-Life 2* (Valve Corporation, 2004) that featured gradually increasing combat situations for the player in three subsequent areas. Internal features of *Half-Life 2* to create game audio (e.g., soundscapes) were not employed, instead a music track was triggered externally and game sounds were turned off using console commands (Nacke et al., 2008).

### 8.2.3 Design

We employed a  $2 \times 2$  repeated-measures factorial design using sound (on and off) and music (on and off) as independent variables, using a counter-balanced, randomized order of sound and music game level stimuli. EMG and EDA responses were measured together with questionnaire items indicating the overall game experience for the different playing conditions. Questionnaire item order was randomized for each participant.

### 8.2.4 Procedure

Individuals were invited to the laboratory, where experiments ran in two-hour sessions. After a brief description of the experimental procedure, each participant filled in two forms. All participants had to give informed consent before commencement of the experiment. Individuals were then seated in a comfortable chair, the electrodes were attached and a resting period followed. During this resting period of 3–5 minutes, individual physiological baselines were recorded. Individuals then played under each of the four sound/music conditions. We will refer to the various conditions of diegetic sound as sound on/off and non-diegetic music as music on/off—reference to *sound* refers to diegetic sound and reference to *music* refers to non-diegetic music.

### 8.2.5 Measures

#### *Facial EMG*

We recorded the activity from left *orbicularis oculi*, *corrugator supercilii*, and *zygomaticus major* muscle regions (Fridlund & Cacioppo, 1986), using BioSemi flat-type active electrodes (11mm width, 17mm length, 4.5mm height) electrodes with sintered Ag-AgCl (silver/silver chloride) electrode pellets having a contact area 4 mm in diameter. The electrodes were filled with low impedance highly conductive Signa electrode gel (Parker Laboratories, Inc.). The raw EMG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz and using ActiView acquisition software.

#### *EDA*

Electrodermal activity was measured using two passive Ag-AgCl (silver/silver chloride) Nihon Kohden electrodes ( $1 \mu\text{A}$ , 512 Hz). The electrode pellets were filled with TD-246 skin conductance electrode paste (Med. Assoc. Inc.) and attached to the thenar and hypothenar eminences of a participant's left hand.

#### *Game Experience Questionnaire*

Different components of game experience were measured using the game experience questionnaire (IJsselsteijn et al., 2008). It combines several game-related subjective measures: immersion, tension, competence, flow, negative affect, positive affect and challenge. The questionnaire was developed based on focus group research and subsequent survey studies.

## 8.3 RESULTS

Initially, we treated the modalities of sound and music as singular sound modalities, using them on different levels of the same independent variable (sound). However, a one-way repeated-measures analysis of variance (ANOVA) showed no significant results for physiological measures. Thus, due to the very different nature of in-game sounds and music, we decided to reanalyze our data, treating each sound and music as separate independent variables with two factorial levels (on = being audible or off = being inaudible). In the following, we will present the results of a two-way repeated-measures factorial ANOVA, using sound and music as within-subjects factors for the dependent variables facial EMG (brow, eye, cheek), EDA, and GEQ dimensions. A few values in the psychophysiological dataset were missing or outliers (due to recording problems), so that for the cleaned psychophysiological analysis 29 cases remained, for which

*Each factor, sound and music, is treated as an independent variable*

we determined whether gender (13.8% female) or age group (27.6% older than 25 years) were factors moderating the effects of sound and music. Before the analysis, mean values of psychophysiological measures were normalized using logarithmic transformation. Only significant findings will be reported.

### 8.3.1 Results of EMG

#### Main effect

Multivariate analysis revealed a significant main effect of music,  $F(3, 24) = 3.81, p < .05, \eta_p^2 = .32$ . This means, if we ignore the influence of the type of sound produced by the game, individuals still showed significant differences in EMG activity. A significant main effect of music would imply that generally facial muscle activity is higher when music is playing than when music is not playing (see Figure 8.1). Univariate tests showed significant main

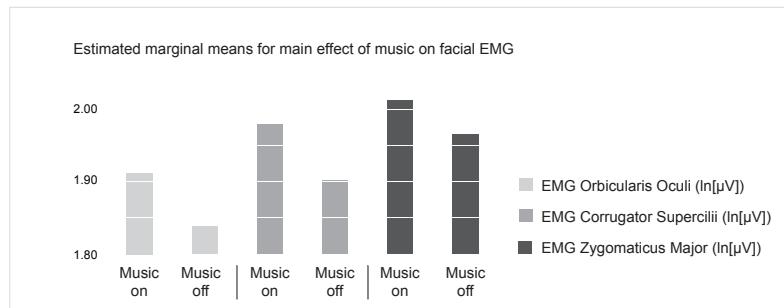


Figure 8.1: Main Effect of Music on EMG

effects of music on brow muscle activity (CS, negative valence),  $F(1, 26) = 5.77, p < .05, \eta_p^2 = .18$ , and on eyelid muscle activity (OO, high arousal positive valence),  $F(1, 26) = 5.11, p < .05, \eta_p^2 = .16$ , but not on cheek muscle activity (ZM, positive valence).

#### Interaction effects

Next, an interaction effect of music and gender on eyelid muscle activity,  $F(1, 26) = 5.32, p < .05, \eta_p^2 = .17$ , was found. This means that music had a different effect on eyelid muscle activity (a psychophysiological indicator of positive affect) for men and women. Men show almost no difference in eyelid activity between music present ( $M = 1.80 \text{ ln}[\mu\text{V}], SE = .07$ ) and music absent ( $M = 1.79 \text{ ln}[\mu\text{V}], SE = .07$ ) conditions, while women show more eyelid activity when music is present ( $M = 2.15 \text{ ln}[\mu\text{V}], SE = .17$ ) than when music is absent ( $M = 1.93 \text{ ln}[\mu\text{V}], SE = .17$ ).

In addition, interaction effects of sound and music were found on eyelid muscle activity,  $F(1, 26) = 4.67, p < .05, \eta_p^2 = .15$ , and on cheek muscle activity,  $F(1, 26) = 4.53, p < .05, \eta_p^2 = .15$  indicating a positive effect of the co-presence of sound and music during gameplay. This shows music has a different effect on positive valence, indicated by brow and cheek muscle activity (Bradley & Lang, 2007), depending on presence of absence of sound during gameplay.

Let us look at eyelid muscle activity first. When both, sound and music are present ( $M = 1.87 \ln[\mu\text{V}], SE = .08$ ), the EMG activity is almost the same as when sound is present and music is absent ( $M = 1.88 \ln[\mu\text{V}], SE = .08$ ). This would indicate a significant effect of sound on eyelid activity, but interestingly sound seems to be mediated by music (as the interaction effect lets us assume). Thus, the absence of sound and presence of music shows higher eyelid activity (high positive valence,  $M = 1.95 \ln[\mu\text{V}], SE = .09$ ) than the absence of both sound and music (low positive valence,  $M = 1.80 \ln[\mu\text{V}], SE = .07$ ).

Let us look at cheek muscle activity next, another stronger indicator of positive valence. The findings here are in line with what we could already observe in eyelid activity. However, when both, sound and music are present ( $M = 1.97 \ln[\mu\text{V}], SE = .09$ ), the EMG activity is lower than when sound is present and music is absent ( $M = 2.01 \ln[\mu\text{V}], SE = .08$ ), indicating that natural game sound seems generally preferable when not combined with non-game music. In line with reported eyelid activity, highest positive valence (via cheek activity) is indicated when music is present and sound is absent ( $M = 2.05 \ln[\mu\text{V}], SE = .09$ ) and lowest positive valence, when both sound and music are absent ( $M = 1.92 \ln[\mu\text{V}], SE = .08$ ).

Finally, interaction effects of sound, music and gender were also discovered on eyelid muscle activity,  $F(1, 26) = 5.16, p < .05, \eta_p^2 = .17$ , and on brow muscle activity,  $F(1, 26) = 5.16, p < .05, \eta_p^2 = .17$ . Here, gender seems to moderate effects of sound and music on positive and negative valence.

Let us look at eyelid muscle activity first. No significant differences between presence and absence of music are notable for each gender when game sound is audible. Women tend to show more eyelid activity in presence of game sounds whether music is on ( $M = 1.99 \ln[\mu\text{V}], SE = .19$ ) or off ( $M = 1.99 \ln[\mu\text{V}], SE = .19$ ), while men in comparison show less eyelid activity whether music is on ( $M = 1.81 \ln[\mu\text{V}], SE = .08$ ) or off ( $M = 1.81 \ln[\mu\text{V}], SE = .08$ ). This situation changes for women, when no game sound is audible. They show higher eyelid activity here ( $M = 2.31 \ln[\mu\text{V}]$ ,

$SE = .19$ ) than during complete absence of sounds and music ( $M = 1.87 \ln[\mu\text{V}]$ ,  $SE = .16$ ). For men, when no game sound is present, no significant changes in eyelid activity can be observed whether music is on ( $M = 1.77 \ln[\mu\text{V}]$ ,  $SE = .08$ ) or off ( $M = 1.76 \ln[\mu\text{V}]$ ,  $SE = .07$ ).

Let us look at brow muscle activity next. For women, when game sound is audible, it makes little difference whether music is on ( $M = 1.91 \ln[\mu\text{V}]$ ,  $SE = .13$ ) or off ( $M = 1.91 \ln[\mu\text{V}]$ ,  $SE = .14$ ). However, when game sound is absent, the presence of music indexes higher brow muscle activity ( $M = 2.28 \ln[\mu\text{V}]$ ,  $SE = .16$ ) than when music is absent ( $M = 1.90 \ln[\mu\text{V}]$ ,  $SE = .13$ ). On the contrary, for male players, when game sound is present, there is a difference in brow activity whether music is audible ( $M = 1.95 \ln[\mu\text{V}]$ ,  $SE = .06$ ) or not ( $M = 1.91 \ln[\mu\text{V}]$ ,  $SE = .06$ ). However, when game sound is off, it makes not much difference for a male audience whether music is on ( $M = 1.90 \ln[\mu\text{V}]$ ,  $SE = .07$ ) or off ( $M = 1.89 \ln[\mu\text{V}]$ ,  $SE = .06$ ).

### 8.3.2 Results of EDA

Analysis revealed only one significant interaction effect of sound, music and gender,  $F(1, 26) = 5.49$ ,  $p < .05$ ,  $\eta_p^2 = .17$ . For men, it makes little difference when either both music and sound are present or both music and sound are absent (see Figure 8.2). They seem to be more excited (indicated by arousal in electrodermal activity) when sound is present and music is absent and when sound is absent to be more excited with music present. Interestingly, female players are more aroused when sound is present than when sound is absent, but when sound is present, not much difference can be seen in arousal whether music is present or absent. However, when sound is turned off, it makes a big difference in arousal for female players whether music is playing or not; excitement seems to be higher, when both, music is off and sound is off than when music is playing without game sounds.

### 8.3.3 Results of Game Experience Questionnaire

For the questionnaire analysis all 36 cases could be used, for which we determined whether gender (19.4% female) or age group (33.3% older than 25 years) were factors moderating the effects of sound and music.

Multivariate analysis revealed a significant main effect of sound on subjective game experience dimensions,  $F(7, 26) = 4.65$ ,  $p < .01$ ,  $\eta_p^2 = .56$ , but no main effect of music. This contrasts with our EMG findings, where music had a significant main effect. However, significant interaction effects of sound, gender and age group,  $F(7, 26)$

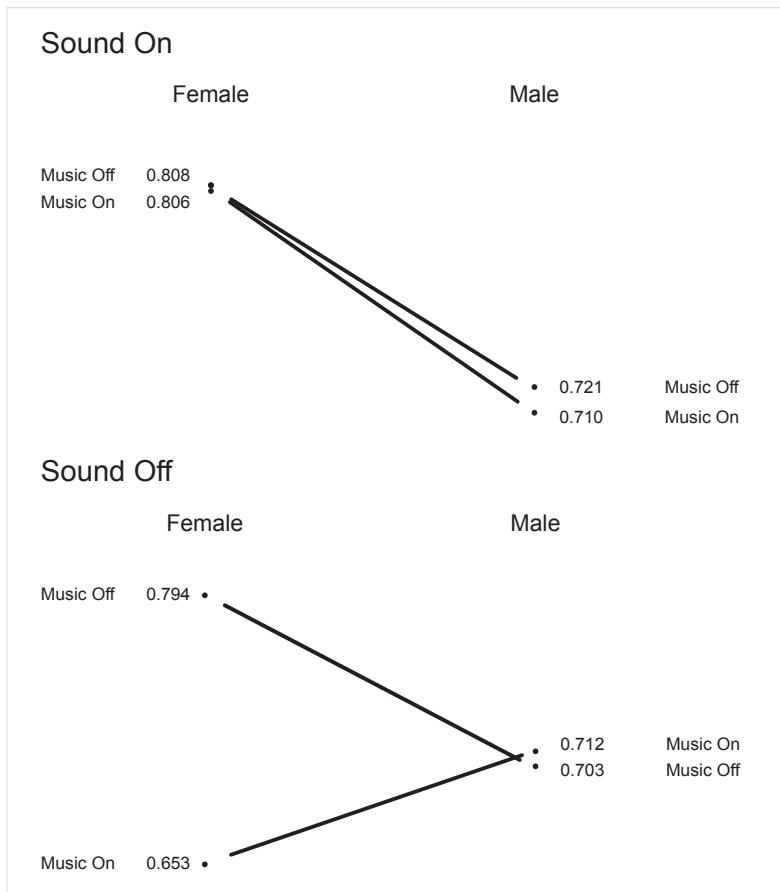


Figure 8.2: Estimated marginal means of electrodermal activity (EDA) in  $\log[\mu\text{S}]$

$= 2.62, p < .05, \eta_p^2 = .41$ , and an interesting, significant interaction effect of sound and music,  $F(7, 26) = 3.36, p < .05, \eta_p^2 = .48$ , were found.

Univariate tests showed a significant main effect of sound on immersion,  $F(1, 32) = 18.72, p < .001, \eta_p^2 = .37$ , flow,  $F(1, 32) = 12.13, p < .01, \eta_p^2 = .28$ , positive affect,  $F(1, 32) = 7.51, p < .05, \eta_p^2 = .19$ , negative affect,  $F(1, 32) = 22.46, p < .001, \eta_p^2 = .41$ , tension,  $F(1, 32) = 11.87, p < .01, \eta_p^2 = .27$ , and challenge,  $F(1, 32) = 9.49, p < .01, \eta_p^2 = .23$ , but not on competence.

Thus, absence or presence of sound seems to influence all subjective GEQ dimensions except for competence, regardless of music. As shown in Figure 8.3, sound has a positive effect on subjective game experience, immersion and flow ratings are higher when

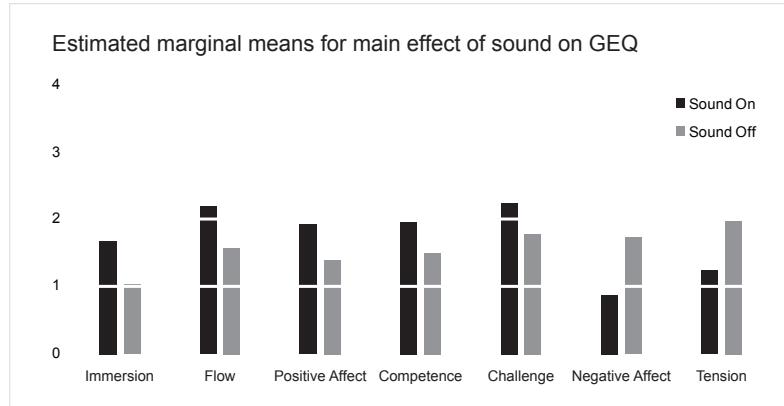


Figure 8.3: Means for main effect of sound on GEQ

sound is on than when it is off, so are positive affect, competence (although insignificant) and challenge ratings.

As expected, interaction effects of sound, gender and age group were found on immersion,  $F(1, 32) = 7.36, p < .05, \eta_p^2 = .19$ , flow,  $F(1, 32) = 12.87, p < .01, \eta_p^2 = .29$ , positive affect,  $F(1, 32) = 7.60, p < .05, \eta_p^2 = .19$ , and challenge,  $F(1, 32) = 15.13, p < .001, \eta_p^2 = .32$ , but not on competence, negative affect, or tension.

Table 8.1 shows that game sound facilitates immersion especially for younger women and, to a lesser extent, older men, while older women and younger men feel subjectively less immersed. No such effect can be witnessed for either gender or age group when sound is turned off. Flow as measured with the questionnaire is experienced higher when sound is on for younger women and older men, while older women and younger men experience less flow when game sound is present. However, the absence of sound seems to facilitate flow for older women and younger men.

A huge difference in positive affect ratings can be observed between younger and older women. Younger women greatly prefer sound to be present, while older women are less affected by game sound being present. Positive affect ratings when game sound is present show little difference between age groups. The same is true when game sound is absent for women, only a marginal difference between the age groups. When sound is off, younger men show more positive affect than older men. Finally, an interesting difference in challenge can be seen across age groups and sound for women. Younger women find a game more challenging when sound is on, while older women find it more challenging when

GEQ	MODE	FEMALE		MALE	
		YOUNG	OLD	YOUNG	OLD
Immersion	Sound	2.56	1.25	1.28	1.68
	On	(0.44)	(0.51)	(0.20)	(0.30)
	Sound	1.13	1.08	0.95	0.97
	Off	(0.39)	(0.45)	(0.17)	(0.26)
Flow	Sound	2.56	1.62	2.17	2.44
	On	(0.52)	(0.60)	(0.23)	(0.34)
	Sound	1.13	2.08	1.74	1.39
	Off	(0.58)	(0.67)	(0.26)	(0.39)
Positive Affect	Sound	2.60	0.83	2.19	2.14
	On	(0.45)	(0.51)	(0.20)	(0.30)
	Sound	1.31	1.25	1.78	1.25
	Off	(0.38)	(0.44)	(0.17)	(0.26)
Challenge	Sound	2.84	1.75	2.01	2.44
	On	(0.37)	(0.43)	(0.17)	(0.25)
	Sound	1.56	2.17	1.84	1.61
	Off	(0.33)	(0.38)	(0.15)	(0.22)

Table 8.1: Overview of estimated marginal means (and standard errors) for significant interaction effects of sound, gender, and age group on immersion, flow, positive affect and challenge. Age group is divided into younger (under 25 years) and older (between 25 and 41 years) participants.

sound is off. Older men find it more challenging to play with sound on, while younger men find it a bit more challenging to play a game when sound is off.

Surprisingly, an interaction effect of music and gender on negative affect,  $F(1, 32) = 5.32, p < .05, \eta_p^2 = .14$ , was found. As Figure 8.4 shows, women show higher negative affect, when music is off than when music is on, irrelevant of sound or age. Female players show less negative affect in the presence of music while playing. However, male players are indifferent to presence or absence of music, showing slightly less negative affect in the music on condition.

In addition, we uncovered an interaction effect of music, gender, and age group on challenge,  $F(1, 32) = 4.63, p < .05, \eta_p^2 = .13$ . Figure 8.5 shows this interaction effect. Younger women experience subjectively more challenge when music is on than when music is off. However, older women experience subjectively more challenge, when music is off. Arbitrarily, male players generally experience

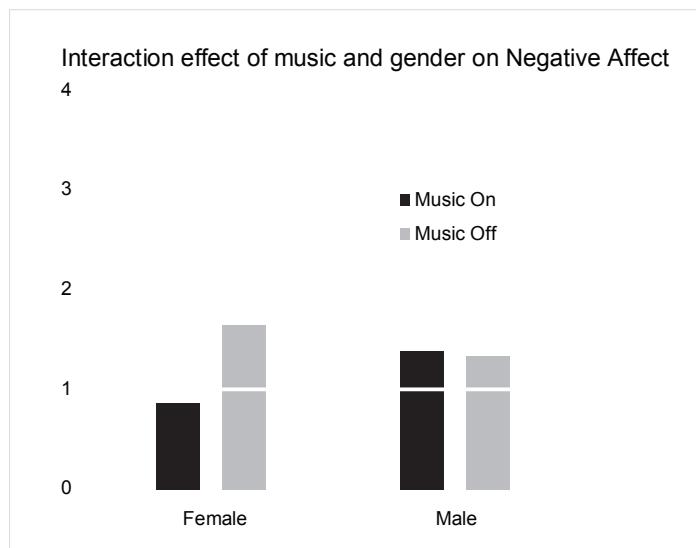


Figure 8.4: Interaction effect of music and gender on negative affect.

more challenge, when music is on than when it is off in both age groups.

In line with our expectations from the multivariate test, we found an interaction effect of sound and music on immersion,  $F(1, 32) = 10.81, p < .01, \eta_p^2 = .25$ , flow,  $F(1, 32) = 7.32, p < .05, \eta_p^2 = .19$ , and tension,  $F(1, 32) = 7.65, p < .01, \eta_p^2 = .19$ . Table 8.2 shows that

GEQ	MODE	MUSIC ON	MUSIC OFF
Immersion	Sound On	1.58 (0.23)	1.80 (0.20)
	Sound Off	1.35 (0.21)	0.72 (0.17)
Flow	Sound On	2.02 (0.28)	2.38 (0.21)
	Sound Off	1.79 (0.29)	1.37 (0.24)
Tension	Sound On	0.90 (0.24)	1.60 (0.17)
	Sound Off	2.06 (0.25)	1.90 (0.23)

Table 8.2: Overview of estimated marginal means (and standard errors) for a significant interaction effect of sound and music on immersion, flow, and tension.

immersion is generally higher, when game sound is on and music is off or when music is on and game sound is off. On balance, immersion is generally higher when game sound is present. The same is true for flow experience, which seems to be best, when

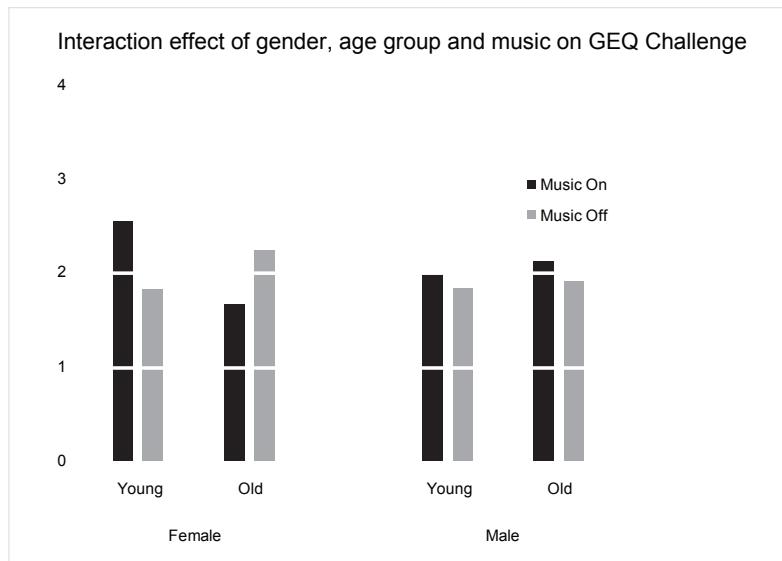


Figure 8.5: Interaction Effect of Gender, Music and Age Group on GEQ Challenge component

music is off and game sound is on.

Sound, music and age group also had a significant effect on tension,  $F(1, 32) = 5.37, p < .05, \eta_p^2 = .14$ . Age group seems to mediate the effects mentioned above. Younger players experience more tension when both music and game sound are present ( $M = 1.26, SE = .31$ ), older players experience this condition as less tense ( $M = 0.53, SE = .37$ ). When sound is present, but music is absent, older players are tenser ( $M = 1.83, SE = .27$ ) than younger players ( $M = 1.37, SE = .22$ ). When sound is absent and music is present older players again are tenser ( $M = 2.22, SE = .39$ ) than younger players ( $M = 1.90, SE = .32$ ). Lastly, when nothing is audible during gameplay, both, young players ( $M = 1.86, SE = .30$ ) and old players ( $M = 1.94, SE = .36$ ) are quite tense. In addition, the prior results showed that tension is highest when music is on and sound is off and lowest when music and sound are on.

Finally, sound, music and gender significantly influenced immersion,  $F(1, 32) = 10.89, p < .01, \eta_p^2 = .25$ , as well as flow,  $F(1, 32) = 4.14, p < .05, \eta_p^2 = .12$ . Table 8.3 shows that women are more immersed, when sound is on and music is off, while men are more immersed when music is on and sound is on. If sound is off, both men and women prefer to play with music on than without any kind of music or sound. Women indicate to be more in flow, when music is off and sound is on or music is on and sound is off, the

GEQ	MODE	FEMALE		MALE	
		MUSIC ON	MUSIC OFF	MUSIC ON	MUSIC OFF
Immersion	Sound	1.60	2.21	1.56	1.39
	On	(0.40)	(0.35)	(0.21)	(0.19)
	Sound	1.65	0.56	1.05	0.88
	Off	(0.36)	(0.31)	(0.19)	(0.16)
Flow	Sound	1.77	2.41	2.27	2.35
	On	(0.49)	(0.37)	(0.26)	(0.19)
	Sound	1.98	1.23	1.61	1.52
	Off	(0.52)	(0.42)	(0.27)	(0.22)

Table 8.3: Overview of estimated marginal means (and standard errors) for significant interaction effects of sound, music, and gender, on immersion and flow.

former being the preferred of both conditions similar to immersion ratings.

#### 8.4 DISCUSSION

The results showed two main effects: (1) a main effect of music (on/off) on EMG brow and eyelid activity and (2) a main effect of sound (on/off) on game UX dimensions immersion, flow, positive affect, negative affect, tension and challenge. Thus, both our hypotheses that both sound and music have an effect on the FPS UX (H1) and that sound and music will have different effects moderated by individual variables (H2) are supported. In more detail, the main effect of music (1) showed that facial muscle activity is higher when music is on than when it is off (cf., Figure 8.1). Prior studies have indicated that the co-activation of all three muscles (eyelid [OO], cheek [ZM], brow [CS]) are most pronounced during expressions of antipathy such as lowering the brow and contracting eyes and cheek (Bradley et al., 2001). However, most of those responses were observed when using simple static stimuli like affective pictures, so that results may not be directly transferable to complex interactive stimuli like digital games. A co-activation of the different muscles may indicate that more than one emotion was present during playing the game, especially when using tonic (i.e., cumulative) psychophysiological measures. A suggested interpretation of this main effect could thus be that presence of music is generally perceived with high arousal, evoking negative as well as positive feelings during playing games more intensely than in

other conditions. Another alternative explanation could be that music is perceived as unpleasant during gameplay—if we neglect the complexity of digital games as stimulus material (Bradley et al., 2001; Bradley & Lang, 2007).

The main effect of sound (2) showed that regardless of music, the presence of sound leads to higher subjective ratings of immersion, flow, positive affect, and challenge and lower ratings of negative affect and tension. We can additionally assume that the challenge rated when sound is on is a positive challenge, while it could be possible that challenge when sound is off is a negatively experienced challenge. Higher negative affect and tension ratings both point to this, which could explain the decrease in immersion, flow, positive affect and competence ratings. Without sound providing audible feedback, players experience the game as tenser and less pleasant. This suggests that sound, regardless of music, leads to a better gameplay experience. A reason for this could be that the auditory feedback, which game sound provides, makes players feel more flow, immersion, challenge and positive affect. Brewster & Crease (1999) suggested that enhancing menus with sound feedback makes them more usable. So, our results could suggest that using sound feedback in games makes them indeed more playable. However, background sound effects are complex means of human-computer interfaces and many task variables are involved in creating the interactive experience and perception (Edworthy, 1998).

Since a good number of interaction effects were found, we will only discuss them briefly here. Sound and music had a combined effect (1) on eyelid and cheek EMG activity and (2) on immersion, flow and tension. The eyelid and cheek activity (1) was highest for music without sound, while cheek EMG activity was also pronounced for the sound with music condition. It seems to have a positive effect on player emotions, when either sound or music is present, removing game sounds and listening to music seems to have a positive effect on players (as it might remove some of the tension and perhaps the effect of immersion related to sounds). Music seems to have a positive, potentially relaxing effect on the player when decoupled from game sounds; however, the absence of both game sounds and background music seems to negatively influence player experience, since less positive valence is indexed. We can conclude that preferred playing conditions are either to play with sound on and music off or with music on and sound off and generally least pleasurable to play with both sound and music off. In reality, silence is a rare condition and, outside the experiment, it is reasonable to expect the participants to be experiencing either sound from the environment (providing reassurance as to

their place in the world) or to be cocooned in a world of music via earphones.

Sound and music effects on immersion, flow and tension (2) showed that in the sound on, music off condition, the ratings for immersion and flow were highest. Together with the main effect of sound on immersion and flow, we can say that game sound plays an important role for facilitating flow and immersion experiences in games. Interestingly, the effect of sound and music on tension showed that tension was rated highest in the music on, sound off condition, while it was rated lowest in the music on, sound on condition. Thus, co-presence of sound and music could have a relaxing effect. When game sound is off, music seems to have a more disturbing effect as players are tenser when listening to music while playing without sound. Game sound facilitates immersion especially for younger women and older men in this study. No such effect can be witnessed for either gender or age group when sound is turned off. Flow ratings are higher when sound is on for younger women and older men.

The effect of sound and music on EMG activity on eyelid and brow seems to be moderated by gender. Women show higher eyelid muscle activity during presence of music, especially when no game sound is present, while men seem to be indifferent to the addition of music. EMG brow activity was also high for women when sound was off and only music was on. Together with our finding that eyelid activity is higher for this condition (sound off, music on), we have to assume that the co-activation of eyelid and brow muscle shows either a variety of positive and negative emotions present during this condition, which could be pleasant high arousal or even an unpleasant emotion (Bradley & Lang, 2007). The high EMG activity on the brow seems to suggest that women enjoy playing without game sound less and even more so, when they have to listen to music. Together with sounds, music seems to be perceived as slightly disturbing for male players. Music could have a negative effect, when game sound is on and when music and game sound are both off. The most pleasant playing conditions (according to EMG activity) are then either music off and sound on or music on and sound off, regardless of gender.

The effect of sound and music on EDA seems also to be moderated by gender (see Figure 8.2). Women show higher arousal than men, when sound is on, but when sound is off and music is off, women show higher EDA than men. However, when sound is off and music is on, they show lower arousal than men and in general have the lowest arousal in this condition. For men, it makes little

difference when either both music and sound are present or both music and sound are absent. Given that women are probably more reactive than men; this mediating effect is not surprising (Bradley & Lang, 2007). It will, in future, be interesting to test whether changes in tension (as noted above) and changes in arousal are apparent in other game genres, particularly those that do not exhibit the unique features of the FPS game. Here, the first-person perspective posits the player as being in the game world while the scenario is that of *the hunter and the hunted*; in *virtuality*, as in reality, the lack of clues as to the possibilities or threats inherent in the environment can be disturbing. The greatest increase in tension found with the condition music on, sound off may be explained not only by the lack of informative sound cues but also, firstly, by the perceptual mismatch between the world that the eyes see and the world that the ears hear and, secondly, by the lack of sonic response and feedback to player actions. We could hypothesize that absence of sound cues makes playing the game more difficult and thus triggers the recorded increase in arousal. In general, the most preferable setting in terms of positive arousal is to play with game sounds on and music off, which is indicated by EDA and EMG results, and this state most accurately mirrors reality.

Another noteworthy interaction effect of music, gender, and age group was recorded for challenge ratings. Younger women have higher challenge ratings when music is on. However, older women have higher challenge ratings, when music is off. Men have higher challenge ratings in both age groups when music is on. The challenge for young women is likely to be related to a positive experience of challenge, while older female players might be less familiar with the control and the challenge could possibly be related to acquiring gameplay competence (Lindley & Sennersten, 2008).

Women have higher negative affect ratings when music is off, regardless of sound. Thus, sound is likely perceived as soothing and pleasant for female players in our study. A similar moderating effect of gender is seen in sound and music interaction effects on immersion and flow.

For men in this study, the pattern is similar regardless of music. They prefer to play with sound on, regardless of music being on or off. However, for females, the conditions that facilitate flow and immersion are either sound on and music off or music on and sound off. The co-presence of music and sound is less preferred than the lone presence of either sound or music. This could indicate, at least for men that sound is a more important driver in creating flow experiences than music, but that music might be a more important

component for creating immersive experiences.

*Most pleasant  
is playing with  
sound on and  
music off*

In summary, we have found that the most pleasant conditions for playing games are playing with sound on and music off or sound off and music on while a number of variable influence these effects. However, in general the absence of both, sound and music leads to least pleasurable experiences in our test. In light of these results, we conclude that both music and sound are elementary and complex components of FPS gameplay with gender-specific emotional impact. In the future, we hope to see more UX evaluations leveraging the power of physiological logging of players' behavior and emotion to create a comprehensive view of gameplay experience. In addition, the increase of immersion and flow ratings together with *positive affect* marks a point of departure for future research on game sound immersion.

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## PSYCHOPHYSIOLOGICAL EFFECTS OF FIRST-PERSON SHOOTER DEATH EVENTS AND GAME AUDIO

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Lennart E. Nacke, J. Matias Kivikangas, and Niklas Ravaja

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### ABSTRACT

*This study examines the emotional valence- and arousal-related phasic psychophysiological responses to player character (PC) death events in an immersive First-Person Shooter (FPS) game modification with automatic event scoring, in which sound (on/off) and music (on/off) were manipulated for 36 participants. During death events, changes in facial electromyographic (EMG) activity and skin conductance level (SCL) were recorded. Contrast tests of event-related changes, during seconds following the death events, revealed that neither sound nor music condition had an effect on phasic physiological EMG responses, but SCL showed a slow increase when both sound and music were off and when music was on and sound was off. In addition, the interaction contrasts revealed a greater linear increase in SCL when sound was off and similar when music was on. The differences between these results and prior psychophysiological studies of death events in games are discussed in light of the game modification and participants used in this study.*

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### 9.1 INTRODUCTION

In many digital games, dying is part of the gameplay experience. Games are typically designed to provide challenge and players rarely master games so perfectly that the death of the player's character (PC) could always be avoided. PC death provides a restart from an earlier point, allowing the player to learn by repetition (i.e., trial and error) how the game mechanic can be mastered. If death in a digital game is supposed to be a motivating factor for learning to play, it could be expected that a death experience should evoke

some negative emotions, so that players are motivated not to die again.

*First-Person  
Shooters are  
ideal for  
studying  
emotional  
effects*

This is especially true for competitive First-Person Shooter (FPS) games, where the PC is invisible or only perceived as virtual hands or weapons, which leads to stronger identification with the PC. Full immersion is achieved here by not directly portraying the player character or avatar (Grimshaw, 2008). The player experiences a sense of spatial presence as acting within the game world (Wirth et al., 2007). Thus, events that are experienced in the FPS game world may be perceived in greater amplification than in other game types and genres. FPSs provide some of the most action-oriented gameplay experiences for players today, employing PC death and respawning as a game mechanic that motivates progression in the game. If a strong atmospheric component, such as a horror scenario or game sound, is added to the game design, then players are likely to have a strong psychophysiological response to the death of their PC. Even if a negative response would be plausible, previous investigations suggest that negative events like player death actually elicit responses that can be interpreted as positive emotions (Kivikangas & Ravaja, 2009; Ravaja et al., 2005, 2008). Although explanations have been offered in the referred papers, there is currently no satisfactory clarification for these unexpected results.

Regarding game sound, Grimshaw & Schott (2008) provide definitions of acoustic ecologies and some conceptual tools for analyzing immersive functions of sound in FPSs and other game genres. The immersive effects of game sound have also been examined with subjective player surveys and it was concluded that auditory immersion in the game world is linked to realistic sound samples (Jørgensen, 2006). However, another publication has investigated game sound with psychophysiological methods such as the measurement of temperature, electrodermal response and heart-rate with the game America's Army as a stimulus (Shilling et al., 2002). The paper is primarily methodological and only makes an assumption about the linkage between high arousal, positive emotion and immersion in games.

*Phasic psycho-  
physiological  
game sound  
effects*

Phasic psychophysiological effects of game sounds have not been analyzed in detail and may not be independent from other factors present in digital games. For example, Wolfson & Case (2000) studied the influence of color (red and blue) and music volume (loud and quiet) on individual performance scores, heart-rate, and survey responses. They found music volume alone to have little influence on the heart-rate and survey measures, but the interaction of red color and loud music to lead to perceptions of excitement

and successful playing. Another investigation was conducted by Grimshaw et al. (2008) analyzing the tonic psychophysiological effects of sound and music on gameplay experience. The psychophysiological results were inconclusive while the survey results pointed to differences in gameplay experience for the different sound and music conditions.

In this paper we aim to explore (1) psychophysiological responses elicited by PC death in an FPS game and (2) if sound and music have a significant impact on psychophysiological responses during these death events.

## 9.2 DIMENSIONAL THEORIES OF EMOTION AND PSYCHOPHYSIOLOGICAL MEASUREMENTS

Dimensional theories are *de facto* standards in psychophysiological research based on a long history of use. Wundt (1896) was one of the first psychologists to classify *simple feelings* into a three-dimensional model, which consisted of the three fundamental axes of pleasure - displeasure (Lust - Unlust), arousal - composure (Erregung - Beruhigung), and tension - resolution (Spannung - Lösung). In a circumplex emotional model suggested by Russell (1980), all emotions are based on dimensions of valence (i.e. tone, from pleasant to unpleasant) and arousal (bodily activation) (Lang, 1995), although several variations of the model have been suggested (Posner et al., 2009, 2005; Watson & Tellegen, 1985). According to the dimensional model, individual emotions, such as joy or fear, are not fundamentally different contrary to what the theories for basic emotions posit (Darwin, 1899; Ekman, 1992; Plutchik, 2001), since individual emotions are - on the level of automatic physiological responses - products of the same two systems (Posner et al., 2005). In this mindset, it is argued that the emotional experience a person feels is a cognitive interpretation of this automatic physiological response (Russell, 2003).

However, it has been criticized that because of the bipolarity of the valence dimension, the circumplex model does not allow simultaneous positive and negative emotions (Tellegen et al., 1999). In experimental emotion research, the emotional responses are typically elicited by unambiguous stimuli (for example, affective pictures) designed to produce only a certain emotion (Bradley & Lang, 2000; Lang et al., 1993). In case of multifaceted and complex emotional stimuli, it has been found that the emotional response can be simultaneously positive and negative (Larsen et al., 2001, 2004). This issue becomes paramount in studies of psychophysio-

*Criticism of the valence-arousal model*

logical effects of complex multimedia stimuli such as digital games, movies, hypertext, and other multimedia narratives. For these areas, another structural hierarchical model of emotion might be more suited, which allows independent positive activation (PA) and negative activation (NA) (Tellegen et al., 1999). In this model, PA is associated with enthusiasm and joy, while NA is associated with distress and fear. Both, PA and NA are linked to neurological motivation systems that can become activated independently of each other: behavioral activation and behavioral inhibition system. These systems regulate approach - withdrawal behavior that in turn is closely related to physiological emotion responses (Cacioppo & Berntson, 1994; Posner et al., 2005; Watson et al., 1999).

#### *EMG Basics*

A method called facial electromyography (EMG) is commonly used in emotion research to index valence of emotional physiological responses. Ekman's insight that basic emotions are reflected in facial expressions was fundamental for subsequent studies investigating facial muscle psychophysiology using facial EMG, which measures subtle electrical activation at muscle sites on the human face (Ekman, 1992; Cacioppo et al., 2004). Empirical studies support the hypothesis that processing pleasant emotions is associated with increased activity in the zygomaticus major (ZM, cheek) muscle, whereas processing unpleasant emotions is associated with increased activity in the corrugator supercilii (CS, brow) muscle (Bradley et al., 2001; Bradley & Lang, 2000, 2007; Simons et al., 1999). Other experimental findings support the association of CS also with heightened attention (Waterink & van Boxtel, 1994). Furthermore, orbicularis oculi (OO, eyelid) muscle has been shown to be associated with high arousal positive emotions (Bradley et al., 2001; Hawk et al., 1992), and it has been proposed to differentiate between genuine pleasure and faked smiles (Duchenne, 1990; Ekman et al., 1990) during co-activation with ZM muscle activity.

#### *EDA Basics*

Measurement of electrodermal activity (EDA) or skin conductance level (SCL, sometimes called galvanic skin response) is one of the easiest and therefore most commonly used psychophysiological methods (Lykken & Venables, 1971). It is either measured from palmar (thenar/hypothenar eminences of the hand) or plantar sites (e.g. above abductor hallucis muscle and midway between the proximal phalanx of the big toe) (Boucsein, 1992). Production of sweat in the eccrine sweat glands, which is entirely controlled by the sympathetic nervous system, is what regulates EDA. Thus, increased sweat gland activity is related to electrical skin conductance. It is considered to have a strong association with arousal (Dawson et al., 2007; Lang et al., 1993). Arousal could have a mediating effect on responses to sound. In related literature, effects of environmental

noise on health and performance were investigated (Glass & Singer, 1972). Too much noise inhibited attention and lead to weak performances while showing excessive levels of arousal.

An advantage of physiological assessment is that it can covertly assess facial muscle activity or skin conductance with great sensitivity to subtle reactions (Ravaja, 2004). During interactive activities, such as playing digital games, the physiological activity of brow, cheek, and eyelid muscle can be recorded continuously without interrupting or disturbing the activity. This enables the assessment of emotional player states at specific game events (Nacke et al., 2008; Ravaja et al., 2008) or even during complete game sessions (Mandryk, 2008; Nacke & Lindley, 2008b; Ravaja et al., 2008).

### 9.3 METHOD

Individuals played a *Half-Life 2* game mod especially designed for a playing time of 10 minutes. The game mod was played four times in different sound and music conditions.

#### 9.3.1 Participants

Data were recorded from 36 undergraduate students (66.7%) and University employees. Their age ranged between 18 and 41 ( $M = 24$ ,  $SD = 4.9$ ). Gender was not evenly distributed, since only 19.4% of all participants were female. All participants played digital games regularly, and 94.4% reported they play games at least once a week. 94.4% believed they had full hearing capacity. A preference for playing games with a music track on was indicated by 69.4%. Of those, 44.4% preferred playing with surround sound speakers, while 33.3% opted for playing with stereo headphones. 11.1% liked playing with stereo speakers and 11.1% preferred surround sound headphones. 41.7% saw themselves as hobby musicians, while only 33.3% played an instrument, which can be explained by people working with sound recording and programming but not playing an instrument. All participants considered sound at least *somewhat important* in games.

#### 9.3.2 Stimulus Materials

The game used in this study was called *The FUGA Project*<sup>1</sup>, a specially designed mod for *Half-Life 2* (Valve Corporation, 2004) that featured gradually increasing combat situations for the player in three subsequent areas and allowed logging of in-game events directly to the

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<sup>1</sup> Available online at <http://developer.valvesoftware.com>

psychophysiology hardware (Nacke et al., 2008). Although *Half-Life 2* allows the control of game audio features internally, sound and music were controlled externally for this experiment. For example, a music track was triggered externally, which was audible during playing and a software trigger controlled whether the game engine would play game sounds or not.

### 9.3.3 Design

We employed a  $2 \times 2$  repeated-measures factorial design using sound (on and off) and music (on and off) as independent variables, using a counter-balanced order of sound and music game-level stimuli. Thus the conditions were: (1) Sound on, Music off, (2) Sound off, Music off, (3) Sound on, Music on, (4) Sound off, Music on. EMG and EDA responses were measured together with questionnaire items indicating the overall game experience for the different playing conditions. Questionnaire item order was randomized for each participant.

### 9.3.4 Procedure

Individuals were invited to the laboratory, where experiments ran in two-hour sessions. After a brief description of the experimental procedure, each participant filled in two forms. All participants had to give informed consent before commencement of the experiment. Individuals were then seated in a comfortable chair, the electrodes were attached and a resting period followed. During this resting period of 3–5 minutes, individual physiological baseline were recorded. Individuals then played under each of the sound and music conditions in a counter-balanced order. Play session lasted a maximum of 10 minutes after which they were interrupted if player were not able to complete the game level. Individuals filled out game experience questionnaires (GEQ) after each session (IJsselsteijn et al., 2008). After all 4 sessions were completed, electrodes were removed, and participants were debriefed, thanked and paid a small participation fee before they were escorted out of the lab.

### 9.3.5 Physiological Measurements

Facial electromyography (EMG) was used to record the activity from left orbicularis oculi, corrugator supercilii, and zygomaticus major muscle regions following the recommendations of Fridlund & Cacioppo (1986) using BioSemi flat-type active electrodes with sintered Ag-AgCl (silver/silver chloride) electrode pellets having a contact area of 4 mm in diameter. The electrodes were filled

with low impedance highly conductive Signa electrode gel (Parker Laboratories, Inc.). The raw EMG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz and using ActiView acquisition software, and afterwards filtered in BESA (MEGIS GmbH, München) using a low cutoff filter (30 Hz, Type: forward, Slope: 6 dB/oct) and a high cutoff filter (400 Hz, Type: zero phase, Slope: 48dB/oct). If data remained noisy, they were excluded from further analysis.

Electrodermal activity (EDA) was measured using two passive Ag-AgCl (silver/silver chloride) Nihon Kohden electrodes ( $1 \mu\text{A}$ , 512 Hz). The electrode pellets were filled with TD-246 skin conductance electrode paste (Med. Assoc. Inc.) and attached to the thenar and hypothenar eminences of a participant's left hand. EMG data were rectified and exported together with EDA data at a sampling interval of 0.49 ms to SPSS (SPSS Inc., Chicago, IL, USA) for further analysis.

### 9.3.6 Data Reduction and Analysis

The physiological data were condensed to seven 1-s means, one second before (baseline; Second 1) and six seconds after the event (the death of the player's own character; Seconds 2–7). To normalize the distributions of physiological data a natural logarithm was taken from EDA and EMG signals. All data were analyzed in SPSS (SPSS Inc., Chicago, IL, USA) by the linear mixed-model procedure with restricted maximum likelihood estimation and a first-order autoregressive covariance structure for the residuals. Participant ID was specified as the subject variable, while the game audio conditions (sound on/music off; sound off/music on; sound on/-music on; sound off/music on), the sequence number of the event, and second (1–7) were specified as the repeated variables. When examining the main effects of game events, the condition, sequence number of an event, and second were selected as factors, and a fixed-effects model that included the main effects of these variables was specified. When examining the interaction effects of condition and game events on physiological activity, the condition, sequence number of an event, and second were selected as factors, and a fixed-effects model that included the main effects of these variables and the Condition  $\times$  Second interaction was specified.

*A linear  
mixed-models  
analysis*

Main effects of event-related changes in physiological activity were tested using the following contrasts.

- Contrast 1: baseline (second 1) vs. response (seconds 2–7).
- Contrast 2: linear trend across Seconds 1 to 7.
- Contrast 3: quadratic trend across Seconds 1 to 7.

Interactions were tested for both quadratic and linear trends. However, since the interaction contrasts with quadratic trends yielded no significant associations, only those using linear trends are reported as follows.

- Interaction Contrast 1a: sound vs. no sound  $\times$  linear trend across Seconds 1 to 7. Interaction Contrast 1b: sound vs. no sound  $\times$  change from baseline (Second 1 vs. Seconds 2 to 7).
- Interaction Contrast 2a: music vs. no music  $\times$  linear trend across Seconds 1 to 7. Interaction Contrast 2b: sound vs. no sound  $\times$  change from baseline (Second 1 vs. Seconds 2 to 7).
- Interaction Contrast 3a: both music and sound vs. neither  $\times$  linear trend across Seconds 1 to 7. Interaction Contrast 3b: sound vs. no sound  $\times$  change from baseline (Second 1 vs. Seconds 2 to 7).
- Interaction Contrast 4a: only music vs. only sound  $\times$  linear trend across Seconds 1 to 7. Interaction Contrast 4b: sound vs. no sound  $\times$  change from baseline (Second 1 vs. Seconds 2 to 7).

#### 9.4 RESULTS

CONDITION	N	PERCENT	TOTAL		PER PARTICIPANT	
			M	MAX	M	MAX
Condition 1: Sound on, Music off	75	22.2	2.41	12		
Condition 2: Sound off, Music off	98	29.0	2.08	8		
Condition 3: Sound on, Music on	66	19.5	1.74	5		
Condition 4: Sound off, Music on	99	29.3	2.12	7		

Table 9.1: Summary of basic statistics for the game events by sound and music conditions (SMCs). Note. In each condition, minimum frequency of events per participant was 0.

Mean frequencies of the game events are presented in Table 9.1. It was found that regardless of the condition, EMG activity for all investigated muscle areas (corrugator supercilii (CS), orbicularis oculi (OO), and zygomaticus major(ZM)) presented a statistically significant quadratic increase.

VARIABLE SOURCE	ESTIMATE	SE	DF	T
<b>CS EMG</b>				
Contrast 1	1.169	0.246	467.174	4.753***
Contrast 3	1.916	0.440	469.790	4.356***
<b>OO EMG</b>				
Contrast 1	2.192	0.324	469.101	6.767***
Contrast 2	1.003	0.340	450.176	2.948**
Contrast 3	3.359	0.580	462.361	5.791***
<b>ZM EMG</b>				
Contrast 1	1.744	0.336	469.937	5.186***
Contrast 3	3.379	0.600	457.737	5.632***

Table 9.2: Contrast analyses for Condition 1 (Sound on, Music off). Note:

Only statistically significant contrasts are reported. Contrast 1: baseline (Second 1) vs. response (Seconds 2–7). Contrast 2: linear trend across Seconds 1 to 7. Contrast 3: quadratic trend across Seconds 1 to 7. \*\* $p < .01$ , \*\*\* $p < .001$

VARIABLE SOURCE	ESTIMATE	SE	DF	T
<b>CS EMG</b>				
Contrast 1	0.854	0.223	666.531	3.829***
Contrast 3	1.505	0.400	663.540	3.765***
<b>OO EMG</b>				
Contrast 1	2.577	0.322	669.393	8.000***
Contrast 2	1.254	0.337	645.294	3.722***
Contrast 3	3.604	0.581	656.414	6.197***
<b>ZM EMG</b>				
Contrast 1	2.348	0.348	670.436	6.758***
Contrast 2	0.949	0.365	640.298	2.601*
Contrast 3	3.815	0.626	652.372	6.094***
<b>EDA</b>				
Contrast 2	0.091	0.039	659.976	2.282*
Contrast 3	-0.090	0.036	639.242	-2.504*

Table 9.3: Contrast analyses for Condition 2 (Sound off, Music off). Note:

Only statistically significant contrasts are reported. Contrast 1: baseline (Second 1) vs. response (Seconds 2–7). Contrast 2: linear trend across Seconds 1 to 7. Contrast 3: quadratic trend across Seconds 1 to 7. \* $p < .05$ , \*\*\* $p < .001$

VARIABLE SOURCE	ESTIMATE	SE	DF	T
CS EMG				
Contrast 1	1.648	0.243	449.197	6.789***
Contrast 3	2.366	0.425	418.814	5.566***
OO EMG				
Contrast 1	3.094	0.366	429.765	8.458***
Contrast 2	1.395	0.395	351.577	3.535***
Contrast 3	4.257	0.635	427.179	6.703***
ZM EMG				
Contrast 1	2.790	0.403	436.903	6.932***
Contrast 2	1.169	0.432	367.770	2.705*
Contrast 3	4.071	0.703	429.406	5.789***

Table 9.4: Contrast analyses for Condition 3 (Sound on, Music on).

Note: Only statistically significant contrasts are reported. Contrast 1: baseline (Second 1) vs. response (Seconds 2–7). Contrast 2: linear trend across Seconds 1 to 7. Contrast 3: quadratic trend across Seconds 1 to 7. \* $p < .05$ , \*\*\* $p < .001$

VARIABLE SOURCE	ESTIMATE	SE	DF	T
CS EMG				
Contrast 1	1.473	0.208	674.711	7.093***
Contrast 3	2.429	0.371	662.364	6.557***
OO EMG				
Contrast 1	2.591	0.300	677.711	8.648***
Contrast 3	4.449	0.541	662.120	8.227***
ZM EMG				
Contrast 1	2.317	0.327	678.387	7.094***
Contrast 3	4.715	0.589	659.994	8.010***
EDA				
Contrast 2	0.106	0.049	634.436	2.164*

Table 9.5: Contrast analyses for Condition 4 (Sound off, Music on).

Note: Only statistically significant contrasts are reported. Contrast 1: baseline (Second 1) vs. response (Seconds 2–7). Contrast 2: linear trend across Seconds 1 to 7. Contrast 3: quadratic trend across Seconds 1 to 7. \* $p < .05$ , \*\*\* $p < .001$

In Condition 1 (sound on, music off), Contrast 1 (first second vs. seconds 2–7) revealed that the response to the death event was a significant increase in EMG activity for CS, OO, and ZM muscle areas ( $p < .001$ , see Table 9.2). Contrast 2, testing linear trend, was significant for OO EMG activity ( $p = .003$ ), but not for others. Results of Contrast 3 showed that the trend was quadratic (first rising and then declining) for all EMG activity measures ( $p < .001$ , see Table 9.2, Figure 9.1). This tendency was repeated in Condition 2 (both sound

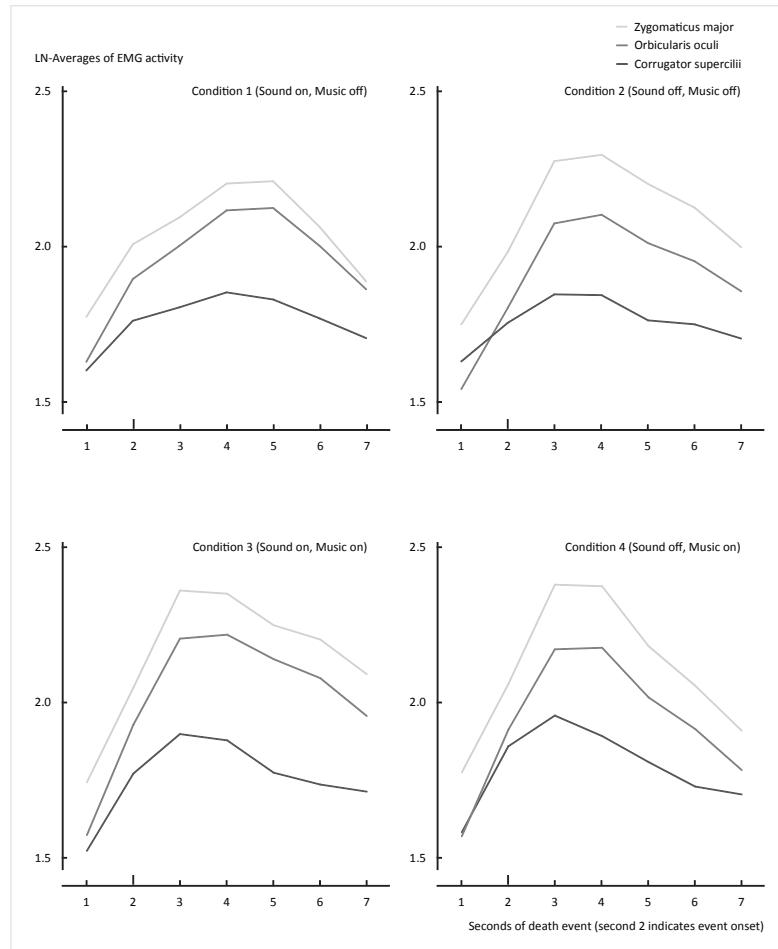


Figure 9.1: Averages of EMG activity during each of the four conditions for ZM, OO, and CS.

and music off, see Table 9.3), Condition 3 (both sound and music on, see Table 9.4), and Condition 4 (sound off, music on, see Table 9.5): Contrast 1 showed that the response was increasing in relation to the baseline second for EMG activity over all muscle areas (all  $p < .001$ ), and Contrast 3 that the response was quadratic, that is, first increasing but decreasing within 7 seconds (all  $p < .001$ ). Contrast 2

yielded significant associations in Condition 2, where sound and music were both turned off, for OO ( $p < .001$ ) and ZM EMG activity ( $p = .010$ ), as it did in Condition 3, both sound and music turned on, ( $p < .001$  and  $p = .007$ , respectively). In Condition 4 (sound off, music on) none of the Contrast 2 tests showed significant associations. However, in all the cases where Contrast 2 was significant suggesting linear trend, t-value for contrast 3 was higher, revealing a trend that was predominantly quadratic. Thus, the results of Contrasts 2 and 3 together indicate that in the most cases, the response to the death event is not an increase in long-term EMG activity level, but rather a transitory peak in EMG activity. The response peaked around Second 3 or 4 in all conditions but the Condition 1, where the peak occurred approximately one second later. In summary, no condition had an effect on the EMG responses elicited by the death event, as the response was in all conditions significant but similar.

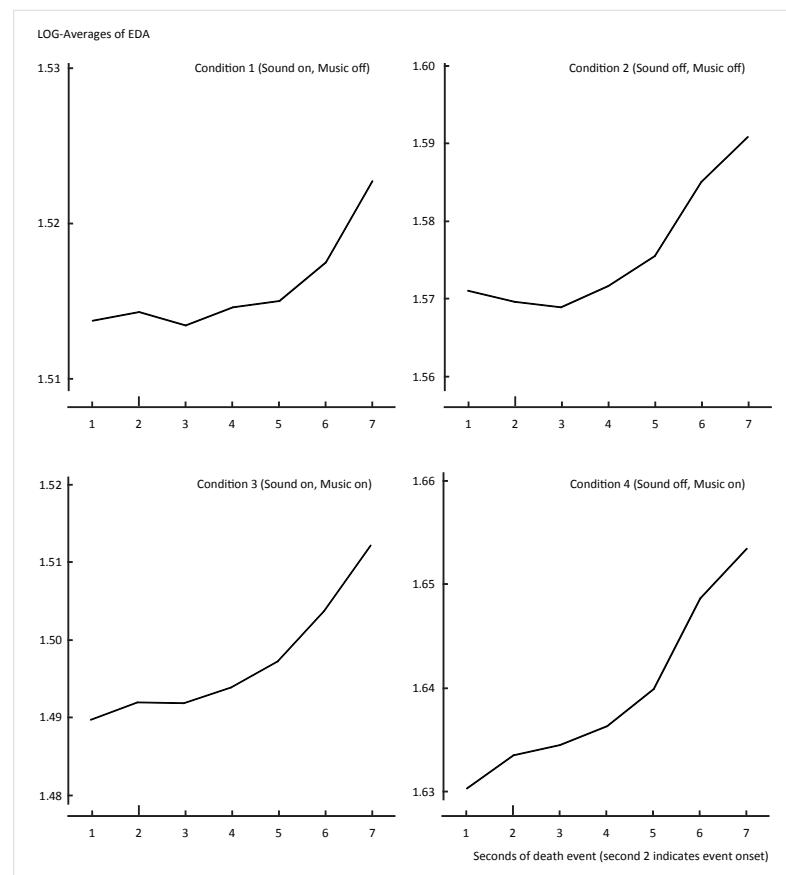


Figure 9.2: Averages of EDA during each of the four conditions. Note the different scales for each condition in the Figure.

The main effects of death events on electrodermal activity showed less uniform responses. In Conditions 1 (sound on, music off) and 3 (sound on, music on), none of the contrasts revealed significant trends; that is, there was no change from the baseline (first second), no linear, and no quadratic trend in response to the event (see Figure 9.2). The trend for EDA in Condition 3 appears linear in visual inspection, but because the amount of death events in this condition was lower than in others, it did not quite reach statistical significance ( $p = .064$ ).

In Condition 2 (sound off, music off), both positive linear and negative quadratic trends ( $p = .023$  and  $.013$  for contrasts 2 and 3, respectively) were found, latter being stronger. Only Contrast 2 showed a significant trend in Condition 4 (sound off, music on) ( $p = .031$ ), revealing a linear increase in EDA as a response to the event.

Contrast analyses tested the interaction between the condition and linear trend of electrodermal activity over seven seconds are presented in Table 9.6. None of the interactions between condi-

VARIABLE SOURCE	ESTIMATE	SE	DF	T
<b>CS EMG</b>				
IA Contrast 2b	1.098	0.464	2242.379	2.367*
IA Contrast 3b	0.790	0.330	2241.504	2.393*
<b>EDA</b>				
IA Contrast 1a	-0.149	0.048	2239.645	-3.084**
IA Contrast 2a	0.123	0.048	2240.459	2.562*
IA Contrast 4a	0.136	0.034	2240.613	4.016***
IA Contrast 4b	0.075	0.032	2278.102	2.314*

Table 9.6: Summary of interaction contrast (IA) analyses for all conditions.

*Note: Only statistically significant contrasts are reported. Interaction Contrast 1: sound vs. no sound (a) × linear trend across seconds 1 to 7, (b) × Second 1 vs. Seconds 2–7. Interaction Contrast 2: music vs. no music (a) × linear trend across seconds 1 to 7, (b) × Second 1 vs. Seconds 2–7. Interaction Contrast 3: both music and sound vs. neither (a) × linear trend across seconds 1 to 7, (b) × Second 1 vs. Seconds 2–7. Interaction Contrast 4: only music vs. only sound (a) × linear trend across seconds 1 to 7, (b) × Second 1 vs. Seconds 2–7. \* $p < .05$ , \*\* $p < .01$  \*\*\* $p < .001$*

tion and quadratic trends showed significant associations, so they are not reported here. Whereas all interactions using linear and quadratic trend EMG activity were non-significant, Interaction Contrasts 2b and 3b testing change from baseline (Second 1) to response

(Seconds 2–7) showed that the CS EMG activity level rose in response to the death event more when music was on than when it was off ( $p = .018$ ), and more when both music and sound were on vs. when they were both off ( $p = .017$ ).

For EDA, Interaction Contrast 1a, testing the interaction of linear trend and the effect of sound vs. no sound, showed that the event prompted a greater linear increase when the sound was off compared to condition where the sound was on (regardless of music). That is, the participants responded with greater arousal to the death event when there were no sounds. Interaction Contrast 2a, testing the interaction of linear trend and the effect of music vs. no music, similarly showed that the event prompted a greater linear increase (greater arousal) when the music was on, as compared to when music was off (regardless of sound). Interaction Contrast 3a was not significant, suggesting that there was no difference in EDA response whether both music and sound were on or off. Interaction Contrast 4a, testing the interaction of linear trend and the effect of only music vs. only sound, revealed that the event elicited a greater linear increase in electrodermal activity when music was on and sound was off, as compared to opposite condition. Interaction Contrast 4b showed that this linear increase was also a significant increase as compared to the baseline (Second 1;  $p = .021$ ). In conclusion, EDA response to the death event increased when the sound was off or music was on, and these effects were cumulative.

## 9.5 DISCUSSION

*No significant phasic effect of sound or music*

Judging from the results of this study, the presence or absence of music or sound does not have a significant effect on phasic facial EMG responses to death events in a first-person shooter digital game, suggesting that the experienced valence during this event is not dependent on the audio. Only CS EMG showed a marginally significant difference between the activity level before and after the event, when comparing the presence and absence of music, and presence of both music and sound and absence of both: in both of these cases the former elicited a little stronger response than the latter, although there was no significant difference in linear or quadratic trends. This could indicate that the negative emotional activation was a little greater when music was on, but the fact that the CS activation increased in any of these cases remains a puzzling result, which contrasts prior studies (Ravaja et al., 2008). This more or less uniform response in ZM and OO EMG activity, which are usually considered as indices of positive emotion, and CS EMG activity, an

index of negative emotion, will be discussed in more detail below.

Experienced arousal, on the other hand, seemed to differ in response to changes whether music and sound were present or not. Results revealed a significant increase in SCL when sound and music, both were off and similarly when music was on and sound was off. Since sound is an important feedback metaphor for software design and usability (Brewster & Crease, 1999), game sound similarly provides feedback for the player about the events and progress in game. Thus, it is reasonable to believe that the lack of sounds makes the game more difficult, which could be related to higher arousal during death events as an index of increased effort in game combat challenges leading to PC death. This was also supported by the interaction test, where comparisons showed greater arousal in conditions where sound was present than in those where it was not. Music seemed to have the opposite, but weaker effect, demonstrated by the fact that the absence of sound elicited an increase in arousal whether there was music or not, but tests for effects of music alone show an increase in arousal in presence of music. Music may thus be seen as a potential facilitator of arousal during death events.

The present study also showed that the death of the PC elicited a temporary increase in ZM and OO EMG activity, typically used as indices for positive emotion, and CS EMG activity, index for negative emotion. The findings for ZM and OO responses were in line with the Ravaja et al. (2008) study. However, the increase in CS activity found in the present study is in disagreement with the Ravaja et al. (2008) study, in which CS activity decreased in response the player character's death. This might be an indicator that the suggested explanation of positive appraisal of player death events does not hold for FPS games with more dramatic and immersive content (e.g. a horror setting). The mixed responses might also be related to the influence of skill on death events, meaning that more skilled players elicit fewer death events and contribute less to the overall physiological assessment. Thus, lesser skilled players might become frustrated by a death event but also enjoy the chance to try again. This is something that might have also been an interesting influence for EDA in Condition 3, which appears linear in visual inspection, but was statistically insignificant because the amount of death events was lower in this condition than in others.

While the co-activation of all three facial muscle areas (ZM, OO, CS) has been shown to indicate a feeling of antipathy in studies using static affective pictures as stimulus material (Bradley & Lang, 2007) the digital game used in this study is likely a much more complex stimulus. Thus, in light of previous results (Wolfson &

Case, 2000), we can assume that psychological assessment of death events in a game is a complex process, possibly moderated by other effects. For example, results of contrast 2, showed a significant linear trend for OO EMG activity but not for others. This could indicate that death events elicit a delayed and attenuated peak of positive OO EMG activity, thus indicating a minor emotional relief some time after the death event.

A possible explanation for the co-activation of facial muscles and the different results in light of prior studies could be the gruesome nature of the death event in the stimulus game (i.e., the horror setting) used in this study. Once a PC is killed the player view drops to the virtual floor, indicating the death of the character out of whose virtual eyes the gameplay is seen. A fading sine tone indicates stopping of a heart, a sound clue known from other media such as television to indicate the death of a person. The screen starts fading into a crimson red instantly, mudding the view into the game world. The emotional relief following several seconds after death event onset could be attached to the complex interaction of these visual cues with the sound cues.

In conclusion, we have studied death events in an FPS game during different game audio conditions and found that neither sound nor music condition had an effect on phasic physiological EMG responses. However, EDA showed a delayed increase when both sound and music were off and when music was on and sound was off. The interaction contrasts revealed a greater linear increase in SCL when sound was off and similar when music was on. These results mark a contradiction to prior reported studies on death events in digital games and reveal that the complexity of game stimuli puts psychophysiological assessment to its limits. It seems also that for EDA, presence of music and absence of sound increase arousal, which could likely be explained with our own game experiences, since lack of sounds makes the game harder and presence of music could make it more thrilling.

Some paths for future work emerge from this study. This could consider correlations between subjective ratings of game sound cues and psychophysiological responses to these cues. In addition, the closer study of brain activity related to death events under different audio conditions might offer better explanations of the attentional and cognitive process involved in these game events. While this study has tried to unravel the impact of game audio on these events, future studies might also consider other aesthetic aspects of game content, such as visual features, and their psychophysiological impact.

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## WIIMOTE VS. CONTROLLER: ELECTROENCEPHALOGRAPHIC MEASUREMENT OF AFFECTIVE GAMEPLAY INTERACTION

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Lennart E. Nacke, and Craig A. Lindley

Submitted for publication.

**Keywords:** *Psychophysiology, entertainment, user experience (UX), digital games, affective gaming, human-centered design, user studies, empirical methods (quantitative), electroencephalography (EEG)*

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### ABSTRACT

*Psychophysiological methods provide non-intrusive, covert and reliable measurements of affective user experience (UX). The nature of affective UX in interactive entertainment, such as digital games, is currently not well understood. With the dawn of new gaming consoles, scientific methodologies for studying user interaction in an immersive entertainment context are needed. This paper reports a study on the influence of interaction modes (Playstation 2 game controller vs. Wii remote and Nunchuk) on subjective experience assessment and brain activity measured with electroencephalography (EEG). Results indicate that EEG alpha and delta power correlate with negative affect and tension when using regular game controller input. EEG beta and gamma power seem to be related to the feeling of possible action in spatial presence with a PS2 game controller. Delta as well as theta power correlate with self-location using a Wii remote and Nunchuk*

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### 10.1 INTRODUCTION

Digital games as a form of immersive media entertainment have matured in their content and interactive design in recent years. The global gaming market was predicted to grow at a compound annual rate of 9.1% to \$48.9 billion in 2011 (PriceWaterhouseCoopers, 2007). One of the driving questions of the game industry is what exactly makes games successful on an atomic level. In light of this, evaluating the design and user experience (UX) of gaming interaction is an open research challenge. With the advent of the Nintendo Wii on the game market, a growing shift of investigations

in game research and industry is happening toward a focus on the human computer interaction (HCI) aspects of digital games. Industry examples for this trend are Microsoft's announcement of *Project Natal* and Sony's planned use of *Eye Toy* as an input tracking technology for novel game interaction. Hence in research, digital games are recently being studied from a UX perspective (Pagulayan et al., 2003), which focuses on user-centered design implications from the affective experiences that digital games create.

#### *New interaction technology for gaming*

While gaming consoles continue to implement different forms of game interaction, tangible and affective forms of interaction are becoming more popular in desktop software design as well. For software and product evaluation studies, this marks a shift from analyses that center on usability to those that are looking at UX with focus on human aspects of interaction, such as behavior, perceptual, emotional and cognitive capabilities of people. This trend indicates that now is a good opportunity for HCI researchers and practitioners to evaluate new methodologies for studying game interaction with scientific rigor. The study of interaction with digital games may inform the interface design of new controllers or the interaction design process in entertainment and desktop applications (Lundgren, 2008).

Most UX research (in games or in general) utilizes qualitative approaches such as usability evaluations, playtesting, interviews and focus groups, and surveys (Pagulayan et al., 2003). For entertainment systems, we are unable to define the same success metrics as for desktop systems, so that regular usability metrics (Law et al., 2008; Tullis & Albert, 2008) (e.g., task completion time, errors) would have to be adapted to work as metrics of in-game behavior, for an example see (Tychsen & Canossa, 2008). Although, more important than performance measures is evaluation the emotional and cognitive experiences provided by game technology and virtual environments. One of the current research problems for evaluation of game interaction is what mental processes relate to which experiential constructs and how to measure these. Establishing such a methodology and correlations for assessing cognitive underpinnings of gameplay experience will be interesting for game researchers and developers as well as for researchers of affective interaction in the UX community.

#### *Sensor technology in HCI*

In the HCI community, we have recently seen studies that use sensor technology (Fairclough, 2008; Nijholt et al., 2008) to unravel the mysteries inherent in the complex human experience in the playing process called gameplay (Mandryk et al., 2006; Nacke & Lindley, 2008b) and assess UX in digital games (Hazlett, 2006; Mandryk,

2008). More specifically, studies have evaluated usability of user interfaces (Smith et al., 2001) and software learnability (Stickel et al., 2007) with the help of electroencephalography (EEG). While other non-invasive techniques for measuring brain activation, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and functional near-infrared spectroscopy (fNIR) exist, EEG is most common because of its relatively easy application in comparison to fMRI and PET. Major limitations of fMRI and PET are among others the pricing, size of the apparatus, required shielding, digestion of a radioactive tracer (PET), and the proneness to motion artifacts. Hence, these techniques are hardly used in HCI research. More recently, the emerging fNIR technique has gained more attention in HCI research (Hirshfield et al., 2009). It uses near-infrared light to spot oxygenated and deoxygenated hemoglobin in the blood flow of the brain as indicators of mental activity. Currently, fNIR and EEG might almost have similar benefits and come close to each other in accuracy. As the technology matures, it might be worthwhile to investigate this as a future supplement to EEG analysis.

Nevertheless, in this paper we follow the common psychophysiological approach using EEG to get a better understanding of UX in games. In addition to the use of psychophysiology in HCI research, we are also seeing more studies that apply neurological and affective methods for examining human experience in design practice (Jenkins et al., 2009). In conclusion, psychophysiological methodology provides non-intrusive, covert and reliable measurements of affective UX, which makes it suitable for studying interactive entertainment (Ravaja, 2004) and possibly evaluating game and interaction design.

In this paper, we will use EEG and subjective questionnaires to establish correlations between EEG activity patterns and described gameplay experience. The paper makes the following contributions to HCI and UX research:

*EEG and  
subjective  
assessment of  
game  
interactions*

1. We present a methodology for affective evaluation of UX in interactive entertainment using EEG signals and subjective surveys. The innovation of this methodology is that it links cumulative brain activity on different frequencies to subjective ratings of experiential phenomena. It builds on prior work that studied relationships between frontal asymmetry and subjective experience (Salminen et al., 2009).
2. The results from our experiment point to a link between EEG beta activity and SP action possibilities (Vorderer et al., 2004) as well as gamma activity and SP action possibilities for PS2

game controller input. There was also a link between theta activity and SP self-location and delta activity and SP self-location for Wii remote and Nunchuk (from here on called *Wiimote*) input. Finally, we could find indicators that alpha activity and negative affect may be related on both Wiimote and regular controller interaction. Thus, EEG activity may be a sign of Wiimote controller input being more intuitive (decreased theta and delta is indicative of lower task load) for a point-and-shoot style game.

## 10.2 RELATED WORK

### 10.2.1 Brief Introduction to Gameplay Experience Constructs

IJsselsteijn et al. (2008) theorized that immersion, tension, competence, flow, negative affect, positive affect, and challenge are important elements of gameplay experience and developed a game experience questionnaire (GEQ) to assess these elements, which will be used in our user study. Preliminary results linking these dimensions to frontal EEG asymmetry during cooperative and competitive play were presented recently (Salminen et al., 2009). In addition, we have seen investigations on spatial presence (SP) that have successfully linked psychometric presence questionnaire data (Vorderer et al., 2004) and EEG activity in a non-interactive virtual reality environment (Baumgartner et al., 2006).

However, these studies did not investigate tonic EEG power differences for game interaction modes and establish correlations of brain wave frequencies with subjective interactive entertainment experience. From an interaction design perspective, we see designing game input modalities and interactions with a digital game as a primary driver for innovation in game design. Thus, our main goal is to establish the correlation of EEG activity measures and subjective reports as a methodology for understanding gameplay design. While we consider EEG to be complementary to many other measures of gameplay experience (e.g., electromyography (EMG) or focus group interviews), it is outside the scope of this article to explore all of these measures in detail.

*Gameplay  
experience*

Gameplay experience may consist of many factors, but the most discussed ones in related literature are immersion (Jennett et al., 2008), presence (Slater, 2002; Wirth et al., 2007), and flow (Csíkszentmihályi, 1990). Jennett et al. (2008) give an extensive conceptual overview of immersion and define it as a gradual, time-based, progressive experience that includes the suppression of all surroundings, together with focused attention and involvement in the sense

of being in a virtual world. Spatial presence is a two-dimensional construct in which the core dimension is the sensation of physical location in a virtual spatial environment and the second dimension entails the perceived action possibilities (i.e., individuals only perceive possible actions relevant to the virtual mediated space) (Wirth et al., 2007). Flow is described as a holistic sensation and peak experience (Csíkszentmihályi, 1990). Hence, complete mental absorption in an activity is fundamental to this concept, which ultimately makes flow an experience mainly elicited in situations with high cognitive load likely accompanied by a feeling of pleasure. All of these three experiential concepts deal with the allocation of attention toward the process of gameplay, which indicates the dedication of cognitive capacities for experiencing the game. Thus, inspection of EEG activity is a plausible approach to researching gameplay experience.

### 10.2.2 *EEG Basics*

Typically, an EEG represents the voltage recorded between two electrodes on the scalp. Electrodes are placed in standard positions on the scalp via a cap adhering to the international standard 10-20 system (Jasper, 1958) or its extended version (Chatrian et al., 1988) known as the 10% system, illustrated for our specific example in Figure 10.1. Each electrode is color-, letter- and number-coded to indicate its positioning (frontal (F), parietal (P), temporal (T), occipital (O), central (C); even numbers denote the right hemisphere and odd numbers the left, z indicates a central position). The neural signals recorded with an EEG are just a rudimentary representation of neural activity, since the electrodes only register the attenuated signal of neuronal activity near the brain's surface. Thus, signals need to be appropriately filtered before analysis to be distinguishable from muscular scalp activity for example.

We recorded brain activity using 32 BioSemi pin-type active electrodes and did not use a ground or reference electrode, because the BioSemi Common Mode Sense (CMS) active electrode and Driven Right Leg (DRL) passive electrode replace the ground electrodes used in conventional systems. The signal is then typically average referenced before any further analysis. This analysis generally includes the calculation of spectral power averages in several frequency bands, such as alpha (e.g. 8–14 Hz), beta (14–30 Hz), theta (4–8 Hz), delta (1–4 Hz), and sometimes gamma (30–50 Hz); for more details see (Cacioppo et al., 2007a). Alpha power increases have been associated with cortical inactivity and mental idleness as well as attentional demand. Beta activity is most evident in the frontal cortex and has been connected to cognitive processes, deci-

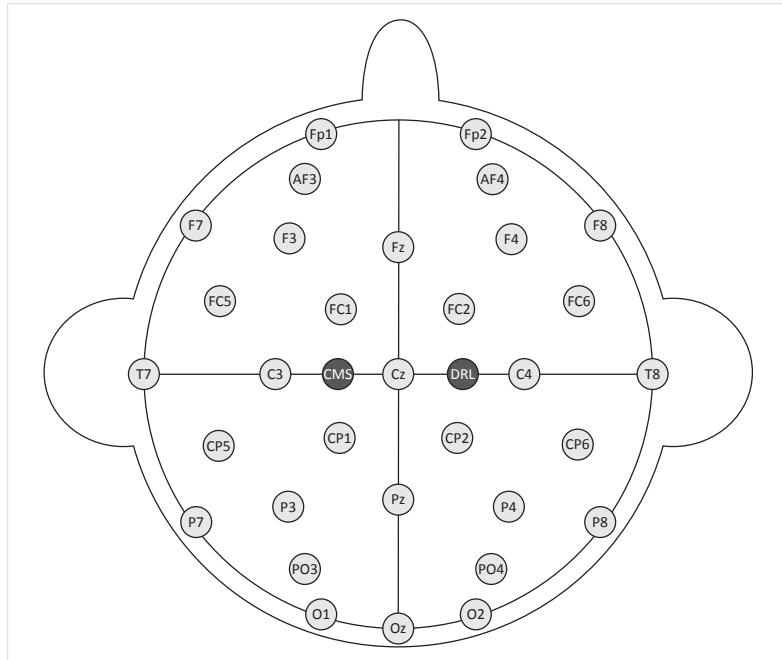


Figure 10.1: Locations of 32 EEG electrodes of the Biosemi ActiveTwo system. The two ground-equivalent electrodes are active common mode sense (CMS) and passive driven right leg (DRL) electrodes.

sion making, problem solving and information processing. Theta activity seems to be related to daydreaming, creativity, intuition, memory recall, emotions and sensations. Delta activity is most prominent during deep sleep and could be associated with unconscious processes, such as fatigue or trance, while Gamma is seldom used because of frequency overlap with muscle activities on the scalp.

### 10.2.3 Evaluative use of EEG in HCI and Game Research

HCI researchers have made use of EEG for classifying cognitive and memory work load (Grimes et al., 2008), for task classification (Lee & Tan, 2006), for monitoring task loading to improve the usability of interfaces (Smith et al., 2001), and also in assessing learnability by discriminating EEG activity averages of top and weak performers (Stickel et al., 2007). In addition, we have seen much research effort in the area of brain-computer interfaces (BCI) in recent years (Wolpaw et al., 2002), especially as an input device for game interaction (Krepki et al., 2007; Mason et al., 2004; Nijholt et al., 2008), while

only a few studies have used EEG as an analytical tool for validating and improving game designs.

EEG studies on game players have shown increased frontal and parietal alpha power activity during a racing game (Schier, 2000) or increasing theta activity during long gaming tasks as an indicator of mental load (He et al., 2008; Sheikholeslami et al., 2007). Another study has investigated EEG modulation of children during digital gameplay activity (Pellouchoud et al., 1999). The study found frontal midline theta activity to increase and alpha activity to attenuate as mental load in games increased. Event-related EEG data was reported for wounding and killing events in a digital console game (Salmi & Ravaja, 2008). Both events evoked increased occipital theta activity, while wounding showed an increase in occipital high theta activity and killing showed a central low alpha asymmetry.

In summary, several different approaches have examined EEG activity during gameplay, but most common is the study of mental load or alpha differences. Only a few current baseline findings of differences in EEG spectral power estimates have been reported so far. No direct correlation between cumulative EEG activity and subjective gameplay experience constructs exists, although we have recently seen research approaching this area (Salmi et al., 2009). In our work, we aim at providing a more complex investigation of relationships between subjective experience and EEG activity using two different forms of gaming input. One of the driving questions for this research was to assess whether a gaming input device will result in subjectively or objectively measurable experience discrepancy.

### 10.3 EXPERIMENTAL USER STUDY

The overarching objective of this experimental study was to help us understand how we can use EEG to measure affective gameplay interaction during an immersive gaming task. Thus, we picked a highly atmospheric horror video game to guarantee an affective interaction experience. We chose the console horror video game *Resident Evil 4* (RE4, Capcom, 2005). The general task in the game was to survive in a gruesome environment by eliminating Zombie-style enemies with a point-and-shoot interaction from a third-person perspective. Participants were asked to play the game on a Sony PlayStation 2 (PS2) console using a regular DualShock 2 analog controller and on a Nintendo Wii using a Wiimote (see Figure 10.2). The game was almost identical on both consoles, except for the

*Experimental  
study goals*



Figure 10.2: Measuring EEG activity during playing games with different interaction devices. Shot taken from experiment during Wiimote condition.

point-and-shoot game interaction mechanic, which we will describe later in this section in detail.

### 10.3.1 Participants

Thirty-six (7 female) Swedish undergraduate university students and employees participated in this experiment. Their age ranged between 18 and 41, having an average ( $M$ ) age of 24 (Standard Deviation [ $SD$ ] = 4.9). Twenty-six participants indicated to play at least once a week. When asked to self-estimate their skill in video game playing, 17 participants rated themselves as casual gamers, 14 as hardcore gamers, with five abstentions. Twelve participants preferred playing single-player games, while 24 participants preferred multi-player games (12 of which liked to play co-located via system link on a console). Ten participants had played the game RE4 before, while 26 had never played it. Three participants were left-handed. Thirty-four participants had full hearing capacity. Inclusion criteria for the frequency analysis were right-handedness and correctly recorded raw data from all electrodes. This constraint

lead to including 27 participants (6 female), aged between 19 and 41 years ( $M = 23.9$ ,  $SD = 5.1$ ) in the analysis after screening the raw data.

### 10.3.2 *Design*

We employed a repeated-measures within-subjects design with game interaction mode as an independent variable in two conditions, classic gamepad input on a PS<sub>2</sub> and point-and-shoot remote input on a Wii. We were especially interested in differences in EEG spectral power activity for the Alpha, Beta, Theta, Delta, and Gamma frequency bands in the two game interaction modes ( $IM: PS_2 \times Wii$ ). At the same time, we employed survey measures to see whether we could correlate spectral power in bands to the questionnaire results. Participants played under each condition in a shifting order (AB, BA) to eliminate repeated-measures effects (using a counter-balanced Latin Squares design). Physiological EEG responses were recorded for each session as well as questionnaire answers.

### 10.3.3 *Procedure*

The experimental sessions were conducted in a European game interaction laboratory during weekdays. The approximate time of each experimental session was one hour. Before the experiment began, participants confirmed that they had filled out a demographic and psychographic screening questionnaire on the web. After a brief description of the experimental procedure, each participant filled out two forms. The first one was a compulsory informed-consent form (with a request not to take part in the experiment when suffering from epileptic seizures or game addiction). The second one was an optional photographic release form. Participants were then seated in a comfortable office chair, which was adjusted according to their individual height. The electrodes were attached and participants were asked to relax. During this resting period of approximately 5 minutes, baseline recordings were taken. The laboratory room was normally illuminated during resting period and game session.

Next, participants were seated in front of a 32-inch cathode-ray tube television monitor, which was connected with a PS<sub>2</sub> and a Wii via a 21-pin SCART connector. Participants played a game session of RE<sub>4</sub> on each console in a counter-balanced order. A saved game was loaded, so that each participant played  $2 \times 10$  minutes (maximum time) of the same game segment, once on a Wii and once on a PS<sub>2</sub>. After completion of the experiment, all electrodes

were removed; the participants were debriefed, thanked and paid a small compensation for partaking before they were escorted out of the lab.

#### 10.3.4 Game and Player Interaction Materials

The game used in this study was the survival horror third-person shooter game RE4 known in Japan as *Biohazard 4*. In this game, the player takes the role of Leon Kennedy, a U.S. secret service agent, set out to investigate the disappearance of the President's daughter in a rural European village. The game segment played in this experiment was the first combat encounter in the Chapter 1 village, where the player has to battle through slow moving enemy throngs called *Los Ganados*. Part of the challenge for eliminating these enemies comes from the slow positioning of the gun to correctly shoot at enemies, who approach players in a speed alternating between slow skulking and rapid dashing.

The content of the game is similar in both console versions used here. However, of particular interest for our study was the different shooting game mechanic employed by controller interaction on PS<sub>2</sub> and by the Wiimote. The controller interaction mode (*IM*) allows players to enter shooting mode with a shoulder button and move about a virtual laser pointer with the right control stick on the controller to find and eliminate targets. This is a standard *IM* for many console shooter games. For the Wii version, the shooter mechanic employs a more direct *IM*, since the Wiimote is used to point at the monitor on which a crosshair appears, allowing for a direct point-and-shoot *IM* known from laser gun arcade shooter games. In summary, for the Wii, the targeting mechanism is a direct mapping of pointing motor action to game interaction and effect, but for the PS<sub>2</sub>, the targeting mechanism is an indirect mapping of stick-control motor action to game interaction. This study investigates effects of these *IMs* on brain activity, subjective game experience and spatial presence.

#### 10.3.5 Equipment and Measures

The equipment used for this study includes Electrooculography (EOG) and EEG psychophysiological measurement apparatus. EOG was used for artifact scoring.

##### *Electroencephalographic Measures*

We recorded brain activity using 32 BioSemi scalp Ag/AgCl (silver/silver chloride), pin-type active electrodes and with Common

Mode Sense (CMS) active electrode and Driven Right Leg (DRL) passive electrode as equivalent to ground, allowing for interference-free, extremely low-noise recordings. The 32 electrodes were placed on the scalp via a cap adhering to the extended 10-20 system (Chatrian et al., 1988; Jasper, 1958), known as the 10% system.

EOG was recorded to correct artifacts from eye movements by placing flat-type active Ag/AgCl electrodes above and below the right eye. Additionally, electromyography (EMG) and electrodermal activity (EDA) were recorded and will form the basis of a future analysis. For EEG electrodes low impedance highly conductive Siga electrode gel was used as a conducting medium. The raw EEG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz, using ActiView acquisition software.

### *Survey Measures*

We used the short version (14 items) of a game experience questionnaire (GEQ) (IJsselsteijn et al., 2008) for this study, which combines several game-related experiential measures. The questionnaire was developed on the basis of focus group research (Poels et al., 2007) and following investigations among frequent players. It consists of the seven dimensions flow, challenge, competence, tension, negative affect, positive affect and sensory and imaginative immersion that are measured each using 2 questionnaire items in the short version. Each item consists of a statement on a five-point scale ranging from 0 (not agreeing with the statement) to 4 (completely agreeing with the statement). In addition, we employed the MEC Spatial Presence Questionnaire (SPQ) (Vorderer et al., 2004). More precisely, we used the spatial presence: self location (SPSL) and spatial presence possible actions (SPPA) subscales, each measured with four items. Each item consisted of a statement on a five-point scale ranging from 1 ("I do not agree at all") to 5 ("I fully agree").

### **10.3.6 Data Reduction and Analysis**

#### *Processing of EEG Data*

Raw EEG signals were recorded using ActiView acquisition software. The raw data was processed in brain-electrical source analysis software BESA. A low cutoff filter of 1 Hz (type: forward, slope: 6dB/oct), a high cutoff filter of 40 Hz (type: zero phase, slope: 48 dB/oct), and a notch filter of 50 Hz (with 2 Hz width) were applied. Since the BioSemi system uses no ground electrodes, the signal was average referenced in BESA and first filtered using a semi-automatic artifact correction with  $\pm 85 \mu\text{V}$  EOG thresholds. Ten minute epochs were selected and visually inspected for artifacts

contamination. Those subjectively interpreted to contain artifacts were rejected for all channels. Average power estimates ( $\mu\text{V}^2$ ) were calculated using Fast-Fourier Transformation (FFT), which was conducted on artifact-free epochs using two-second blocks (4096 points per block) for averaging and including individual baseline values. The power estimates were calculated for the following frequency bands: Delta (1–4 Hz), Theta (4–8 Hz), Alpha (8–14 Hz), Beta (10–30 Hz), and Gamma (30–50 Hz). Spectral power estimates were then averaged over all 32 electrodes for each frequency band and finally transformed using a natural logarithm ( $\ln$ ) to normalize the data distribution (reported as  $5 + \ln$  to adjust for positive values).

### *Statistical Analysis*

The band power averages were analyzed in SPSS using repeated-measures analyses of variance (ANOVAs) with *IM* (PS<sub>2</sub> × Wii) as within-subjects factor and checking for moderating effects of *gender* (*G*), *skill level* (*SL*: hardcore, casual, abstention), *multi vs. single player preference* (*PP*), and *prior playing experience* (*PX*) of the RE<sub>4</sub> game (on the PS<sub>2</sub>) as between-subjects factors.

## 10.4 EXPERIMENT RESULTS

### 10.4.1 Results of EEG

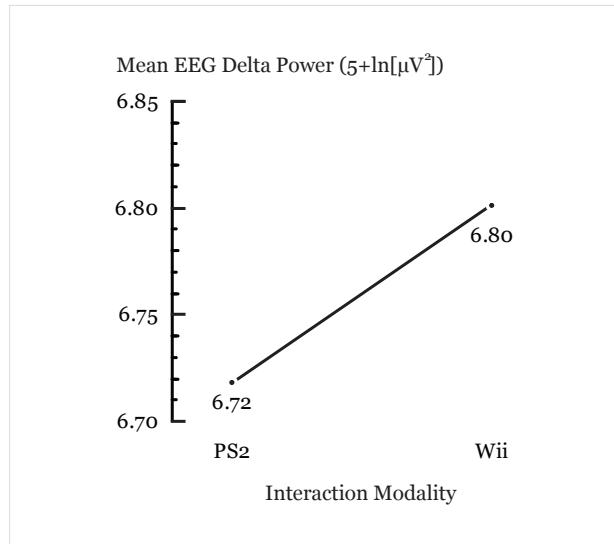


Figure 10.3: Mean EEG power for delta band, showing greater delta activity during Wiimote interaction.

Multivariate analysis of variance (MANOVA) showed general effects of *IM* on band power averages. Specifically, there was a main effect of *IM*,  $F(5, 13) = 6.52, p < .01, \eta_p^2 = .72$ , on spectral power, showing a general increase of brain activity in the Wii condition. This effect seems to be moderated by *SL* and *PP*, since we also found an interaction effect of *IM* with *SL*,  $F(10, 28) = 3.12, p < .01, \eta_p^2 = .53$ , and an interaction effect of *IM* with *PP*,  $F(5, 13) = 5.90, p < .01, \eta_p^2 = .69$ , as well as a complex three way interaction between *SL*, *IM*, and *PP*,  $F(5, 13) = 9.28, p < .01, \eta_p^2 = .78$ .

There were a number of interesting effects on delta power. A main effect of *IM* on delta power (1–4 Hz,  $F_{1,17} = 7.31, p < .05, \eta_p^2 = .30$ , see Figure 10.3). This means that regardless of other factors, the delta power ( $5 + \ln[\mu\text{V}^2]$ ) was significantly higher in the Wii *IM* ( $M = 6.80, SE = .08$ ) than in the PS2 *IM* ( $M = 6.72, SE = .07$ ). This main effect seems to be moderated by a number of interaction effects, first an interaction effect of *IM* and *SL* on delta waves  $F(1, 17) = 4.38, p < .05, \eta_p^2 = .34$ .

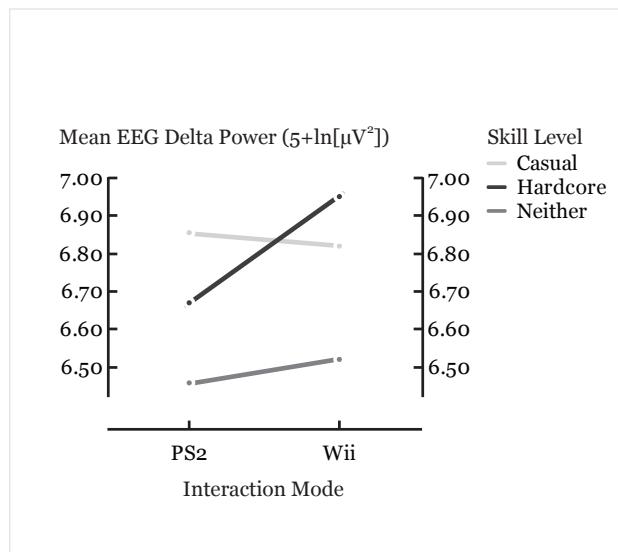


Figure 10.4: Mean EEG power for delta band, showing greater delta activity during Wiimote interaction

This means that participants, who rated themselves as hardcore players, had higher delta activity with Wiimote interaction than with PS2 interaction (see Figure 10.4). For casual gamers and abstentions, there was no significant difference in delta activity between the two conditions, although casual gamers showed a slight attenuation of delta activity in the Wiimote condition. Another interaction effect of *IM* and *PP* was found on delta power estimates  $F(1, 17)$

$\eta_p^2 = .454$ ,  $p < .05$ ,  $\eta_p^2 = .21$ . There was a significant increase of delta activity in the Wiimote condition for participants that prefer single player games ( $M_{PS2} = 6.64$ ,  $SE_{PS2} = .12$ ,  $M_{Wii} = 6.77$ ,  $SE_{Wii} = .12$ ), while this increase was not as prominent for participants with multiplayer preference ( $M_{PS2} = 6.77$ ,  $SE_{PS2} = .09$ ,  $M_{Wii} = 6.82$ ,  $SE_{Wii} = .097$ ). Finally, an interaction effect of *IM* and *PX* on delta activity  $F(1, 17) = 5.93$ ,  $p < .05$ ,  $\eta_p^2 = .26$ ) was significant. Similar to the interaction effect of *IM* and *PP* on delta, we found that participants that had played RE<sub>4</sub> before had a more prominent increase in delta activity ( $M_{PS2} = 6.59$ ,  $SE_{PS2} = .13$ ,  $M_{Wii} = 6.75$ ,  $SE_{Wii} = .13$ ) than those who had not played it before the experiment ( $M_{PS2} = 6.75$ ,  $SE_{PS2} = .09$ ,  $M_{Wii} = 6.81$ ,  $SE_{Wii} = .09$ ).

Another interesting interaction effect was found on alpha power estimates, *IM* and *PX* had a significant effect on alpha power  $F(1, 17) = 8.34$ ,  $p < .05$ ,  $\eta_p^2 = .33$ . For participants, who had played RE<sub>4</sub> before, we found a noteworthy increase in alpha activity in the Wiimote condition ( $M_{PS2} = 6.22$ ,  $SE_{PS2} = .19$ ,  $M_{Wii} = 6.40$ ,  $SE_{Wii} = .17$ ), while those who had not played it before the experiment showed attenuated alpha power in the Wiimote condition ( $M_{PS2} = 6.14$ ,  $SE_{PS2} = .13$ ,  $M_{Wii} = 6.08$ ,  $SE_{Wii} = .11$ ) compared to PS<sub>2</sub>. In general, people who had played RE<sub>4</sub> before elicited higher alpha power.

The same interaction effect (*IM*  $\times$  *PX*) was found on beta power  $F(1, 17) = 9.52$ ,  $p < .01$ ,  $\eta_p^2 = .36$ , but here people who had played RE<sub>4</sub> before elicited generally lower beta power. Participants, who had played RE<sub>4</sub> before had increased beta activity in the Wiimote condition ( $M_{PS2} = 6.73$ ,  $SE_{PS2} = .17$ ,  $M_{Wii} = 6.93$ ,  $SE_{Wii} = .16$ ), while those who had not played it before the experiment showed attenuated beta power in the Wiimote condition ( $M_{PS2} = 7.08$ ,  $SE_{PS2} = .11$ ,  $M_{Wii} = 6.99$ ,  $SE_{Wii} = .11$ ). Finally, a complex interaction effect of *IM*  $\times$  *SL*  $\times$  *PP* on beta power was found  $F(1, 17) = 6.72$ ,  $p < .05$ ,  $\eta_p^2 = .28$ . Hardcore players, who preferred to play in single player mode, showed attenuated beta power in the Wiimote condition ( $M_{PS2} = 6.73$ ,  $SE_{PS2} = .40$ ,  $M_{Wii} = 6.48$ ,  $SE_{Wii} = .38$ ), while generally having a lower power average than casual gamers or abstentions, for which beta power did not change notably between Wii and PS<sub>2</sub>. Hardcore players, who preferred to play in multiplayer mode, showed increased beta power in the Wiimote condition ( $M_{PS2} = 6.83$ ,  $SE_{PS2} = .13$ ,  $M_{Wii} = 6.95$ ,  $SE_{Wii} = .12$ ), the same was true for abstentions that preferred multiplayer ( $M_{PS2} = 6.40$ ,  $SE_{PS2} = .40$ ,  $M_{Wii} = 6.59$ ,  $SE_{Wii} = .38$ ), while casual players with multiplayer preference showed attenuated beta power in this condition ( $M_{PS2} = 7.03$ ,  $SE_{PS2} = .19$ ,  $M_{Wii} = 6.85$ ,  $SE_{Wii} = .18$ ).

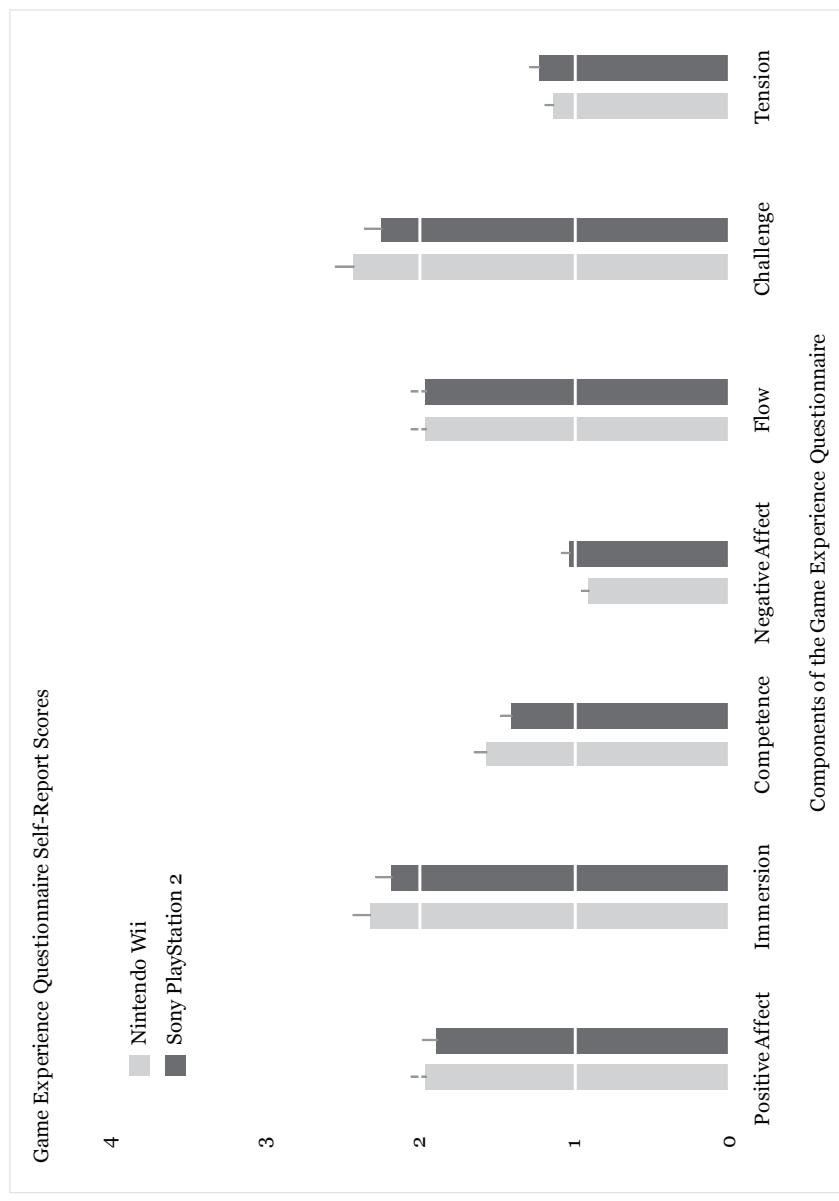


Figure 10.5: Results of the game experience self-report questionnaire (GEQ). Error bars show +95% CI for all bar charts.

On a side note, gender seemed to have moderating effects on alpha  $F(1, 17) = 8.39, p < .05, \eta_p^2 = .33$ , beta  $F(1, 17) = 17.93, p < .01, \eta_p^2 = .51$  and gamma  $F(1, 17) = 8.88, p < .01, \eta_p^2 = .34$ , power, which is likely due to females generally eliciting stronger psychophysiological signals (Cacioppo et al., 2007a).

#### 10.4.2 Results of the GEQ

No significant main effect of IM or other significant interaction effects were found on the GEQ results shown in Figure 10.5. Thus, although we found significantly different physiological results, subjectively playing with Wiimote and PS2 Controller was experienced equally.

#### 10.4.3 Results of the SP Questionnaire

Spatial presence self-location was rated significantly different between Wii and PS2  $F(1, 35) = 4.44, p < .05, \eta_p^2 = .11$ .

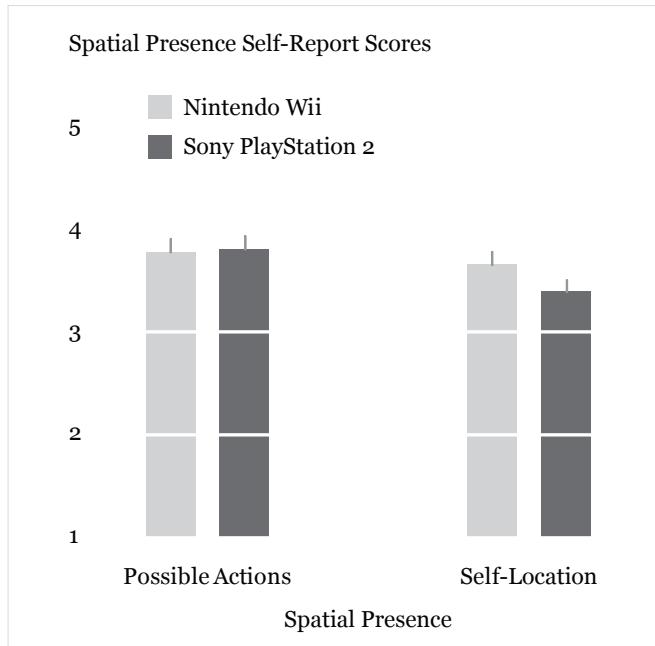


Figure 10.6: Results of MEC spatial presence questionnaire (Vorderer et al., 2004) for our experimental game interaction conditions.

The feeling of self-location spatial presence in the game world was experience significantly higher using the Wiimote controller compared to the PS2 controller (see Figure 10.6). Interaction with

the Wiimote seemed to have facilitated the experience of spatial presence through self-location.

#### 10.4.4 Correlations of EEG Power and SP Ratings

EEG BAND	SP POSSIBLE ACTIONS	SP SELF-LOCATION
Alpha		
PS2	.124	-.096
Wii	-.231	-.275
Beta		
PS2	.396*	.311
Wii	-.166	.058
Theta		
PS2	-.097	-.240
Wii	-.307	-.450*
Delta		
PS2	-.122	-.179
Wii	-.357	-.448*
Gamma		
PS2	.413*	.370
Wii	-.123	.089

Table 10.1: Correlations coefficients (Pearson's  $r$ ) in the two interaction mode (*IM*) conditions between mean EEG power bands ( $5+\ln[\mu\text{V}^2]$ ) and MEC spatial presence self-report survey answers (Vorderer et al., 2004) ( $N=27$ ). \* $p < .05$

We ran a correlation analysis (using Pearson's  $r$ ) within the two *IM* conditions between normalized EEG power averages and SPQ subjective ratings. The correlation results are presented in Table 10.1. The pattern that emerges from the correlations of EEG power and SPQ lets us assume that with increasing beta power and increasing gamma power, ratings for spatial presence possible actions increase when playing with a PS2 controller. On the other hand, attenuated delta and theta power is related to an increase in spatial presence self-location ratings when playing with a Wiimote.

EEG BAND	POSITIVE AFFECT	NEGATIVE AFFECT	IMMERSION	COMPETENCE	FLOW	CHALLENGE	TENSION
Alpha							
PS2	-.179	.435*	-.153	.042	-.095	.062	.395*
Wii	-.177	.398*	-.129	.047	-.206	-.045	.249
Beta							
PS2	.247	.116	.083	.156	.190	.258	.076
Wii	-.248	.160	-.055	-.215	-.001	.015	.331
Theta							
PS2	-.340	.376	-.315	.028	-.228	-.080	.348
Wii	-.244	.205	-.291	-.058	-.319	-.113	.206
Delta							
PS2	-.256	.425*	-.263	.007	-.202	-.071	.353
Wii	-.240	.219	-.323	-.057	-.244	-.172	.194
Gamma							
PS2	.365	-.024	.132	.158	.215	.217	-.091
Wii	-.236	-.026	-.045	-.339	.048	-.027	.288

Table 10.2: Correlations (Pearson's *r*) in the two interaction mode (*IM*) conditions between mean EEG power bands ( $5 + \ln[\mu\text{V}^2]$ ) and GEQ items ( $N = 27$ ). \* $p < .05$ .

#### 10.4.5 Correlations of EEG Power and GEQ Ratings

We ran another correlation analysis (using Pearson's  $r$ ) for EEG power averages and GEQ ratings, which showed a significant positive correlation between alpha power and negative affect ratings in both *IM* conditions (see Table 10.2). Therefore, an increase of alpha power during gameplay with either controller might be related to an increase in subjective negative affect ratings.

For the *IM* with PS<sub>2</sub> controller, there is also a significant positive correlation between tension ratings and alpha power. Thus, the more tension is felt, when playing with a PS<sub>2</sub> controller, the more alpha activity is elicited. In addition, delta power positively correlates with negative affect when a PS<sub>2</sub> controller is used. Thus, we both, delta power and alpha power correlated with negative affect ratings in this experiment. None of the other correlations were significant.

Interesting to note, although not significant, is also the negative correlation between immersion as well as flow ratings and theta power for both *IMs*. Since increased theta power is related to mental processing, a worthy future endeavor would be to analyze immersion and flow with respect to attenuation in theta activity.

#### 10.5 DISCUSSION AND FUTURE WORK

In our experimental study, we have found a main effect of *IM* on EEG delta power, where playing with the Wiimote showed increased delta activity. This is somewhat surprising and hard to interpret, since increased delta power usually indicates sleep or drowsiness. Skill level seemed to have been the moderating factor for this result (see again Figure 3). It could possibly indicate that hardcore players simply did not have as much mental activity when playing with the Wiimote. This would be in line with the attenuated beta for single player hardcore gamers in the interaction of *IM* × *SL* × *PP*, which would indicate less information processing for this group when playing with the Wiimote. However, this would somehow contrast the finding that people with prior playing experience of RE<sub>4</sub> showed increased beta power with the Wii, possibly because they did not play this version before and information processing was increased for learning the input controls.

This could give another explanation for the increased delta activity, since motion interaction with the Wiimote could also have a fatigue effect on players. Thus, the increase in beta power would indicate increased mental effort, together with the physical effort exerted this could rapidly lead to *interaction fatigue* when using the

*Interaction fatigue*

Wiimote. If this *interaction fatigue* is of a physical nature, the alpha power increase we found for the same interaction effect ( $IM \times PX$ ) could be explained as decreased mental leading to fatigue in line with findings stating that as mental load in games increases, alpha activity is attenuated (Pellouchoud et al., 1999). While there is less alpha power than beta power in both conditions, alpha power is still increased in the Wiimote condition, indicating fatigue. Since all of these explanations are highly hypothetical, main and interaction effects of  $IM$  on brain power estimates remain inconclusive in this study.

However, the correlations that were found between brain power estimates and subjective questionnaire ratings paint an interesting picture of brain power counterparts to subjective experience. First, the interesting correlation of alpha power and negative affect seems to support the notion that if a game is not experienced as positively challenging it might be due to low mental workload. Or the other way around, mental idleness may lead to subjective experienced negative affect. For the PS2 an additional correlation with delta power was significant. Thus, delta power in this case is likely to indicate a state of low mental load or general sleepiness (potentially not triggered by the game, but by external factors), which then leads to the increased negative affect ratings.

Furthermore, the correlation between tension and alpha activity could indicate that when a game is not mentally challenging enough, possibly leading to attentional demand indicated by an alpha power increase, it is experienced in a negative tense way. Or on the other hand, when a game is too difficult, the player is likely going to lose interest and thus elicit increased alpha power as an indicator for cortical inactivity. For future studies, employing a success metric for playing (e.g., a high score) could potentially lead to interesting correlations of performance and alpha activity.

#### *Correlations with spatial presence*

The correlation results of the spatial presence questionnaire were even more interesting in a game interaction context. The positive correlation between beta and gamma power and the possible actions items seem to support the notion that increased mental activity in a game enhances spatial presence through allowing more actions. In the context of RE4, the game controller required a significant amount of cognitive processing for the point-and-shoot task, while the more intuitive Wiimote might have required less cognitive processing (therefore the increased delta). Hence, it would not have significantly influenced the feeling of possible actions. On the other hand, delta and theta attenuation point to increased sense of self-location with the Wiimote. Participants that had low delta or theta activation

felt a stronger sense of self-location. Self-location could therefore also be a construct fueled by mental activity for the cognitive effort necessary to suspend disbelief and immerse inside the game world. The negative correlations between theta and immersion or flow all support the idea of active cognitive information processing for mental transference to the game world. Positive game experiences in this context might be related to the cognitive effort involved in creating such experiences. Increased delta power points to the idea that less mental effort is needed when playing a game with a more intuitive input device.

In summary, we have demonstrated that the accumulated use of EEG spectral power and survey measures can help us understand gameplay experience phenomena from a cognitive processing perspective. We have likely witnessed a phenomenon, we would like to call *interaction fatigue* that can result from physical interaction with a game using sensor controllers like the Wiimote. In the future, we would like to supplement EEG analysis with techniques like fNIR, EMG, and EDA to get a more complete picture of emotional and cognitive engagement with interactive entertainment.

## 10.6 CONCLUSION

We have shown that EEG evaluation of UX in games is a valuable tool for understanding neural underpinnings of qualitative descriptions of experience. In addition, we have provided further support for construct validation of the GEQ with the demonstrated correlations of GEQ results and different EEG patterns. Using our established methodology, interaction designers might be able to validate their designs by correlating brain activation patterns with subjective evaluations of interaction design or game design features. Thus, we have achieved a better understanding of the human component, the user of interactive entertainment, in HCI, which can hopefully inspire new design directions for game and interaction design in the future.



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Part IV  
APPENDIX



# A

## EXPERIMENTAL PROCEDURE

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*This guideline was developed on the internal GAMALab Wiki to help students set up psychophysiological experiments using the available lab equipment.*

### A.1 DISPOSABLES CHECKLIST

*(There should always be a decent supply of these in the laboratory, syringes should be checked every once in a while)*

- TD-246 SC Electrode Paste for Galvanic Skin Response
- Signa gel by Parker (low impedance highly conductive gel, for EEG and EMG)
- E6 Disposable Sponge Disks (100-packs can be ordered through Cephalon)
- Tubegauze elastic net (allows the cap to fit more snugly at posterior electrodes without requiring that the cap be overly tight)
- Synapse conductive electrode eream for Electromyography. Measurement of muscle activity through electrodes on the skin (EMG) (SYN 1505), 5oz. Refillable squeeze bottle.
- PDI electrode skin prep pads
- Adhesive disks
- 3M Micropore Surgical Tape
- Towels
- Liquid soap or shampoo for participants (for washing gel off hair after the experiment)
- Drinking water

*Ideally, a laboratory inventory would keep track of these items, allowing researchers to reorder anything in good time ahead of upcoming experiments*

### A.2 BEFORE EXPERIMENTS START

1. Turn on computers
2. Put "Experiments, do not disturb" sign on door
3. *OPTIONAL:* Prepare glasses and mineral water at a table

4. OPTIONAL: Prepare refreshments in bowls at the same table
5. Print out *informed-consent* forms
6. Print out *photographic-release* forms
7. Check availability of equipment
8. If you want to make video or audio recordings check the recorders for free space, eventually perform a backup of the data, do this well in advance! Make a test recording and delete it from hard disk to save space.

### A.3 COURSE OF OPERATION

*Please follow these steps when conducting a psychophysiological experiment in the Games and Media Arts Laboratory.*

*Using a gray background puts less strain on the eyes and allows the participants to relax with eyes open. In this condition, good EEG baseline recordings can be made.*



Figure A.1: The image used for fixation during psychophysiological resting period.

1. Before the day of the experiment, inform participants of time and place, explain to them the basics of EEG (no brain control or thought access), also tell them that on the day of the experiment no coffee, tobacco, snus, caffeine/energy drinks or too much candy should be consumed.
2. If participant is chewing gum, make sure he spits it out before experiments start
  - Always act *professional* as you proceed
3. Participant signs informed-consent form and photographic-release forms
4. Check participants name and email address (cell phone no.) off your list

- If participants had to fill out a questionnaire beforehand, make sure questionnaire was successfully completed
5. If EKG is used, attach the electrodes to the frontal body first, should only be used with disposable electrodes
  6. Attach the electrodes in the following order: EKG, EMG (OO, CS, ZM), EEG, EOG (upper, lower), EDA
    - Attach skin conductance (SCL) electrodes to the *thenar* and *hypothenar* eminences of the left hand of the subject
    - Attach EEG cap to participant comfortably
    - Check correct alignment of cap (consult Biosemi manual if necessary)
    - Load syringe with gel
    - Fill electrode holes in cap gently with electrolyte gel (consult Biosemi manual if necessary)
    - Attach electrodes to EEG cap (color and letter coding)
    - Plug EEG cable into ActiveTwo System
    - Attach Ex1 flat-type electrode to *orbicularis oculi* area (EMG)
    - Attach Ex2 flat-type electrode to *corrugator supercilii* area (EMG)
    - Attach Ex3 flat-type electrode to *zygomaticus major* area (EMG)
    - Attach Ex4 flat-type electrode to upper eye (OO) area (EOG)
    - Attach Ex5 flat-type electrode to lower eye (OO) area (EOG)
    - Plug cables into ActiveTwo system
  7. Before you start ActiView, make sure it has the right default ActiView configuration file.
  8. Start the system and check for artifacts or noise in the signals, eventually repeat above procedure until artifacts disappear
  9. Participant then has to get a baseline state when recording using the fixation cross on gray background (see Figure A.1). Participant should sit comfortably and fixate the cross for 5–7 minutes, while a test recording is saved as YYYYMMDD-Test-NN.bdf in the desired folder for the experiment (YYYYMMDD being the date and NN being a consecutive number).

10. Ideally, experimenters should not be present in the room during and after this.
11. Short instruction on the experiment should then be given to the participant
12. Then the game should be played for a maximum of 5 minutes, especially for those players unacquainted with the control scheme
13. Experiments should log all unusual events in an experiment protocol, which should refer to the participant ID and the time and date.
  - If subjects need to repeat something, let them proceed—even with huge recording problems (e.g., when you cannot get the noise out of the EEG signal after the third try) and mark the data as faulty afterwards—blame the system, not the participant
14. Try to get some small informal feedback from the participants after the experiment and log that for future improvements
15. By all means **back up data** after each experiment or at least at the end of each day! Put all data in a recognizable folder structure, ideally integrating all data from different recording systems within one folder per participant. Save this as the participant ID, so you can quickly access it later.

# B

## GAME EXPERIENCE QUESTIONNAIRE (GEQ)

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IJsselsteijn *et al.* (2008) developed this game experience questionnaire (GEQ) in the FUGA EC-funded project (*The fun of gaming: Measuring the human experience of media enjoyment, STREP/NEST-PATH Deliverable D3.3*) for assessing game experience. The GEQ is a self-report measure, which aims to dependably and broadly characterize the versatile experience of playing digital games. Its inception paved the way for assessing other measures of game experience in the FUGA project such as psychophysiological measurements. The questionnaire is based on focus group research and subsequent survey investigations among frequent players (Poels *et al.*, 2007).

### B.1 INTRODUCTION TO THE CORE GEQ

This is the heart of the GEQ that allows assessing many components of players' experience directly after a digital gaming session. Table B.1 shows the scale on which each questionnaire item was rated.

NOT AT ALL	SLIGHTLY	MODERATELY	FAIRLY	EXTREMELY
0	1	2	3	4

Table B.1: On the GEQ scale, players have to indicate how they felt while playing the game for each of the items of the questionnaire.

Tables B.2 and B.3 show the 7 components of the core GEQ: Sensory and Imaginative Immersion, Tension, Competence, Flow, Negative Affect, Positive Affect, and Challenge. Each component is measured with 5 question items, except for Sensory and Imaginative Immersion, which is measured with 6 items.

### B.2 CORE GEQ TABLES

In the following I have listed the complete GEQ items. Cronbach's  $\alpha$  was reported to be an average of .81 in the first tests for FUGA Deliverable 3.3. In the first FUGA pilot study conducted at BTH, the average Cronbach's  $\alpha$  for the GEQ was .85 (boring game level), .76 (immersing game level), and .87 (flow game level).

FACTOR	ITEM	STATEMENT
Immersion*	3	I was interested in the game's story
	14	It was aesthetically pleasing
	20	I felt imaginative
	21	I felt that I could explore things
	30	I found it impressive
	33	It felt like a rich experience
Flow	5	I felt completely absorbed
	15	I forgot everything around me
	28	I lost track of time
	31	I was deeply concentrated in the game
	34	I lost connection with the outside world
	40	I was fully occupied with the game
Competence	2	I felt skillful
	12	I felt strong
	17	I was good at it
	19	I felt successful
	23	I was fast at reaching the game's targets
	42	I felt competent
Tension	7	I felt tense
	9	I felt restless
	24	I felt annoyed
	27	I felt irritable
	32	I felt frustrated
	39	I felt pressured
Challenge	8	I felt that I was learning
	13	I thought it was hard
	26	I felt stimulated
	29	I felt challenged
	36	I had to put a lot of effort into it
	37	I felt time pressure

Table B.2: GEQ components competence, immersion, flow, tension, and challenge and their respective questionnaire items. Spare items are colored gray. \*Immersion refers to Sensory and Imaginative Immersion and is measured with 6 items.

COMPONENT	ITEM	STATEMENT
Positive Affect	1	I felt content
	4	I could laugh about it
	6	I felt happy
	16	I felt good
	22	I enjoyed it
	41	I thought it was fun
Negative Affect	10	I thought about other things
	11	I found it tiresome
	18	I felt bored
	25	I was distracted
	35	I was bored by the story
	38	It gave me a bad mood

Table B.3: Positive and Negative Affect Items on the GEQ scale. Spare items are colored gray.

In the second FUGA pilot study at BTH, the reliability of the GEQ was a bit deviant as shown in Table B.4 for the 4 conditions used in the experiment.

GEQ COMPONENT	C1 $\alpha$	C2 $r$	C3 $r$	C4 $r$
Immersion	.86**	.37	.60	.46
Flow	.83*	.63	.85	.75
Competence	.90*	.75	.69	.72
Tension	.78*	.71	.77	.77
Challenge	.53*	.30 <sup>+</sup>	.15 <sup>++</sup>	.54
Positive affect	.89*	.50	.68	.75
Negative affect	.55*	.58	.37	.38

Table B.4: For condition C1 = Sound on | Music off, Cronbach's  $\alpha$  was used. For conditions C2 = Sound off | Music off, C3 = Sound off | Music on, and C4 = Sound on | Music on, Pearson's correlation coefficient  $r$  was used.  $N = 36$ ,  $N_{\text{Items}} = 2(^{*}5)(^{**}4)$ ,  $p < 0.05$  for all  $r$ , except <sup>+</sup>( $p < 0.1$ ) and <sup>++</sup>( $p > 0.1$ ).

## B.3 GEQ TRANSLATIONS

## B.3.1 Swedish Version of the GEQ

*The Swedish version of the GEQ was translated by my colleague Charlotte Sennерsten during the FUGA project.*

1. Jag kände mig nöjd
2. Jag kände mig skicklig
3. Jag var intresserad i spelets berättelse
4. Jag kunde skratta åt det
5. Jag kände mig fullständigt absorberad
6. Jag kände mig lycklig
7. Jag kände mig spänd
8. Jag kände att jag lärde mig
9. Jag kände mig rastlös
10. Jag tänkte på andra saker
11. Jag tyckte det var tröttsamt
12. Jag kände mig stark
13. Jag tyckte det var svårt
14. Det var estetiskt tilltalande
15. Jag glömde allting runtom mig
16. Jag mådde bra
17. Jag var bra på det
18. Jag kände mig uttråkad
19. Jag kände mig lyckad
20. Jag kände mig fantasifull
21. Jag kände att jag kunde utforska saker
22. Jag tyckte om det
23. Jag var snabb att nå spelet's mål
24. Jag kände mig irriterad
25. Jag var disträ
26. Jag kände mig stimulerad

27. Jag kände mig lättretlig
28. Jag förlorade tidsuppfattning
29. Jag kände mig utmanad
30. Jag tyckte det var imponerande
31. Jag var djupt koncentrerad i spelet
32. Jag kände mig frustrerad
33. Det kändes som en maffig upplevelse
34. Jag förlorade kontakt med den yttre omgivningen
35. Jag var uttråkad av berättelsen
36. Jag var tvungen att anstränga mig
37. Jag kände tidspress
38. Jag blev på dåligt humör
39. Jag kände mig pressad
40. Jag var fullt upptagen med spelet
41. Jag tyckte det var roligt
42. Jag kände mig kompetent

### B.3.2 German Version of the GEQ

1. Ich fühlte mich zufrieden
2. Ich habe mich geschickt gefühlt
3. Ich interessierte mich für die Handlung des Spiels
4. Ich konnte über Sachen im Spiel lachen
5. Ich war völlig gefesselt
6. Ich habe mich glücklich gefühlt
7. Ich war angespannt
8. Ich hatte das Gefühl, etwas zu lernen
9. Ich fühlte mich ruhelos
10. Ich habe an andere Dinge gedacht
11. Ich fand es ermüdend

*The German version of the GEQ was translated by our colleagues Dorotheé Hefner and Christoph Klimmt.*

12. Ich fühlte mich sicher
13. Ich fand es schwierig
14. Das Spiel war ästhetisch ansprechend
15. Ich habe alles um mich herum vergessen
16. Ich habe mich gut gefühlt
17. Ich war gut
18. Ich habe mich gelangweilt
19. Ich habe mich erfolgreich gefühlt
20. Ich kam mir einfallsreich vor
21. Ich hatte das Gefühl Dinge erforschen zu können
22. Ich hatte Spaß
23. Ich habe die Spielziele schnell erreicht
24. Ich habe mich verärgert gefühlt
25. Ich war abgelenkt
26. Ich fühlte mich stimuliert
27. Ich war reizbar
28. Ich habe mein Zeitgefühl verloren
29. Ich fühlte mich herausgefordert
30. Ich fand es beeindruckend
31. Ich habe mich sehr auf das Spiel konzentriert
32. Ich fühlte mich frustriert
33. Das Spiel bot eine reichhaltige Erfahrung
34. Ich habe die Verbindung zur Außenwelt verloren
35. Ich war von der Geschichte gelangweilt
36. Ich musste mich beim Spielen sehr anstrengen
37. Ich habe Zeitdruck verspürt
38. Es hat mich in eine schlechte Stimmung gebracht
39. Ich habe mich unter Druck gefühlt
40. Ich wurde komplett vom Spiel vereinnahmt
41. Ich fand, es hat Spaß gemacht
42. Ich habe mich kompetent gefühlt

## B.4 STATISTICAL ANALYSIS OF THE GEQ

```

*GEQ Immersion Scale Reliability.
RELIABILITY
/VARIABLES=GEQ_03 GEQ_14 GEQ_20 GEQ_21 GEQ_30 GEQ_33
/SCALE('Sensory and Imaginative Immersion') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.

*GEQ Competence Scale Reliability, GEQ_42 can be omitted.
RELIABILITY
/VARIABLES=GEQ_02 GEQ_12 GEQ_17 GEQ_19 GEQ_23 GEQ_42
/SCALE('Competence') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.
*GEQ Flow Scale Reliability, GEQ_40 can be omitted.
RELIABILITY
/VARIABLES=GEQ_05 GEQ_15 GEQ_28 GEQ_31 GEQ_34 GEQ_40
/SCALE('Flow') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.
*GEQ Tension Scale Reliability, GEQ_39 can be omitted.
RELIABILITY
/VARIABLES=GEQ_07 GEQ_09 GEQ_24 GEQ_27 GEQ_32 GEQ_39
/SCALE('Tension') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.
*GEQ Challenge Scale Reliability, GEQ_37 can be omitted.
RELIABILITY
/VARIABLES=GEQ_08 GEQ_13 GEQ_26 GEQ_29 GEQ_36 GEQ_37
/SCALE('Challenge') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.
*GEQ Positive Affect Scale Reliability, GEQ_41 can be omitted.
RELIABILITY
/VARIABLES=GEQ_01 GEQ_04 GEQ_06 GEQ_16 GEQ_22 GEQ_41
/SCALE('Positive Affect') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.
*GEQ Negative Affect Scale Reliability, GEQ_38 can be omitted.
RELIABILITY
/VARIABLES=GEQ_10 GEQ_11 GEQ_18 GEQ_25 GEQ_35 GEQ_38
/SCALE('Negative Affect') ALL
/MODEL=ALPHA
/STATISTICS=DESCRIPTIVE SCALE.

```

Listing B.1: SPSS code snippet for GEQ item reliability tests

```
*SPSS GEQ Scoring.  
COMPUTE GEQ_SIM=MEAN(GEQ_03,GEQ_14,GEQ_20,GEQ_21,GEQ_30,GEQ_33).  
COMPUTE GEQ_COM=MEAN(GEQ_02,GEQ_12,GEQ_17,GEQ_19,GEQ_23,GEQ_42).  
COMPUTE GEQ_FLW=MEAN(GEQ_05,GEQ_15,GEQ_28,GEQ_31,GEQ_34,GEQ_40).  
COMPUTE GEQ_TNS=MEAN(GEQ_07,GEQ_09,GEQ_24,GEQ_27,GEQ_32,GEQ_39).  
COMPUTE GEQ_CHL=MEAN(GEQ_08,GEQ_13,GEQ_26,GEQ_29,GEQ_36,GEQ_37).  
COMPUTE GEQ_PAF=MEAN(GEQ_01,GEQ_04,GEQ_06,GEQ_16,GEQ_22,GEQ_41).  
COMPUTE GEQ_NAF=MEAN(GEQ_10,GEQ_11,GEQ_18,GEQ_25,GEQ_35,GEQ_38).  
VARIABLE LABELS GEQ_SIM 'Sensory and Imaginative Immersion'.  
VARIABLE LABELS GEQ_COM 'Competence'.  
VARIABLE LABELS GEQ_FLW 'Flow'.  
VARIABLE LABELS GEQ_TNS 'Tension'.  
VARIABLE LABELS GEQ_CHL 'Challenge'.  
VARIABLE LABELS GEQ_PAF 'Positive Affect'.  
VARIABLE LABELS GEQ_NAF 'Negative Affect'.  
EXECUTE.
```

Listing B.2: SPSS code snippet for calculating GEQ means

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## ACRONYMS

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3D	Three-dimensional. Refers to the virtual, rendered three-dimensional space of computer games
AI	Artificial Intelligence
ANOVA	Analysis of variance: A statistics procedure for testing the fit of a linear model
ANS	Autonomic nervous system
API	Application programming interface; a set of programming libraries or data structures
BCI	Brain-Computer Interface
BESA	Brain-electrical source analysis software developed by MEGIS Software GmbH
BTH	Blekinge Tekniska Högskola. International acronym for Blekinge Institute of Technology
C++	An object-orientied general purpose programming language based on the C-language
CI	Confidence interval.
CMS	Common mode sense active electrode as ground substitute in the Biosemi system
CS	Corrugator supercilii – Brow muscle used in facial EMG to indicate negative valence
DRL	Driven-right leg passive electrode as ground substitute in the Biosemi system
DS	Nintendo DS (the acronym denotes the double-screen) portable gaming console
EDA	Electrodermal activity. Measurement of changes in ability of skin to conduct electricity
EEG	Electroencephalography. Measurement of brainwaves through electrodes on the scalp
EKG	Electrocardiography. Measurement of heart activity through skin electrodes

EMG	Electromyography. Measurement of muscle activity through electrodes on the skin
EOG	Electrooculography. Measurement of eye muscle activity
ERP	Event-related brain potentials
EC	European Commission
FFT	Fast fourier transformation. An efficient signal processing algorithm for computing the discrete Fourier transformation of a function into the frequency domain.
fMRI	functional Magnetic Resonance Imaging
fNIR	functional Near-Infrared Spectroscopy
FUGA	The Fun of Gaming: Measuring the Human Experience of Media Enjoyment. An EC-funded research project
FPS	First-person shooters: A shooter game, where the player controls the viewport camera and weapons from first-person perspective
GEQ	Game experience questionnaire developed in FUGA
GLM	General Linear Model: Used in ANOVAs for significance testing.
GTA	Grand theft auto: A digital game series
GSR	Galvanic skin response: A certain type of EDA response
GX	Gameplay experience, see Chapter 2
HCI	Human-computer interaction
HRV	Heart rate variability
ICT	Information and Communication Technologies
IM	Interaction mode; Refers to the mode of game control
ISO	International organization for standardization
LDC	Level Design Condition
M	Mean value
MANOVA	Multivariate Analysis of variance, see ANOVA
MEC	Measurement, Effects, Conditions. An EC-funded research project
NPC	Non-player character

NEST	New and Emerging Science and Technology. 6th Framework Programme of the EC
OO	Orbicularis oculi – Eye lid muscle used in facial EMG to indicate positive valence
PAL	Phase alternating line is analogue television encoding system, for example used in Europe
PET	Positron Emission Tomography
PDA	Personal digital assistant
PC	Personal computer. By some academics also used to refer to player character, depending on context
PS2	Sony PlayStation 2; a gaming console.
RE4	Resident Evil 4. A digital game.
SAM	Self-assessment mannequin scale, see Lang (1980)
SC	Skin conductance, also referred to as EDA.
SCI	A model of immersion, made popular by Ermi & Mäyrä (2005). SCI refers to sensory (S), challenge-based (C) and imaginative (I) forms of immersion.
SCL	The level of skin conductance (SC) often described in the context of a phasic psychophysiological analysis (see for example Ravaja et al. (2005)).
SD	Standard deviation
SDK	Software development kit. Compilation of tools, application and code libraries for the development of software
SE	Standard error
SP	Spatial presence
SPQ	MEC Spatial Presence Questionnaire
SPPA	Spatial presence possible actions
SPSL	Spatial presence self-location
SPSS	Statistical Package for the Social Sciences, a software package for statistical data analysis.
UX	User experience
Wii	Nintendo Wii; a gaming console.
ZM	Zygomaticus major; cheek muscle used in facial EMG to indicate positive valence.



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## COLOPHON

This thesis was typeset with L<sup>A</sup>T<sub>E</sub>X 2<sub>E</sub> using Miede's excellent package *classicthesis*, which is based on Bringhurst's *The Elements of Typographic Style*. The graphical visualization of the statistical data in this thesis is deeply inspired by guidelines from Tufte's *The Visual Display of Quantitative Information*. The statistical analyses during my Ph.D. studies would not have been possible without the joyful reading of Field's *Discovering Statistics* book; something I recommend for anyone interested in quantitative research. All chapters are slightly modified author versions of papers submitted or accepted for publication, proper reference is given if final work has already been published.

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## ABSTRACT

Digital games provide the most engaging interactive experiences. Researching gameplay experience is done mainly in the science and technology (e.g., human-computer interaction, physiological and entertainment computing) and social science (e.g., media psychology, psychophysiology, and communication sciences) research communities. This thesis is located at the intersection of these research areas, bringing together emerging methodological and scientific approaches from these multi-faceted communities for an affective ludology; a novel take on game analysis and design with focus on the player.

The thesis contributes to game research with three important results: (1) the establishment of an objective/subjective correlation methodology founded on psychophysiological methods, (2) the creation of a formal theoretical framework in which to conduct user experience (UX) research related to games, and (3) the combination of results regarding cognitive and emotional factors for describing, defining, and classifying the interactive relationship between players and games.

Two approaches for measuring gameplay experience are used in this thesis. First, objective assessment of physiological user responses together with automated event-logging techniques, so called game metrics, allows collecting essential player- and game-related variables for a comprehensive understanding of their interaction. Second, using psychometric questionnaires allows a reliable assessment of players' subjective emotion and cognition during gameplay. The benefit of psychophysiological methods is that they are non-intrusive, covert, reliable, and objective. To fully understand psychophysiological results, a correlation between subjective gameplay experience ratings and psychophysiological responses is neces-

sary and has been done in this thesis and prior work it builds on.

This thesis explores objective and subjective assessment of gameplay experience in several experiments. The experiments focus on (1) level design implications from psychophysiological and questionnaire measurements, (2) the impact of form and age on subjective gameplay experience, (3) the impact of game audio and sound on objective and subjective player responses, and (4) the impact of game interaction design on and the relationship between experience and electroencephalographic measures. In addition, the thesis includes a theoretical framework for UX research in games, which classifies gameplay experience along the dimensions of abstraction and time. One remaining conceptual and empirical challenge for this framework is the huge variety of vaguely defined experiential phenomena, such as immersion, flow, presence, and engagement. However, the results from the experimental studies show that by establishing correlations between psychophysiological responses and questionnaire data, we are approaching a better, scientifically grounded, understanding of gameplay experience.

Many possibilities open from here. More detailed analyses of cognition will help us understand to what extent gameplay experience depends on emotional or cognitive processing. In addition, the inclusion of more complex and detailed gameplay metrics data together with psychophysiological metrics will enable a comprehensive analysis of player behavior, attention, and motivation. Finally, the integration of new measurement technologies in interactive entertainment applications will not only allow a detailed assessment of gameplay, but also improve physical and mental interaction with future games.

