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The work described in this document was performed as part of the xDELIA project ('Boosting Deliberate Practice and Handling Biases through Immersive Cognitive and Emotional Reinforcement Strategies & Tools') which is funded under contract No. 231830 of the European Community. The project is a collaboration between CIMNE (coordinating partner), Forschungszentrum Informatik, Open University, Blekinge Tekniska Högskola (Game Systems and Interaction Research Laboratory), Erasmus University Rotterdam (Erasmus Centre for Neuroeconomics), University of Bristol (Personal Finance Research Centre), and Saxo Bank A/S. The opinions, findings and conclusions expressed in this report are those of the authors alone and do not necessarily reflect those of the EC or any other organisation involved in the project.

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Executive Summary

This document provides a detailed account of what is meant by ‘cognitive games’ in WP4, describes the game design process in relation to this perspective and describes both cognitive methods for studying games, and other methods of a more pragmatic nature used in the development and evaluation of game prototypes.

Two fundamentally different cognitive perspectives on games are cognitivism and social constructivism. The cognitivist approach implies the use of methodologies derived from cognitive science and psychology for studying the affects of gameplay, and in particular the use of measurement methods that can be used to explore the existence of correlations among descriptions of players, game features, and game interaction derived from game studies, which may be explained in terms of models of underlying cognitive structures, or schemas. The primary cognitive schemas motivating the development of the prototype games are those representing emotional biases in decision making. In stable contexts, a cognitivist approach can be used to explicate learning affects of gameplay, but the conditions and scope of this stability must be understood in order to understand where these affects apply and where they do not, a key issue in the question of the transfer of learning effectiveness of games. Moreover, games continue to develop and evolve in form, which means that these taxonomies must also continue to develop. This includes taxonomies for describing players derived from clustering studies of player behaviours and communications, since play styles, motivations and preferences evolve in tandem with new opportunities provided by evolving game forms.

From a social constructivist perspective, games provide accessible and safe environments for the social construction of meaning and the development of knowledge and skills by action, offering virtual environments for learning that cannot exist in the physical world. This is not to say, however, that these games provide a simple alternative in the face of the difficulty of exploring the combinatorial space of game/player features from a cognitivist perspective. For learning highly stereotypes skills that are well defined in stable contexts, the social constructivist approach is too open. Hence these paradigms provide different methods suited to different purposes.

Part 2 presents the games that have been developed in xDELIA up to the time of writing and places these in the context of the cognitivist and social constructivist perspectives informing their development, as well as more general methods for game development. Through the different phases of the design process, methods such as SCRUM, Participatory Design and Constructive development have been used, together with partner/stake-holder involvement at critical stages where decisions requiring application domain expertise are needed. The major theoretical domains in xDELIA lay within economics, investment and financial competence. For game development, this has meant a strong focus on iterative prototyping and participatory design methods, to shape a comprehension of the possibilities in game design for the partners with application domain expertise, and to shape a collective understanding among the game developers of the requirements upon viable game components within leaning interventions.
Part 3 of this document describes the evaluation of the games from both game development and cognitive perspectives. More cognitive approaches to the study of gameplay affects are documented in more detail in the xDELIA studies. However, the studies do not exhaust the different purposes and methods of evaluation used, which are therefore surveyed in Part 3 of this document. The Evaluation Methodology provides a broad, easy-to-use framework for the assessment of both existing games and game prototypes in the development. The aim is to identify game design and implementation flaws at a variety of levels, both technical and game experience-oriented.
Cognitive/emotional skills, game design and evaluation

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## Appendix B - Gameplay Heuristics

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Document Purpose and Scope

The purpose of Part 1 of this document is to explain and provide a detailed account of what is meant by ‘cognitive games’ in WP4, what this means in terms of: the expectations and approach involved in developing games for learning, the implications in terms of evaluation methodologies, and how this relates to recent work in game studies. A major issue in relation to expectations and approach is that two fundamentally different cognitive perspectives may apply, one being what is here characterised as cognitivism, and the other being social constructivism. These approaches are explained and their consequences for game development are considered. The cognitivist approach implies the use of methodologies derived from cognitive science and psychology for studying the affects of gameplay, and in particular the use of measurement methods that can be used to explore the existence of correlations among descriptions of players, game features, and game interaction, by the use of suitable measurement methods. Descriptions of players and game features may draw from taxonomies in game studies, while measurement methods include the use of psychophysiological sensors and eyetracking. In Part 2 we present the games that have been developed in xDELIA at the time of writing and place these in the context of the cognitivist and social constructivist perspectives informing their development. Other aspects of game design are also included in Part 2. Part 3 then goes on to describe the evaluation of the games from both game development and cognitive perspectives. More cognitive approaches to the study of gameplay affects are documented in more detail in the xDELIA studies. However, the studies do not exhaust the different purposes and methods of evaluation used, which are therefore surveyed in Part 3 of this document.

1.1 What Do We Mean by a Cognitive Framework for Understanding Gameplay?

Lindley and Sannersten (2006 and 2007) referred to a cognitive framework for analysing gameplay that included the use of cognitive schemas (Schank and Abelson, 1977, Mandler, 1984) to model decision processes of the players of computer games. This use was considered to form part of a nomology for the scientific study of games and digital gameplay, based upon the formulation of Cronbach and Meehl (1955), where a nomological network includes “the theoretical framework for what you are trying to measure, an empirical framework for how you are going to measure it, and specification of the linkages among and between these two frameworks”. For a construct (i.e. a distinction, concept or theory) to be scientifically admissible, it should occur within a nomological (or ‘lawful’) net.

The concept of a specifically cognitive framework for understanding gameplay arose from the observation that a great deal of computer gameplay involves players in highly repetitive actions carried out for long periods of time (see Lindley, 2002). Learning to play was observed to be a process of learning how to perform successful patterns of interaction for making progress within the inner terms of a specific game. These patterns require the successful decoding of meaningful perceptual signs, and the selection of successful actions from a repertoire of in-game synthesised actions made available via the computer interface (typically a keyboard and mouse, or a game console). Learning to play a game was observed to progress from being a highly deliberate and conscious process to a process that is more skill-based and if still conscious, then involving little or no deliberation about how to play most of the time. These observations apply for many game genres, and more so for games based upon the need for rapid action in order to progress (e.g. first-person shooters, fighting games, racing games, platform games, and dynamic visual puzzle games such as Tetris™). The simplicity of game interaction for these forms of games suggested a close analogy to experiments in cognitive psychology, leading to an approach to studying games derived from cognitive psychological methodology, and with the concept of schemas as abstract representations of the functional capacity underlying observed gameplay patterns (described in Lindley and Sannersten, 2006 and 2007). The overall perspective is close to cognitivism, as characterised below. In this document we elaborate the nature of a cognitivist framework for analysing gameplay, but then also summarise several critiques of cognitivism with an emphasis upon how it has been manifested in artificial intelligence (AI) research. The focus is upon cognitivism in AI because AI seeks to develop cognitive models that are sufficiently detailed to be able to function as software systems, a more rigorous criterion of success than modes of validity pursued in psychological research. We then go on to reconsider the nature of a cognitive framework, especially in the context of the development of serious games for learning, and taking into account the implications of the critique of cognitivism. Subsequent sections describe i) a series of games developed by the xDELIA project that have been produced within, and partially exemplify the application of, the approach expressed in this part of the document, and ii) an overall toolkit of methods for evaluation that have been used to verify and validate these games. The aim of the document is to explain the theoretical
1.2 Description Spaces for Cognitivist Gameplay Analysis

Within a cognitivist perspective, when applied to the scientific study of digital gameplay, construct validity may be interpreted to include requirements for description spaces, or taxonomies, for:

i) Design features of games
ii) Players of digital games
iii) Player-game interaction and/or interaction patterns
iv) Cognitive facilities and affects of gameplay

One measure of the value of constructs is that they have discrimination power among the objects that they characterise, according to the metrics used for their quantification and correlation; two constructs that refer to exactly the same set of objects are at least denotationally equivalent. Cognitive schemas are a method of modelling processes, or structures underlying processes, described by constructs of description space iii), hence providing descriptions of mappings among description constructs of types i), iii) and iii), and perhaps varying systematically in relation to constructs of type ii). The four description spaces above are considered briefly in turn in this subsection and then elaborated in more detail below.

1.2.1 Design Features of digital games

Any discussion of the design features of digital games immediately raises the question what is a game?, a question considered at the beginning of nearly every PhD thesis in game development produced over the past decade. Here we adopt the following refinement of the definition put forward by Lindley (2003):

Gameplay is a goal-directed, competitive activity conducted within a framework of agreed rules.

A game can then be described as a system supporting specific forms of gameplay, including its rules, logical game space, and logical game objects. For example, chess is the set of rules of chess, a set of logical pieces (having many possible physical, virtual and abstract implementations) and a logical chess board (an 8 x 8 square grid, again having many possible physical, virtual and abstract implementations). Again following Lindley (2003), a game can be distinguished from a narrative, which is a discourse of event representations following a culturally dependent form, such as the three-act restorative structure of commercial cinema, derived from Campbell, 1949, via Vogler, 1998. A game or a narrative can also be distinguished from a simulation, which Lindley (2003) defines as “a representation of the function, operation or features of one process or system through the use of another”. These
definitions identify aspects of form that frequently occur together in the design of many systems, but can be exemplified as very distinct modes of experience. E.g. a game of tennis played between human players in the physical world involves no simulation and does not have an experiential structure conforming to a strong narrative form (although it may be reported retrospectively in strong narrative form). A strong narrative, such as a highly conventional commercial film or story, involves no gameplay on the part of the viewer, and an aircraft simulation may be experienced with no gameplay and no story structure in any strong sense.

These definitions are not strict formal definitions, although they do aspire to provide discrimination within the larger set of what are popularly called computer games. They are also independent of technology and therefore miss critical elements of what are popularly understood as commercial digital games. In this regard, interactive commercial computer games can be understood as interactive 2D/3D visualisation (and sonification) programs facilitating user experiences informed by design principles of gameplay, narratives and/or simulations, by the above definitions. This characterisation is an abstraction from commodities understood extensionally (i.e. what our media and consumer outlets call games, and what are discussed as games in popular culture). It is a characterisation that admits of degrees of membership corresponding with typicality within this vaguely defined extensional set. This vagueness is problematic for a nomology of scientific game investigation, since it leaves the description space of game features on loose foundations. There is a lot of ongoing work in the creation of game taxonomies, what Zagal et al (2005) refer to as game ontology (see, for example, Caillois, 1961, Aarseth, 2003, Björk and Holopainen, 2004, Lindley and Sennersten, 2008). Since there is no widely accepted exhaustive consensual taxonomy of game design features, from the perspective of games created to achieve specific affects beyond entertainment (i.e. serious games), construct validation requires the identification of a taxonomy that captures design features having an impact upon affects of interest. This can be expected to be highly specific to the purpose of a game and its context, and the scope of the usefulness of any developed taxonomy will emerge as a function of the stability of contexts within which it can be successfully applied. Hence in xDELIA, it is critical to establish the effectiveness of particular game interventions together with the constructs by which their design features are described, in relation to the particular objectives of the games in improving decision quality in trading and investment. Examples of such constructs are provided in the case studies presented in Part 2 of this document. The purpose- and context-specificity of the description spaces of constructs within a framework for scientifically investigating serious game interventions also applies to the other description spaces summarised below.

1.2.2 Players of digital games

Empirically validated taxonomies for players are under development within entertainment game studies. These taxonomies cover, for e.g.:

- Stylistic preferences of play (Bartle 1996, 2004); stylistic preferences include constructs such as socialisation, achievement, exploration and aggression (‘killers’)
• Goals/Motivations of players (Kim, 1998, Yee, 2002); goal and motivation categories are similar to those of play style, but concern motivations of play rather than actual style of play

• Experiences, emotions and personality of players (e.g. see http://fuga.aalto.fi/); experiences include commonly used but imprecisely defined constructs such as immersion, engagement and flow, while emotional dispositions and personality may be assessed using well-established personality assessment instruments from psychological practice

While the emotional factors involved in game enjoyment and the rewards of play are clearly relevant to creating serious games that are immersive and/or engaging, broader stylistic preferences and motivations of players, and aspects of player personality, may have a strong modulating effect upon the experience of emotions for a player of a game with specific design features. In a scientific approach it is never possible to generalise about the immersiveness of a specific game unless this is based upon empirical test data. Empirically derived measures of immersiveness must also be correlated with descriptors for characterising who a game is or is not immersive for (avoiding the realm of arbitrary opinion and personal taste). For serious games, it is critical that immersiveness is tested with target audiences of learning interventions.

1.2.3 Player-game interaction/patterns and Measurement

Scientific studies of game interaction must, by definition, be based upon measurement and the resulting empirical data. Descriptions of players and gameplay experience have been obtained using, for example, a variety of novel or standard questionnaires, behavioural observations, psychophysiological measures, eyetracking, and fMRI (e.g. see http://fuga.aalto.fi/). A major source of gameplay interaction data is instrumentation and logging of game stimuli and in-game metrics of game performance. These varieties of data provide a foundation for correlation studies between the description spaces of game features and player characteristics. Correlation studies provide a basis for the inference and validation of hypotheses about the cognitive and emotional systems and resources underlying observed gameplay behaviour. Correlations are a basis for inferred causal relationships among experimental variables regardless of what those variables are theoretically meant to represent, what Maxwell and Delaney (2004) refer to as internal validity.

Empirical data provides a basis for validation of the effectiveness of games, where the most widely used forms of validation include:

• construct validation, as discussed above, showing that we have effective descriptors with discriminative power and meaningfully associated measures for the goals of the project

• reliability, showing that identified patterns are reproducible cross multiple experiments

• ecological validity, showing that results from laboratory studies transfer to other contexts
In general, reliability may require ongoing experiments within a research community, since it requires considerable time and resources. Hence it is important that experiments are documented in sufficient detail to allow replication by other researchers.

1.2.4 Cognitive affects of gameplay

As noted by Lindley and Sannersten (2007), “since computer games are predominantly played by the use of very generic interaction technologies (e.g. a keyboard and mouse), learning and adaptation in play are, for the most part, processes of developing cognitive skills focused upon the mechanics of a game and its media realization, based upon an existing general skill set for computer use. Keyboard and mouse operations are mapped onto in-game actions in a game world synthesized by the game software. Learning how to play can therefore be divided into three phases: 1. learning interaction mechanics, that is, the basic motor operations required to operate (for example) a keyboard and mouse in a largely unconscious way, 2. learning interaction semantics, that is, the simple associative mappings from keyboard and mouse operations to in-game actions (and meta-game actions, such as setting play options, or loading and saving game states), and 3. learning gameplay competence, that is, how to select and perform in-game actions in the context of a current game state in a way that supports progress within a game. Interaction semantics represent a basic level of competence in playing a particular genre; these mappings are often carried across different games within a genre and even across genres (e.g. using ‘w’, ‘a’, ‘s’ and ‘d’ keys to move a player character forwards, left, backwards and right, respectively). Learning interaction semantics represents a form of game challenge ..., but once the basic mappings have been learned, they become a largely unconscious foundation for ongoing gameplay. The focus of learning then shifts to the development of gameplay competence, which includes the development of forms of in-game situation awareness and decision making needed to meet the more complex challenges”.

Gameplay competence involves the ability to: 1. decode the audiovisual sensory and perceptual information delivered by the game media (e.g. the computer interface) into the apprehension of a local situation within the synthesized game world (or game space), 2. evaluate this understanding of the local in-game situation in terms of the overall objectives of play, current goals and tasks, the state of the player character within the game (e.g. capabilities, health and other statistics), and anticipation of various rewards of playing the game, 3. make decisions about which in-game tactics and action(s) to perform next, based upon the perceived situation and its evaluation, and 4. perform action(s) based upon competence in interaction mechanics and semantics. The details of the cognitive process underlying this repetitive sequence, which could be described as the sense->model->evaluate->plan->act sequence (essentially the same as the sense->model->plan->act structure used to simulate higher level action control in robots and agents within artificial intelligence research; see below), are the primary higher level cognitive learning outcome of learning how to play a particular computer game.

The general usefulness of these different aspects of learning in gameplay in situations outside of the game depends upon to the degree to which the knowledge or skills learned may transfer to other contexts. Competence in interaction mechanics is very general, transferring to all contexts within which the same interaction technologies are used; games in this case may provide effective motivation for learning how to use specific interface technology.
Competence in interaction semantics transfers only to other systems using the same mappings from mechanical interaction operations to in-game actions. This may include many other games, especially those within the same genre but also across genres, depending upon their adoption of implicit or explicit conventions in game interaction design. However, interaction semantics may be limited in their transferability to other contexts, since contemporary methods of triggering synthetic actions synthesized by a computer game are unlikely to be the same as methods of realising actions that are not synthesized by a computer. Hence it may be a reasonable hypothesis that a driving game played by mouse and keyboard is less effective for actual driving training than the use of a steering wheel as an interface to the game.

Gameplay competence has similar transferability across computer games to competence in interaction semantics, i.e. high transferability within a genre but decreasing across genres. However, the potential for transfer of gameplay competence to contexts other than computer games may be much greater, since similar cognitive processes implementing a sense->model->evaluate->plan->act sequence could apply within those contexts. For example, a flight simulator based upon accurately modelled flight planning and air traffic control procedures may help players to learn how to manage flight planning and air traffic control operations in a real flying context. The key issue here is whether the particular mechanics and design features of the game lead to the development of cognitive structures that can transfer to other contexts. Interaction mechanics and semantics may also be implicated in encoding and retrieval of in-game decision process competence, and thereby have an influence upon transfer of decision skills to out-of-game contexts, potentially limiting cognitive performance due to different mechanical interaction requirements.

If the mechanics and semantics of interaction are preserved or do not intervene in the development of cognitive decision skills, effective learning still cannot be taken for granted. Within the first stage of their five stage model of the development of expertise, Dreyfus and Dreyfus (2005) describe how “Normally, the instruction process begins with the instructor decomposing the task environment into context-free features that the beginner can recognize without the desired skill. The beginner is then given rules for determining actions on the basis of these features, like a computer following a program.” Typical computer games present just such a context-free feature set and zone of action, allowing for players to develop repetitive gameplay skills that indeed lead to performance resembling the execution of a highly restricted computer algorithm. Dreyfus and Dreyfus go on to note that “merely following rules will produce poor performance in the real world”. However, a computer game is not the external world, and patterns of player interaction are likely to be highly adapted and specialized to work within the very restricted constraints of the rules of the game enforced by the executing game software. In highly stereotyped and restricted game genres (e.g. shooters, strategy games) players do seek liberation from these restrictions within the game world, typically once a game has been mastered and no longer presents any challenge in its modes of designer-intended gameplay, in behaviours that are beyond the intentions of game designers, violating the rules in the form of cheats (see Consalvo, 2007). However, the bulk of interaction occurs within the implicitly agreed constraints of a small set of game rules. The small number of game rules means that the scope for player action is greatly limited, and the ability to save and retrieve game states ensures that decisions are not irreversible. Hence computer games typically provide what Dreyfus and Dreyfus refer to as crude skills, characterized by “a larger margin for error, … time to make corrections, and the results are not irreversible”. Crude skills are contrasted with refined skills, such as chess, music, and
sports, where “a tiny difference in what one does can make a huge difference in the result, so being an expert requires learning to make subtle discriminations. Also, one has to act quickly and, usually, doesn’t get a chance to correct one’s mistakes on the fly” (Dreyfus and Dreyfus, 2005, p. 789). Dreyfus and Dreyfus quote the recurring figure of around 10 years for developing expertise. It is a mark of computer games that in order to satisfy a large market, they are much easier to learn than this, mastery coming after a few weeks of regular playing. One of the pleasures of gameplay is that one may simulate expertise very quickly that would otherwise take years of effort to develop. A good example is the various music playing games played using interface devices that simulate musical instruments. Players of Guitar Hero must learn to enact rapid trigger responses on the interface device in response to visual cues for when notes are to be played; all of the expertise of skilled guitar playing is reduced to this simple stimulus-response pattern learnable in time scales measurable in weeks. Similarly for the Nintendo Wii, which can be used, for example, to play virtual tennis by physical strokes of the arms. In this case, a generous envelope of action is mapped to simple in-game triggers, such large differences in how the player moves are filtered away and mapped to small differences in triggered in-game actions, circumventing the years of dedicated training required to become a truly skilled physical tennis player.

The sense->model->evaluate->plan->act sequence involves an underlying cognitive architecture for the processing of sensory information, creating world understanding, implementation of decisions based upon the world understanding, and the selection and execution of actions as an outcome of decisions. Hence gameplay competence is a fundamentally cognitive process, and the development of cognitive structures is at the core of learning how to play a game. Lindley and Sannersten (2006 and 2007) propose the use of schemas to model the cognitive structures underlying gameplay competence, and schema models may provide a technique for assessing decision processes learned from playing games. However, there are some fundamental constraints upon what may be expected from this technique, as discussed in the next section.

1.3 Cognition, Context and the Limits of a Scientific Approach

Schema theory was first articulated by Piaget as an account of cognitive mechanisms underlying childhood learning (e.g. see Sutherland, 1992). The vector from Piaget to the formulations of schema theory by Schank and Abelson (1977) and Mandler, (1984) can be seen to be part of the broader development of knowledge representation languages within artificial intelligence research. Schank and Abelson began with the premise that structured knowledge dominates understanding and then developed their own schema theory in answer to the question of what knowledge structures are. Ongoing artificial intelligence research has sought to further the development of languages for representing human knowledge, and algorithms for processing those representations. The identity of schemas has become blurred within this ongoing development and largely superceded by the more general terms of knowledge structures or knowledge representations. The search for knowledge structures representing human knowledge content has developed into the activity of knowledge engineering, and computational knowledge systems capable of representing and processing the knowledge of human experts developed into the field of expert systems. Hence, the proposal to use schema theory to model both intended and actual cognitive learning outcomes of gameplay becomes a proposal to represent the cognitive knowledge structures of gameplay, a process amounting to knowledge engineering.
Historically, *cognitive science* has emphasised attempts to understand human cognition in terms of an information processing metaphor (e.g. see [http://plato.stanford.edu/entries/cognitive-science/](http://plato.stanford.edu/entries/cognitive-science/)). Here we refer to this as the *cognitivist* perspective. A central theme within cognitive science is the computational synthesis of behaviour that, when performed by humans, is regarded as a manifestation of intelligence. For cognitivism, replication of intellectual behaviour by a computer system provides evidence that the computer program underlying that replication embodies an adequate theory and explanation of the human intellectual processes that it seeks to model. Processing of represented knowledge structures has typically been accomplished by *deliberation*, where the link from sensor or input data to action production or output data is mediated by knowledge-based planning or logical reasoning. In the context of robotics, and hence applicable also to human gameplay (where we are also concerned with action generation in response to goals and perception), Arkin (1998) refers to these approaches as Sense-Plan-Act approaches, while Brooks (1999) refers to them perhaps more clearly as Sense->Model->Plan->Act (SMPA) approaches. The essential idea is that an agent (a robot or a human being) receives sense data about the world, uses that data to update a symbolic representation of the world, processes that representation using logical reasoning in order to create a plan for what to do, and then executes the next temporal element of the current plan. Knowledge representation and reasoning are at the core of SMPA systems.

AI systems based upon knowledge representation and reasoning have been called Good Old-Fashioned AI (GOFAI, Hayes et al, 1994), since they are very clearly based upon Newell and Simon’s (1975) *physical symbol system hypothesis* that: “A physical symbol system has the necessary and sufficient means for general intelligent action.”, where: “A physical symbol system consists of a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called an expression (or symbol structure). Thus, a symbol structure is composed of a number of instances (or tokens) of symbols related in some physical way (such as one token being next to another). At any instant of time the system will contain a collection of these symbol structures. Besides these structures, the system also contains a collection of processes that operate on expressions to produce other expressions: processes of creation, modification, reproduction and destruction. A physical symbol system is a machine that produces through time an evolving collection of symbol structures. Such a system exists in a world of objects wider than just these symbolic expressions themselves.”

The physical symbol system hypothesis has for many (perhaps most) AI researchers been the foundation of artificial intelligence, implying that a computing system is capable of manifesting intelligence. As Newell and Simon (1975) note, “The notion of physical symbol system had taken essentially its present form by the middle of the 1950's, and one can date from that time the growth of artificial intelligence as a coherent subfield of computer science.” It is the foundation of knowledge-based and deliberative AI, which process symbol structures represented as more formalised versions of the symbols used in human natural language, and processed by algorithms based upon human logical inference.

The physical symbol system hypothesis spawned a great deal of productive research and many successful outcomes. Famous early examples include the expert systems Prospector, an expert system for mineral exploration (Hart, 1975), MYCIN, for the diagnosis of blood
infections (Shortliffe, 1976, Buchanan and Shortliffe, 1985), and Dendral, an expert system for inferring molecular structure from spectrometer data (Lindsey et al, 1980).

Despite these and many ongoing successes, there are a number of intrinsic challenges for GOFAI, organised below in what we regard as an increasing order of severity:

**Brittleness**
Lenat and Feigenbaum (1991) observed that expert systems are narrow in their domain of successful application, and very brittle at the edges, i.e. not robust when usage is not restricted to narrow circumstances. For Lennart and Feigenbaum proposed that the solution to this is to embed specialized expert and knowledge systems within a more general environment of common sense knowledge that allows reasoning about their applicability and adaptation for broader purposes. Cyc (http://www.cyc.com/) is a project to create this common sense knowledge base, although the resulting knowledge system has had limited applications to date.

**The Knowledge Acquisition Bottleneck**
There is the problem of acquiring knowledge, the so-called knowledge acquisition bottleneck, or considering the whole system lifecycle, the knowledge engineering bottleneck. One or more knowledgeable sources may be available (e.g. domain experts, documents), but the bottleneck refers to the difficulty of extracting the knowledge from primary sources in such a way that it can be represented within a GOFAI system, and then effectively maintaining and updating it (Cullen and Bryman, 1988). Wagner (2006) summarises four aspects of the knowledge engineering bottleneck: i) narrow bandwidth, that the channels of converting knowledge from its initial sources are very limited, ii) acquisition latency, that there is frequently a significant gap between when explicit knowledge is created and making it available where it is needed, iii) knowledge inaccuracy, created when experts make mistakes, knowledge engineers make misinterpretations, or errors are introduced during maintenance, and iv) the maintenance trap, that a knowledge system becomes increasingly difficult to maintain as it expands, and more so as it accrues errors.

**Multiple Experts**
Knowledge engineering also encounters the problem of multiple experts (Medsker, Tan and Turban, 1995), that when more than one expert is involved in the knowledge acquisition process, it can be very challenging (and perhaps impossible) to gain their agreement or consensus on a representation of valid domain knowledge.

**Context**
The brittleness of knowledge systems immediately raises the well established problem of context (e.g. see Schilit, Adams and Want, 1994, Dey, 2000). That is, for a system to have knowledge of its own applicability, it must have a representation of those contexts in which it is applicable or not. Of course, the scope of possible contexts is unlimited, so the
attempt to represent context is necessarily endless. The representation of context is also eternally regressive, since the meaning of a context may be modified by its own context, and so on. Also, how is the context distinguished from the core domain of a knowledge system? That is, what are the criteria for deciding where to draw the line in trying to define a reasonable range of possible contexts that a system is expected to be able to deal with? A general solution to context in AI would be to build methods into a system for evolving its knowledge content in ways that reflect positive adaptations to dynamic contexts; but this is far beyond the means of existing knowledge systems in non-trivial domains.

**Continuous Change**

Both knowledge and its contexts undergo *continuous change*. This places a limited temporal window upon the validity of a GOFAI knowledge base, and also creates a challenge for a knowledge base to remain relevant within its operational context. In the context of robotics this problem concerns the operation of perception and action generation in unpredictable and inadequately modelled physical environments. In the robotics case more successful solutions to basic movement controls have been based upon low-level, reactive and functional control levels (Arkin, 1998, Brooks, 1999), methods more closely associated with the mathematical, functional approach of Norbert Wiener’s cybernetics (see Storrs-Hall, 2007). Solutions of this kind are not appropriate for systems embedded in more abstract (textual) information environments, with inputs and outputs taking the form of meaningful text.

**Regression**

Related to the problem of context, the need for representation as a basis for intelligence is endlessly regressive. As noted by Brooks (1999), representing the world suggests that it is not enough for the world to stand for itself. Hence understanding is mediated by a knowledge model. But does this not imply that understanding the knowledge model may itself require a knowledge model, and that model another model, and so on endlessly? Or if a single model is enough, why then can’t the world itself be enough, such that reasoning, problem solving, etc. can be a direct reaction to sense data? Another way of putting this is that GOFAI sees an intelligent being as having a homunculus within it, observing and reacting to a model of the world. But then, the same must apply to the mind of the homunculus, leading to an infinite regression of homunculi within homunculi.

**Symbol Grounding**

A fundamental *problem of symbol grounding* (Anderson, 2003) arises from the very formulation of the physical symbol system hypothesis: how the link can be maintained from knowledge representations to the things that they refer to, or, how abstract symbols can acquire real-world meaning. For successful expert systems and knowledge based systems this link is provided by the authors of the representations and the users of the system for whom textual inputs and outputs can be read meaningfully within a context, as
long as the system is well authored and its contexts of application are both understood and stable. Symbols, by definition, have a conventional relationship with their referents. An authored knowledge representation gains its meaning from the author’s understanding of the meanings of the symbols used. But this understanding is not automatically transferred to a machine when it stores and processes binary strings that are displayed in a form that to a human represent linguistic symbols. This is the problem described by Searle’s (1980) thought experiment of the Chinese room: taking in tokens, processing those tokens by rules, and outputting other tokens as directed by the rules and according to the input tokens, does not require any understanding of the meaning of the tokens. This actually implies an alternative formulation to the physical symbol systems hypothesis, that instead of intelligence being fundamentally tied to the ability to manipulate symbols, it may be tied to the ability to find symbols meaningful, and to be able to create and use symbols (or more generally, representations) in ways that are not limited to manipulation within the constrains and according to the production rules of a formal language system. This can be regarded as an alternative view of AI as computational semiotics.

‘Compiled’ Expertise

Most specialized knowledge has a highly ‘compiled’ nature (Feigenbaum and McCorduck, 1983), that it is not immediately available to human experts in an explicit declarative form typically envisaged by GOFAI. For example, exemplar theories of conceptualization (e.g. see Murphy, 2002) imply that any representation of knowledge is a novel creation highly dependent upon the context and circumstances of its creation. Exemplar theories reinforce the view (e.g. Lindley, 1995) that a knowledge base is akin to a work of literature, being an external authored symbolic artefact rather than a direct mirror and expression of knowledge represented within anyone’s cognitive system. Of course there are many examples of successful knowledge base systems, but like any text, they are dependent upon external conventions of use and interpretations to make them useful. The production of such a text is usually a painstaking process very different to the rapid decision-making of domain experts. As Dreyfus and Dreyfus (2005) note, and consistent with exemplar theories, expertise “cannot be captured in rule-based expert systems, since expertise is based on the making of immediate, unreflective situational responses; intuitive judgment is the hallmark of expertise. Deliberation is certainly used by experts, if time permits, but it is done for the purpose of improving intuition, not replacing it.” From the xDELIA perspective, expert traders and investors are like the example of Euthyphro presented by Plato (used by Dreyfus and Dreyfus, 2005), who knows how to tell pious acts from impious ones, but cannot state the rules which generate his judgments: a good trader may often know how to tell a good trade from a bad trade, but cannot necessarily state the complete set of rules that generate those judgments. Particularly, traders may know very precisely what external information is required for decisions and can easily state a set of rules for how that information is to be used, but the process of decision making under risk is often strongly influenced by emotions for which traders cannot make explicit statements about and which often lead to judgments that deviate from those projected from their known rule set. If we agree with Plato and GOFAI knowledge engineers, knowledge may be in the minds of experts in the forms of rules, but not in a way that it is conscious, and it is the role of the knowledge engineer (or philosopher) to make these rules explicit. However, the existence of rules in the brain is inferred from behavioural
observation, and their ontological status is unknown; we are still seeking the neurophysiological foundations of knowledge representation. And as Dreyfus and Dreyfus (2004) suggest, it may be that the acquisition of skill and expertise develops from abstract rules to particular cases, over long periods of experience. This is compatible with exemplar theory and a view of cognition in which rules are abstractions created on the spot in a situation where they are needed, based upon a vast experience of specific past events and with no intrinsic criteria for relevance or transfer of those rules to any situation other than that of their creation.

**Social/Cultural Situatedness and the Social Construction of Knowledge**

Situated cognition theories regard knowledge not as the content of a brain or a mind, but as a form of relationship, a reciprocal interaction between a knower and their environment (e.g. see Barab and Roth, 2006). Such views derive from social constructivism (e.g. Berger and Luckmann, 1966), which views meaning and knowledge as inhering in the fabric of society, rather than within individuals. This compatible with the view of knowledge systems as texts, and indeed suggests the kind of conversational, decentralised and collective process of knowledge authorship proposed by Wagner (2006). However, just as the case with exemplar theories of expertise, it is problematic for the use of schemas as representations of learning outcomes, unless these are regarded as texts representing observable patterns within constrained contexts or situations of relevance (an understanding within which concepts such as construct validity, reliability and ecological validity can also maintain useful functions).

It is also important to note that the information processing metaphor has been somewhat overturned by the increased attention paid to the role of emotion; cognitive psychology no longer sees cognitive and emotional processes as separate. It is increasingly clear that any approach to understanding human decision-making (including expert decision-making) should consider the role played by emotion.

Advances in neuroscience are demonstrating that, as Phelps (2006: 46) concludes in a recent review,

“The mechanisms of emotion and cognition are intertwined from early perception to complex reasoning. ... Examining cognitive functions without an appreciation for the social, emotional, and motivational context will result in an understanding that may be limited in its applicability outside of the research laboratory.”

Research has begun to show the importance of emotion in understanding financial decision-making and risk behaviour more generally (Bechara & Damasio, 2005; Damasio, 1994; Finucane, Alhakami, Slovic, & Johnson, 2000). There is evidence both of emotion playing a biasing role on judgement which is detrimental to human performance and of emotions playing a role which enhances performance. First, emotions can bias information retrieval. For example, Meyer, and colleagues (1990) offer evidence that it is most easy to recall experiences that are congruent with current emotional states. Second, emotions can directly bias the cognitive processes engaged in decision-making. For example, Lerner and Keltner
(2001) show that fear increases risk perception (and decreases riskiness of choices) and that anger reduces risk perception (and increases riskiness of choices). Lo, Repin and Steenbarger (2005) found some clear associations between day-traders’ emotions (as measured by an emotional-state survey), their decision making, and performance (N=80). Investors who experienced more intense positive and negative emotional reactions to gain and loss were poorer performers than those with more attenuated emotional responses.

However, there is also evidence that the use of emotional cues offers an important advantage in everyday decision-making (Bechara & Damasio, 2005; Brickner, 1932). There is some evidence too in support of the idea that emotions may support effective decision-making in a financial context. For example Seo and Barrett (2007) carried out a study of investment club members (N=101), using an internet-based investment simulation accompanied by emotional-state surveys. They found that individuals who experienced more intense emotions achieved higher decision-making performance. There is some degree of support for two contrasting perspectives. The first suggests that emotions primarily interfere with rational assessment of information and risk. The second that emotions by representing experience gained across many relevant prior situations are an aid to navigation in complex information environments. Accounts of emotions as bias focus primarily on the role of non-relevant emotions. By contrast, accounts of emotions as information focus primarily on the role of emotions in encapsulating prior relevant experience. In principle, these two perspectives may not then be in contradiction.

The implications of this critique for the initial proposal for a cognitive (or cognitivist) framework for analysing gameplay do not necessarily require throwing out the proposal. Rather, it is necessary to understand a cognitive framework in a way that preserves potential value in its application, without taking it too far. Within highly rule-constrained gameplay, where a small range of action patterns are rewarded, a schema model can be a reasonable representation of minimal functional capability required to realise such a pattern in interaction with the stimuli of a dynamic game environment, given a suitable paradigm of schema execution. This may at least be useful as a descriptive abstraction representing the range and variability of successful behaviours. If a learning goal may be achieved by skills acquired by playing a game implementing rules that require the development of such stereotyped behaviour patterns in order to progress within the game, then a schema model might function as an effective representation of those skills. However, this does not mean that the schema is implemented as any form of symbolic representation structure within the cognitive system of a player. It is merely an abstract representation implying a range of behaviour in relation to constrained stimuli. The actual mechanisms underlying the generation of behaviour could be modelled from a variety of perspectives, including the neurophysiological. From a neurophysiological perspective, the nature of neural representation is poorly understood. Evidence that is currently available attributes the manifestations of neural systems to underlying electrochemical dynamics more effectively described in terms of complex systems and nested cycles of electrical activity (e.g. Arena, 2008). This is far from the understanding of schemas in Cartesian schema theory, and a neurally grounded theory should aspire to explain schemas and other representations as manifestations of complex electrochemical dynamics.

Understanding schemas in this way allows for the description of schema models as abstractions implying a range of behaviours that typically emerge as players learn how to successfully interact with and make progress in a digital game. Appealing to methodological
principles from psychology, it is possible to seek to establish forms of plausibility for these models, including construct validity, reliability and ecological validity, as noted above. However, the critique of constructivism presented here suggests that the degree to which these criteria are or are not met does not establish the correctness of a schema model (or not) in general. Rather, it is a reflection of the constraints upon the applicability of a schema model. One might establish that a specific model describes the range of behaviour of players of a described type in interaction with a game having specified features, within the limits of a statistical characterisation of the results of a set of experimental measurements for a group of participants. But, this requires a conceptual space (and at least an implied description space) for characterising behaviours, players, interactions and game features, as noted above. Exhaustive characterisation of these factors suffers from the problems of brittleness, context-dependency and dynamism that any symbolic representation suffers from. Hence the meaning of standard psychological concepts of validity is far from clear. Notably, experiments in cognitive psychology typically take place in highly controlled and simplified laboratory settings, i.e. specified and largely static settings in which the influences of context are minimised. It is only within such constrained settings that psychological measures of reliability and validity have meaning, and failures of repeatability raise immediate questions about variability of the experimental context, as well as hypotheses under test. Hence failures of reliability or validity suggest the need for additional constructs for describing previously undescribed factors. Of course, this quickly becomes hopeless beyond simplified laboratory settings, and even within the laboratory, the space of possible combinations of features (of games, players and measurable affects of gameplay) is impossibly complex (as observed by Ravaja and Kivikangas, 2009). This critique has also been made of experimental designs in cognitive psychology where simplified stimuli-response interactions often are decontextualised and have the form of isolated tasks which may not transfer beyond the laboratory setting (Eysenck and Keane, 2010).

For an explanation (theory, etc.) to be regarded as scientific, it must imply clear mappings from descriptions of initial conditions to correct (perhaps probabilistic) prediction(s) of consequences causally dependent upon those initial conditions. This requires verified descriptors for, and stability of, the contexts and descriptors of preconditions and predictions. To the degree that stability of descriptors, contexts and causal relationships to predicted consequences cannot be obtained, a phenomenon is not amenable to scientific analysis. Hence, any situation in which actors of interest are creative social agents within the system of concepts, events, causal relations, structures, etc. under study, is not amenable to scientific analysis, since the presence of creative agents within the system undermines the descriptive and predictive stability of the constructs and causal relations upon which scientific method depends. Hence, i) cognitive studies of human performance require highly constrained and carefully structured experimental environments that minimise the scope for the interference of human creativity, and ii) phenomena at the social level, for which creative human agents are the media, cannot be studied scientifically. This is consistent with epistemic constructivism (e.g. Berger and Luckmann, 1966) in which human knowledge is regarded as being, not merely continuously reinvented by its agents, but actually resident in and comprised by the dynamic relations between human agents. Constructivism tends to imply relativism and oppose scientific positivism. However, the point here is not to debate this issue as one of philosophy, and it is clear that applying scientific methods to the investigation of social, interpersonal and cultural phenomena that are in constant flux does not work. Nor does it work to perform experimental manipulations on the scale of societies and cultures.
Here we propose that it is possible to view the functions of digital gameplay, therefore, in terms of a continuum from one extreme that we call **cognitivism**, emphasising the *intrapersonal* and cases of stereotyped patterned behaviour, and another extreme that we call **social constructivism** (hereafter abbreviated to *constructivism*), emphasising the *interpersonal* and dynamic. These extremes can be characterised by the features shown in Figure 1.

<table>
<thead>
<tr>
<th><strong>cognitivism</strong></th>
<th><strong>constructivism</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- stable, sparse context</td>
<td>- unstable, rich context</td>
</tr>
<tr>
<td>- repetitive stimuli</td>
<td>- variable stimuli</td>
</tr>
<tr>
<td>- repetitive response patterns</td>
<td>- variable response patterns</td>
</tr>
<tr>
<td>- predictable stimulus-response associations</td>
<td>- unpredictable stimulus-response associations</td>
</tr>
<tr>
<td>- focus on the individual actor</td>
<td>- focus on social dynamics</td>
</tr>
<tr>
<td>- concepts of validity and reliability apply</td>
<td>- concepts of validity and reliability do not apply</td>
</tr>
<tr>
<td>- internal processes observed from external behaviour</td>
<td>- internal processes not in focus</td>
</tr>
<tr>
<td>- results generalise across individuals</td>
<td>- results may not generalise across individuals</td>
</tr>
<tr>
<td>- quantitative evaluations possible</td>
<td>- quantitative evaluations not possible</td>
</tr>
</tbody>
</table>

Games are of interest from both perspectives in terms of their applications in learning, offering the potential for both active interaction and participation at the centre of constructivist approaches to learning, and repetitive but motivated interaction amenable to cognitivist study. Much enthusiastic writing about the potential and application of games as learning systems emphasises their functions as *communities of practice* (COP, see Wenger, 1998), views falling clearly within constructivist perspectives (e.g. Gee, 2003, Shaffer et al, 2005, Barab and Roth, 2006). This is consistent with an interest in *emergent gameplay* among game designers (e.g. Smith 2001, 2002), where play structures and even narratives created by players are created within a space of possibilities defined by implemented game rules, but are not specifically intended by game designers (although facilitation of emergence may be intended). A simple example is players of a multiplayer strategy game working together to build the largest possible city, instead of having their armies fight one another. Arci (2008), Barab and Roth (2006), Barab et al (2007), and Gresalfi el at (2009) report increased learning engagement and improved learning outcomes with the use of immersive 3D games for teaching school children via often collaborative gameplay, where the virtual worlds of the games provide situated contexts for the application of learning content, thereby supporting creative learning by action, that would be impractical in the physical world. This is a common justification for simulation-based training in many contexts (e.g. training of NATO ISAF forces; Sennersten, 2010). In learning environments for children, principles of game design provide additional motivational factors for engagement within the game world; games also provide a more familiar learning environment for contemporary students than more traditional learning media.

### 1.4 Application to xDELIA Learning Interventions

For the xDELIA project, immersive 3D worlds for action-based learning could apply to the originally planned target groups for financial competence development, such as teenagers or young adults. For investors and traders, however, this model does not apply for several reasons. These reasons are derived from the application domain expertise of xDELIA project
members (especially Saxo Bank and the Open University) and understanding gained by all project partners during the course of the project:

Although immersive 3D worlds for action-based learning could apply to some of target groups considered for financial competence development, such as teenagers or young adults, during earlier phases of the project, for the primary target group of investors and traders as considered in this document, this model does not apply for several reasons. These reasons are derived from the application domain expertise of xDELIA project members (especially Saxo Bank and the Open University) and understanding gained by all project partners during the course of the project:

i) trading simulators for training already exist and are readily available to professional private investor, including, of course, the demo version of Saxo Bank’s own trading platform. These simulators have interfaces similar to, or the same as, actual trading interfaces, allowing the opportunity to practice trading and investment without risk of financial loss. There is no requirement from the application sector for replacing these systems with 3D virtual world simulators resembling entertainment computer games, since existing simulators already provide effective training in interaction mechanics, interaction semantics, and basic application competence in ways that different forms of games would not provide.

ii) the contexts of trading and investing are intrinsically motivating due to the financial stakes involved, and to the form of trading and investing activity already being intrinsically that of a game. In this case, the game is highly stochastic, wherein developing and exercising skills must be considered in terms of the information agents possess.

iii) better-than-chance performance in such games requires the development of expertise over long periods of time, which is not feasible as a goal of game-based learning interventions. Rather, game-based learning interventions must have a more focussed role addressing specifically identified aspects of performance as a contribution to accelerating longer term development of expertise.

iv) The nature, and even the existence, of the competence underlying better-than-chance performance in trading and investing may be considered controversial. However, there is some evidence that better performance is positively correlated with better regulation of emotion in trade/investment decision making. This leads to the central hypothesis of the xDELIA project for learning interventions in trading and investing: the development of trading/investing competence may be accelerated by learning interventions that encourage, facilitate or support more effective regulation of emotions in trading/investment decision making.

It is not realistic to hope to model all of the factors behind trading decisions, for all of the reasons concerning context, dynamism and expertise (etc.) noted above. However, the nature of the decisions and forms of presented information providing dynamic financial data inputs to decisions constitute a relatively stable context and generic decision requirements. Hence it is possible to identify specific, measurable and small scale emotional/cognitive patterns (i.e.
schemas) that occur within trading and investing interaction, and to assess these patterns in terms of stable characterisations of decision biases manifesting unfavourable emotional factors in decision making. Candidate patterns include:

- Disposition affect
- Risk-taking or risk aversion tendencies
- Impulsivity
- Capability for emotion regulation
- House money effect
- Regret
- ... etc.

The stability of the manifestations of these patterns and the circumstances in which they occur strongly suggests the following further and more detailed hypotheses that may be assessed using cognitivist methodologies:

H1: patterns manifesting emotional biases are amenable to detection in the interaction patterns of players of suitably designed digital games.

H2: these manifestations are stable enough to be shown to have construct validity, reliability and ecological validity by empirical, quantitative studies using cognitivist methodologies.

H3: information that specific patterns have been detected can be fed back to users as a foundation for learning processes targeting improved emotion regulation and mindfulness.

H4: pattern detection and feedback can be achieved by games external to trading and investing systems and their interfaces, although they might also be integrated within system interfaces in eventual deployed forms.

H5: measurable effects in improving emotion awareness and regulation achieved by learning interventions based upon games that detect emotional biases will transfer to trading and investing practice.

These hypotheses motivate the design and evaluation of games addressing emotion regulation and online mindfulness interventions within the xDELIA project. To be effective, the games need to be designed within the context of broader learning intervention design.

1.5 Cognitive Modelling of Gameplay

From the discussion above it may be concluded that detailed cognitive modelling of gameplay processes is applicable in cases where:

- Gameplay is highly repetitive and predictable within a narrow scope of variations

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1 At the time of writing, a decision has been made to focus primarily on the disposition effect as a proof of concept for the xDelia learning interventions.
• Stimulus (i.e. game interface) features are accessible and measurable

• Player actions and responses are observable and measurable

Analysis can be conducted using a theoretical framework providing an account of the features of game designs, of player cognition, and of play interaction relating design features to cognitive processes. This comparative analysis can be used as a basis for validating or adapting models of hypothetical cognitive schemas underlying gameplay, or to modify the overall theoretical framework if those modifications are found to better account for observed play patterns. It is also possible to adopt a computational cognitive science methodology, leading to the computational implementation of the hypothetical schemas of players, followed by comparison of the play results with those of human players as a method of refining and validating the schema models (although this is beyond the scope of xDELIA).

1.5.1 Modelling Gameplay Schemas

Hypothetical schema models representing decision processes compatible with observed gameplay can be developed using Cognitive Task Analysis (CTA) (Lindley and Sennersten, 2006). CTA refers to a variety of methods used to analyse and represent the knowledge and cognitive activities that people utilize to perform complex tasks in a work domain (CTA methods and related techniques are reviewed at http://mentalmodels.mitre.org/cog_eng/ce_methods_I.htm). Different CTA methodologies emphasise different aspects of tasks and their context and use their own particular task definition constructs. For example, Critical Decision Method (CDM) uses probes, which are targeted analysis questions addressing Decision Point Options, Cues, Causal Factors, Goal Shifts, Analogues, Errors, Hypotheticals, Missing Data, Imagery and Task Analysis. Particular probes in this method are cross-referenced to specific forms of knowledge, including Structure, Perceptual, Conceptual, Analogues and Prototypes (see Klein, 1996). GOMS (standing for Goals, Operators, Methods and Selection; see John and Kiers, 1994) is a promising foundation for detailed player cognitive task modelling, with the advantage of having variants that can be computationally executed.

Variants of CTA may address issues such as the identification of knowledge resources within organisations and the contextual functions of cognitive decision processes within broader operational systems. These contextual issues are of limited relevance to the cognitive task analysis of entertainment gameplay, although player subcultures and the contexts of play may have a strong influence on functions, expectations and motivations of play for individual players. Furthermore, verbal methods, such as structured interviews and think-aloud protocols, relied upon heavily in many CTA methodologies, are of limited effectiveness for analysing less conscious or heavily automated aspects of gameplay, or for observing small scale details of cognitive processes and their interaction with limbic (i.e. emotional) processes. Hence verbal techniques need to be complemented with sociological/ethnographic methods, together with interaction logging, psychophysiological methods, eye-tracking, brain scanning, etc.
Attention theory addresses issues of attentional focus, management of attention (including attentional selection), and the allocation of cognitive resources to cognitive tasks. Ongoing research is addressing the question of the detailed operation of attentional mechanisms, including questions such as the degree to which attentional capacity is specific to specific cognitive resources (or modes) or sharable among resources according to demand, and the stage of processing of perceptual information at which perceptual information is selected for attentional priority. Attention theory provides a model of the energetic resources available to cognition, together with an account of principles for the distribution of energy (or attention) to the cognitive resources that use (or manifest) it (see, for example, Johnson and Proctor, 2004). CTA provides a representation of cognitive tasks involved in gameplay at a level of description that makes sense to an observer and conforms to an observed (set of) gameplay interaction patterns. A cognitive task (CT) model can be used for workload analyses that relate subjective experiences of cognitive workload to contextual demands, psychophysiological indicators, situation awareness and performance (see, for e.g., GARTEUR, 2003). A detailed account of the cognitive processes and structures involved in gameplay that underlay and explain task performance as addressed by workload analysis can include the mechanisms by which attention is orchestrated together with cognitive resources, process and skills, in relation to perceptual inputs and in order to generate the motor outputs involved in gameplay. Hence CTA and workload analysis may provide ‘top down’ routes towards understanding the cognitive functions and structures of gameplay. GOMS is a more detailed CTA method, but further detail is required in order to address learning, fatigue and mapping to neurophysiological mechanisms. Furthermore, task models do not address declarative understandings or structures facilitating comprehension and task performance.

A CTA itself provides a first approximation description of a gameplay schema, but a CTA is also heavily determined by the language and cultural constructs of the observer. For a complete explanation in scientific terms, the phenomenologically meaningful terms of a CTA must be further analysed to account for the ways in which those high level constructs are actually realised by underlying neurophysiological constructs, and this mapping is likely to involve different parsings of functional units at the CTA and neurophysiological levels. Hence a gameplay schema might be described at different levels of abstraction, some being meaningful in terms of the subjective languages of task performance (e.g. the terms of self-reported task performance) or CTA and others in terms of implementational neurophysiology that may have a very different structure and functional decomposition than that of more linguistically conditioned accounts. Different levels of abstraction in the description of gameplay schemas are equally valid, neurophysiological descriptions providing an implementational explanation of verbally expressed task-oriented descriptions.

1.5.2 Hierarchical Time and Schema Structure in Games

Games are designed with time structures that can be considered in terms of a hierarchy of time scales (Lindley 2005a,b, Lindley and Sennersten, 2006). At the smallest scale of time units the game simulates continuous actions and processes, such as character, non-player character (NPC) and virtual agent movements, weapon and projectile behaviour, flowing water, rockfalls, the movement of abstract geometrical objects, doors opening, explosions, etc.. These simulations proceed according to a sequence of discrete simulation time steps, or ticks, that may (but do not necessarily) correspond with the rate of update of graphical display frames. Perhaps with the exception of movement control (e.g. by pressing ‘a’, ‘w’, ‘s’ and ‘d’)
keys to move left, forwards, backwards or right over extended simulation ticks) player actions
are usually not tracked as extended sequences over ticks at this scale; more typically player
actions occur at discrete points within the time sequence, functioning as triggers initiated by a
key press or release, a mouse button press or release, etc.. Those player actions may be made
meaningful at a scale above that of single simulation ticks, initiating the automated simulation
of synthetic actions over an extended number of ticks, such as slashing with a sword or firing
a missile. These larger scale units of meaning may be said to belong to the game moves in more traditional (non-computational)
game forms. In general, the available (legal) types of games moves in a particular game are
the types of actions specified in game rules, while events at the simulation scale in a computer
game implement game moves.

Game moves are primitive player actions that can be interpreted from several perspectives.
The game perspective grounds their significance in the competitive, rule constrained form of a
game. However, moves can be regarded from other perspectives, such as socialisation,
construction, trading and dramatic performance. As noted in Lindley (2005a, 2005b), game
moves regarded from the perspective of narrative or dramatic performance are equivalent to
what Mackay (2001) refers to as fictive blocks, basic fragments or units of fictional/narrative
significance that may be strung together to form a larger scale narrative. Mackay takes fictive
blocks divorced from their original context to be equivalent to Scheckner’s strips of imaginary behaviour, patterns that constitute a repertoire of potential behaviours that are
performed by an actor in new arrangements in ways that may appear spontaneous and
unrehearsed during improvisational performances.

This for interpreting and providing significance to game moves is not merely a matter of
arbitrary interpretation, but a fundamental condition of making the play experience
comprehensible. A computer game typically provides a player with a limited number of
commands to perform, including both the initiation or performance of game moves and
metagame commands such as saving the game state or quitting the game. Game moves may
be moves such as ‘move left’, ‘move forward’, ‘move right’, ‘fire’, ‘toggle run/walk’, ‘cycle
weapon’, ‘gesture’, ‘tilt’, etc.. Suppose there are a total of 30 such move types to choose from
while playing a specific computer RPG (this is an easy figure to reach considering basic
movement controls and the possibility of having multiple hotkey assignments to each function
key, e.g. for selecting weapons, health boosts, spells, etc.). Considering a sequence of 10
moves made by the player, the number of combinations of 10 selections from 30 available
moves is $30^{10}$, or $59\ 049\times 10^{10}$ move sequences. Since a typical single player RPG may be
played for a hundred hours or so, often with the player selecting several moves per second,
the combinatorial space of possible move sequences over the play time required to finish the
game is extremely large (in excess of $10^{5319}$).

By far the major part of this vast space of possible move sequences would make no sense at
all to play. ‘Making sense’ here is a matter of conforming to the pattern of expectations of a
higher level play structure, which is a temporal gameplay schema, and in particular a script,
providing at least an implicit perspective for the interpretation of the meaning of moves.
Many kinds of scripts might apply to making sense of a player’s selection of game moves in a
play sequence. Some examples of these are:
• a script for the combative engagement of an enemy. This script might begin with the
detection of an enemy and then proceed through selecting a configuration of armour,
weapons and magic according to the enemy type, deciding upon a tactic for
approaching and engaging the enemy, configuring companions if the player controls
a party of NPCs, selecting a formation and/or angle of attack, launching the attack,
perhaps with a specific sequence for using different weapons upon approach, cycling
between attacking, parrying and taking health boosts, deciding to retreat or carrying
on to death or victory

• a script for exploring a labyrinth, e.g. the ‘left hand rule’ of following the left wall
and occasionally checking to detect traps or secret doors, until the character arrives
back at the entrance

• a script for interacting with a trader, including evaluating items, selling unwanted
and unnecessary items, upgrading useful items and replenishing diminishable stocks

• a script for negotiating quests, e.g. exploring background information, considering
alignment implications, accepting or rejecting a quest, returning to a quest giver
when the quest is accomplished, accepting or rejecting rewards or punishments,
deciding upon follow on quests, etc..

Many schemas are possible, including those for interacting with other players for
accomplishing various group tasks or activities in multiplayer games.

FPS and RPG computer games frequently embed the moves of players within higher level
pre-designed time structures, including structures of game levels and high level narratives
with key structural elements (such as introducing a central conflict, major plot points, and
final closure after defeating a game boss) being delivered as non-interactive cut scenes
(Lindley, 2005a, 2005b). Schemas for stories (Mandler, 1984) provide structures by which
players may anticipate and comprehend high-level story structures within which their
gameplay is embedded. Game structure schemas based upon levels do not need to present any
more specific narrative structure, but include expectations of thematic changes and changes in
the difficulty of play, increases in player character experience, and increases in the statistics
of items such as found weapons and artefacts. Story schemas for computer games can include
transitions between story sections that also function as level transitions with their associated
expectations and features.

The function of player schemas in making a gameplay experience comprehensible raises a
critical question of how design intentions are translated into game design features with which
the player interacts. Design decisions are also made according to schemas, this time in the
cognitive systems of designers. These latter schemas amount to the designers’ understanding
of how players will make design features meaningful. Once a design is released, however,
only the design features remain and it is up to players to find ways of creating their meaning.
Shared schemas among designers and players can facilitate effective game design. Designers’
conceptions of play schemas may take the form of high level ideas about broad styles of play,
but are otherwise implicit and learned from the designers’ own playing and design experience.
Undesirable consequences may follow from this. For example, players may play a new game
according to their established schemas and thereby miss new possibilities of play afforded by
the design. To overcome this, specific design techniques may be required to disrupt established player schemas and initiate a fresh gameplay schema learning process. High level story structures, which have been an ongoing issue of contention in game design, are problematic not only due to problems of requiring cognitive resources to be directed away from gameplay for full comprehension of the story, or not appealing to taste variations within players (Lindley, 2005b), but also due to potential mismatch between schema-driven story construction on the part of players on one hand with pre-designed story elements created according to the story schemas of designers on the other. Since players are active and highly immersed participants in creating the details of the history of the game experience, their own story schemas can be used to create their own retrospective story of the play experience. These schemas may be different from those of the designers, or may cast or conceive of the player character and its experiences in a role suiting the players’ own tastes, needs, motivations and desires. Infrequent pre-defined story elements, which are not immersive in the same way as the interactive play experience, may not figure strongly in these player constructed stories, or may even clash with them, resulting in player distaste for those design elements. This might be avoided by design techniques based upon heavy infiltration of the play experience with pre-designed story content (as in the Final Fantasy series of games), forcing players to ‘play the designers’ story’, or by designing to facilitate player story construction, with little or no pre-designed story content.

The question of differences between player scripts and designers’ expectations of player interaction patterns is not always problematic, and can in fact be intended by designers. This amounts to the design of games facilitating emergent (discussed, for example, by Salen and Zimmerman, 2004), where complex player behaviours are derived during play in interaction with a game system based upon comparatively simple game rules. Design principles for emergent gameplay are not yet well developed and a schema-based theory, derived from observation of gameplay schemas and taking into account schema learning processes, could provide a foundation for developing stronger emergent gameplay design principles.

1.5.3 Modelling Game Features

1.5.3.1 Game Elements

Figure 1 shows components of a game design (from Lindley and Sennersten, 2008), based upon the driving concept of the gameplay experience, a consideration of what remains the same when a game is realized in different ways, and what design elements change in different implementations of ‘the same’ game. These are the various elements of form representing the final outcome of design and that shape and constitute the designed artifact. In this model, gameplay is at the centre since this represents the core and overall goal of game design, being the design of the space of possible interactive experiences for players. This space may vary from restricting the player to very limited possibilities (e.g. in a simple game like Tic-Tac-To) to very open games having a lot of scope for players themselves to shape their own experiences (e.g. live-action role-playing games, or larps); the more restricted forms are amenable to cognitivist study as characterised above, while more open forms are more amenable to more constructivist investigations. In all cases, the scope for players to vary their play within the constraints of a particular game system is always at least implicitly a design decision.
Intended gameplay provides a specification for the design of a logical game system and elements needed to support a space of possible play experiences. The logical game system and elements include:

- **game rules** that specify legal moves that players may make, the consequences of moves, win/lose criteria, etc.

- **game objects**, which are the things within the game that are referred to by the rules and may be manipulated by the player and/or game system; objects may be active or passive, and their specification can include attributes relevant to gameplay and referred to by the rules and game system

- a **game space**, also referred to by the rules and defining a logical space within which play takes place

- the **game system** which specifies how all of these elements are orchestrated together to constitute a complete game; the game system includes procedures for the execution of game moves and the manipulation of game objects, according to the rules, within the logical game space, and in terms of the media used to realize a game.

![Diagram of Elements of Designed Game Form](image)

**Figure 1. Elements of Designed Game Form.**

The game system might include media-specific procedures, but the rest of the logical game system and elements will often be transferable across different media. For example, sports games specify particular rules, game objects (such as bats and balls), player roles and a game space (such as courts or fields); however, there are many computer versions of sports games where these elements are intact in a virtual form, although the system of play and the nature of the play experience are different. To the extent that the system and the play experiences
differ across different media, these are examples of different games, but to the extent that the logical game rules, objects, player roles and game space are the same, then they are the same game: the identity of a game follows from the (variable) scope of elements taken as constituting that identity.

Once the logical game system and elements are specified, it is possible to undertake the design of the game media components. This may include 2D and 3D graphics, animations, video, audio, lighting, costumes, sets or stages, interfaces, technology and infrastructure. For computer games, costumes, sets and stages are virtual, and the game space may be organised into game levels within an overall virtual game world. For physically staged games, these elements will be physical, such as the costumes of larpers or the uniforms of sports players. Design techniques from established design fields are applied for different forms of media used to realise a game, but always in terms of meeting the gameplay- (and therefore user experience-) driven requirements of the game system. Hence established methods address the design of media elements, while game design as such is concerned with the inner core of gameplay and the design of the logical game elements and system required to facilitate gameplay.

Beyond game artefact design, game design also has a bearing upon the context of play. For example, a board game designed for a context such as a family home makes assumptions about what is possible within that context (e.g. a clear table around which six adults may sit); if the context does not accommodate those assumptions (e.g. no room for a 6-person table) then the context must be modified if the game is to be played (e.g. other furniture may be moved out). Hence the game design implies or specifies requirements for features within the context of play, amounting to a degree of context design that may be satisfied either by selecting a suitable context or modifying a context to render it suitable. Contextual requirements are well understood for computer games and actively analysed by the designers of console games. Contextual factors are a significant challenge to overcome for the widespread commercialization of some new game forms, such as augmented reality games or technology enhanced games.

### 1.5.3.2 Game Form

The description of logical game form is concerned with abstract formal structures of games that are central to the identity of specific games and are largely independent of their modes or media of realisation. There is a lot of ongoing work on the development of game taxonomies/ontologies. A taxonomy can be understood as a system of named and defined classes or categories and their subclass/superclass relationships. An ontology can be understood as a taxonomy with the addition of class properties and relations between classes (Lindley and Sennersen, 2008). Here the terms will be used interchangeably, although in general an ontology provides a more detailed description of the conceptual structure of a domain than a taxonomy.

Numerous proposals for game ontologies have been made for discussing logical game form (as distinct from realisation elements described above) and raising the structure of the conceptual domain of games into greater awareness. The classic work of Caillolais (1958) presents a taxonomy of forms of play based upon an analysis of Latin terminology, including agon, based upon competition, alea, based upon chance, mimicy, based upon simulation and
the kind of play associated with acting a role in a theatre production, and \textit{ilinx}, based upon vertigo, “an attempt to momentarily destroy the stability of perception and inflict a kind of voluptuous panic upon an otherwise lucid mind”. Cailliois (1958) also discusses the distinction between \textit{Paidia} as uncontrolled, free, improvised and ecstatic play, and \textit{ludus}, which is play tightly bound up with arbitrary, mandatory and often tedious rules and conventions. Between paida and ludus are degrees of variation, from total freedom to heavy but arbitrary constraint. While Cailliois’ taxonomy primarily addresses forms of play, the taxonomy has a direct bearing upon requirements for logical game form facilitating (or not) different forms of play.

Lindley (2003, 2005a) identifies basic distinctions between simulations, games and narratives as alternate formal systems associated with respectively increasing time scales in the design process; simulations are concerned with modeling tick by tick (or frame-by-frame) changes, games with modeling player-controlled actions at intermediate time scales, and narratives with the largest scales of time structure. Lindley (2003) further distinguishes the orthogonal classification dimensions of factual/fictional representational functions and physical/virtual staging strategies for games. Aarseth et al (2003) propose a taxonomy based upon a variety of formal (i.e. non-narrative and non-representational) characteristics covering space (perspective, topography, environment), time (pace, representation, teleology), player structure, control (mutability, savability, determinism), and rules (topological, time-based, objective-based). Björk and Holopainen (2005) present a taxonomy of the high level aspects of games, presented as a game component framework that includes: Holistic Components dealing with aspects of the game regarded as a whole (game instances, game sessions, and play sessions), Structural Components that are the basic parts of the game manipulated by the players and the system (including an interface, game elements, players, a game facilitator and game time), Boundary Components that limit the activities of a player of a game either by only allowing certain actions or by making some actions more rewarding than others (including rules, modes of play, goals and subgoals), and Temporal Components that describe the time flow of a game (including actions, events, closures and subclosures, end conditions and evaluation functions).

Game design patterns, another form of game ontology, have been described by Kreimeier (2002), Björk and Holopainen (2005) and Kirk (2005). Björk and Holopainen (2005) define game design patterns as “semiformal interdependent descriptions of commonly reoccurring parts of the design of a game that concern gameplay”. Game design patterns are essentially higher-level structures of game elements described in terms of component-oriented taxonomies, together with interaction patterns. Björk and Holopainen (2005) present 200 game design patterns, including the familiar patterns of Paper-Rock-Scissors, Save-Load Cycles, Enemies, Game World and Combat. The balance between interaction structure and other contents of game design patterns varies. It is an issue of ongoing concern to validate the usefulness of the existing patterns within different contexts, and to further refine them or specify new patterns for purposes for which the currently identified patterns are not adequate.

Design ‘cookbooks’ (Lindley and Sennersten, 2008) are compilations of design ‘recipes’ consisting of rules, principles and heuristics for the design of game form, all of which imply formal taxonomical components of game form. Cookbook principles include Barwood’s ‘400 design rules’ project (Barwood, 2001, and Barwood and Falstein 2002; see also http://www.theinspiracy.com/400_so_far.htm). Examples of rules from Barwood’s collection include: Maintain Level of Abstraction, Make Subgames, Let the Player Turn the Game Off,
Maintain Suspension of Disbelief, Differentiate Interactivity from Non-Interactivity, Make the Game Fun for the Player, not the Designer or Computer, Provide an Enticing Long Term Goal, etc.. Cookbook elements are a substantial part of many game design publications (e.g. Rollings and Adams, 2003, Oxland, 2004, Salen and Zimmerman, 2004, Novak, 2005, Rouse, 2005, Bateman and Boon, 2006).

Game challenges are of particular interest from a cognitive perspective, since game challenges tend to be expressed in terms of cognitive skills in forms close to those investigated by cognitive psychology experiments (e.g. Eysenk and Keane, 2010). For example, Rollings and Adams (2003) provide a useful list of the following challenges:

- **Logic and inference challenges**, mostly used in games of **perfect information**, and typical of traditional board games.
- **Lateral thinking challenges**, => existing knowledge and skills applied in a new and unexpected way, **Intrinsic or Extrinsic** to the game world
- **Memory challenges** are purely intrinsic and make demands of the player’s memory of what has happened previously within the game world
- **Knowledge-based challenges** rely upon the factual knowledge of the player, a classic example being the game **Trivial Pursuit**.
- **Pattern recognition challenges** are often found in older computer games of the “twitch” variety, such as **Star Wars** and **Galaxians**.
- **Moral challenges**, are a rather undeveloped form but found in some games
- **Spatial awareness challenges** are usually implicit, often dealing with the need to escape from a disorienting maze (eg. **Quake**)
- **Coordination challenges** are usually found together with reflex/reaction time challenges
- **Reflex/reaction time challenges** test the player’s timing abilities. Many games incorporate these challenges, including platform games, shooters, arcade and racing games
- **Physical challenges** are rare in computer games (with an increasing number of exceptions such as dance and music games or Wii games), but are present by definition in physical (i.e. not computer-based) sports games

Additional pure challenges (not mentioned by Rollings and Adams) might include:

- **Adaptation challenges**, to develop a successful pattern of interaction that allows progress to be made within the game, typically achieved by trial and error, with a lack of propositional content (ie. Facts). These challenges are present in most (if not all) entertainment computer games.
Learning challenges are present in all games. They are a kind of high-level challenge. The Rollings and Adams list is very static, suggesting that the player is tested for their existing skill in the manner of an IQ test. Actually the player is often required to learn new skills, or at least to increase skills through the course of playing.

Social challenges (especially relevant to multiplayer and massive multiplayer games). Players meet social challenges involved in forming successful task-achieving teams with other players.

Political challenges are a specialization of social challenges dealing with more complex issues and scales of social structures (e.g. organizing guilds and guild actions).

Perceptual challenges involve skills in perceptual discrimination (e.g. player must match a simple musical melody)

Aesthetic challenges involve the need to develop or understand a particular aesthetic style or pattern (see http://www.soundtoys.net/)

Game challenges present problem solving opportunities and as such require the application of cognitive skills for their solution. As noted by Kili (2005), to overcome game challenges the player (1) generates ideas to face the challenges, (2), develops his or her ideas taking the constraints of the game into account and tests different solutions in the experience loop, (3) starts to explore what might work, (4) reflectively observes the feedback in ways that may lead to construction of new schemata, that (5) in turn can lead to new improved solutions. Hence the nature and design of game challenges is central to the forms of cognitive skill involved in learning how to play specific games and game genres.

1.5.4 Modelling Players

There are two broad aspects of modelling game players. One concerns modelling the subjective nature of the gameplay experience, emotions and states of consciousness that occur during gameplay, and the substructure of these factors that motivate or reward players and thereby lead them to continue to play. This aspect is critical in the application of game design in technology-enhanced learning approaches that seek to use the motivational aspects of games and gameplay to increase the motivation of learners to engage with learning interventions (e.g. Gee, 2003, Squire, 2005). The second aspect involves more generic characterisations of players, e.g. using gameplay styles and preferences, or more general instruments such as standardised personality assessment metrics. Each of these is considered in turn.

1.5.4.1 Gameplay Experience, Schemas, Immersion and the Pleasures of Play

Gameplay schemas provide a foundation for analysing and understanding the various motivational factors that keep players engaged and immersed in gameplay. Holopainen and Meyers (2000) suggest that players are driven to continue in gameplay due to the desire for both predictive and dramatic closure, where predictive closure is a desire to complete a mental model, while dramatic closure is the resolution of the tension driving a story structure. Holopainen and Meyers suggest that gameplay consists of the performance of typically
repetitive actions, driven by the expectation of closure where in a well-designed game there are multiple hierarchical levels of subclosures. Holopainen and Meyers also suggest an important role for spatial and temporal displacement, which is the tendency of players to project themselves into the representations of the play experience such that rewards defined within the fictional world of a game are experienced as rewards bestowed upon the player. In the terms of the framework described here, temporal closure may be attributed to the operation of schemas having resolutions corresponding with successful executions of the schemas. Hierarchical structures of closures correspond with hierarchical schema operation. Displacement can be regarded as a higher level cognitive process by which the representation of agency achieved by game media, together with interaction within the dynamics of the representation via the feedback loop from perception of game events to motor operations enacting game moves, achieves a level of player identification with the player character (‘I killed the goblin’, rather than ‘my character killed the goblin’). A player’s self-identification with their game character links perceptual events attended according to schema priorities with more general criteria of self value and reward built into the player’s cognitive construction of identity.

Klimmt (2003) offers an account of the enjoyment of gameplay based upon three factors: the experience of effectance, cyclic feelings of suspense and relief, and the fascination of a temporary escape to an alternative reality provided by the fictional world represented by a game. Effectance on the most basic level, corresponding to the atomic level of initiating and experiencing the consequences of game moves, is realised as a series of single loops of player input followed by game system response and output. Effectance provides inherent pleasure in the form of immediate feedback to the player as a causal agent influencing the game world, a satisfying experience in comparison with the often ambiguous or limited influence of actions or intentions in the everyday world. The pleasures of effectance in computer gameplay may be greatly enhanced, since a small scale action like clicking a mouse button can have large scale in-game consequences, such as mass destruction, landscape alteration or transfers of large amounts of virtual wealth.

Klimmt describes the next level of organisation in gameplay in terms of episodes consisting of sequences of input/output loops structured by possibilities or a necessity to act followed by action and a result (e.g. overcoming a game challenge) leading to the next episode. Hence an episode corresponds with what Lindley (2005a, 2005b) refers to as a game bout or round, actually constituting a complete mini-game as a self-contained competitive experience, this corresponding to an action sequence executed according to a gameplay schema. Enjoyment within episodes may include the excitement of possible action, the pleasures of curiosity and discovery, the pleasures of experiencing the negative emotions of suspense followed by the transference of arousal to an ecstatic experience when the challenge creating the anxiety of suspense is overcome, and enhanced self-esteem. Due to the interactive nature of games and the strong ego involvement via identification of players with their game character (i.e the displacement phenomenon described by Holopainen and Meyers, 2000), the pleasures of relief at the resolution of episodes are greatly enhanced in comparison with non-interactive media since they function to boost player self-esteem. Since games offer long sequences of short episodes, they uniquely offer an ongoing opportunity for the pleasures involved in the transference of arousal from suspense to joyful resolution, driven according to underlying gameplay schemas.
Finally, Klimmt describes the whole session of playing that includes the sequence of episodes and provides the player with the experience of participating in a narrative. As active participants in the events of the narrative, players have the pleasure of being able to experience new objects, actions, social interactions and experiences at no risk. These vicarious experiences can help players to cope with felt frustrations and deficiencies in their everyday lives, a process both of catharsis and of perception of increased competence and relevance.

Klimmt’s model provides a basis for explaining reward during the detailed execution of gameplay schemas during which each mapping from perception through a decision process to an action is rewarded as the experience of effectance. Schemas offer greater discrimination at the level of episodes by allowing different forms of episodes to be modelled as the result of different schema patterns (e.g. different scripts for combat, exploration, trading and quest negotiation). All of these script types can be rewarded upon completion by the intrinsic rewards of completion described by Holopainen and Meyers (2000), while different types of scripts may have their own specific rewards, such as curiosity and discovery for exploration scripts, the overcoming of suspense for combat scripts, and enhanced self-esteem for trading and questing scripts. Schemas for stories include rewards not just via displacement facilitating vicarious experience, but also through the gratifications of expectations created by the story schema structure being met, a large scale manifestation of the rewards of completion.

Schema models may, then, provide a detailed description of the processes underlying gameplay that can accommodate a variety of different forms of player reward. In addition to this, schema theory can provide detailed hypotheses regarding the nature of game engagement and immersion. Douglas and Hargadon (2001) note that it is highly normative schemas that enable readers of narrative texts to ‘lose’ themselves in the text in what they refer to as an immersive affective experience. Douglas and Hargadon contrast this with engaged affective experience where contradictory schemas or elements defying conventional schemas tend to disrupt reader immersion in the text “obliging them to assume an extra-textual perspective on the text itself, as well as on the schemas that have shaped it and the scripts operating within it”. Disruption of expectations requires engagement with an unfamiliar narrative structure.

While Douglas and Hargadon use schemas to explain immersion in and engagement with hypertexts, the same concepts apply to gameplay schemas. As noted above, when a gameplay schema has been learned, a player may attempt to apply it within games that appear to resemble those within which the schema has previously been successful. Hence players may repeat gameplay patterns without exploring new interaction possibilities afforded by new games, as long as the established patterns support progress within the game. A new kind of game in which previously established gameplay schemas do not work might in these terms be said to require players to become involved in the engaged affective experience required for developing new gameplay schemas (or indeed to initially determine which already available schemas apply within a specific game). Once a successful schema is matched or formed, the player shifts from engaged affective experience to immersed affective experience in the performance of the schema.

Extrapolating from Douglas and Hargadon’s (2001) suggestion for the case of interactive hypertexts, and as previously observed by Turkle (1984) in the case of games, gameplay often reaches states of timeless loss of self-consciousness, involving the state of consciousness that
Csikszentmihalyi (1991) calls flow, a state at the boundaries between engagement and immersion, of being totally absorbed in meeting a constantly unfolding challenge. Contrary to Douglas and Hargadon’s view, however, this need not have anything to do with narrative. For games it is generally a state of pure gameplay, in the present terms, a state of selecting and performing gameplay schemas to provide immersion in performance within the internal world of a game, but not (necessarily) in the internal world of a narrative. The performance is itself a process requiring attention, and for successful flow the attentional demands of performing an integrated cognitive and instrumental pattern must fall above thresholds of boredom and within the bounds of what is achievable and sustainable for the player in a flowing state of concentration. Csikszentmihalyi characterizes flow, an experience that is simultaneously challenging and rewarding, as one of the most enjoyable and valuable experiences that a person can have. Careful study of the structure of gameplay schemas, together with an exploration of the attentional mechanisms orchestrated by schema structure, may provide a cognitive explanation of this experience of flow and its variants.

It may be asked whether a schema-based explanation is sufficient to explain all forms of immersion in gameplay. Based upon observations of children playing games, Ermi and Mäyrä (2005) have proposed the SCI model in which immersion in gameplay can take three forms. Sensory immersion involves an immersion in the audiovisual perceptual qualities of a game. Challenge-based immersion involves immersion in the cognitive and motor tasks performed in order to meet the challenges designed into a game. Imaginative immersion involves immersion within the represented imaginary world and fantasy of a game. In terms of the framework presented here, imaginative immersion can be regarded as immersion facilitated by the execution of story schemas and other schemas of being in a world. Challenge-based immersion can be regarded as immersion facilitated by the execution of gameplay schemas. It is not clear, however, that sensory immersion can be accounted for by a schema theory. Some forms of sensory immersion may be accounted for by schema models, such as immersion in the musical experience of a game, or in visual completions within the visual representational functions of a game (e.g. perceiving an environment, involving scene schemas, or in the rewards of gestalt completion for recognising objects in the game world by cognitively grouping a set of perceptual components). However, immersion in more freely structured perceptual phenomena, involving sounds, colours, lines, textures, movement and forms beyond what they represent, may involve different neural processes, perhaps similar to the kind of selective activation of neural centres to which Ramachandran and Hirstein (1999) attribute the general appreciation of aesthetic value. In this sense sensory immersion may be extra-schematic, an immersion in lower level perceptual cognition when perception is not attached to decision processes.

This section has considered gameplay and experience from a rather low level, cognitive perspective. Detailed investigations of emotions, attentional states and states of consciousness associated with specific in-game events and actions are ongoing (e.g. see IJsselsteijn et al, 2008, Kallinen et al, 2007, Kivikangas et al, 2008, Nacke and Lindley, 2008, Ravaja and Kivikangas, 2008, Ravaja et al, 2008, Lindley and Sennersten, 2008, 2009). However, as noted by Ravaja and Kivikangas (2009), these investigations rapidly become very complex in the number of relevant factors bearing upon quantitative results. If we take the broad capacity for digital games to present both rich and highly social virtual worlds, the experience and rewards of play rapidly become impossible to pin down to a small number of principles, becoming instead as broad as all possible motivations and rewards in the world, both physical
and (by computational synthesis) virtual. It is not possible within such a broader view to adopt a narrow methodological perspective to try to understand all possible motivations and rewards of gameplay.

1.5.4.2 Player Typologies

Useful player typologies should make distinctions among players that can be correlated with different descriptions of emotional experiences, affects, states of consciousness and rewards when different players interact with the same game design features. The hypothesis here is that gameplay affects vary among players and the goal of finding validated descriptors for differentiating among players is to be able to make these variations explicit as a foundation for analysis and game design practice. Different players may want very different kinds of experience from a game, and the interrelationships between player motivation, game mechanics and play style may be complex. A particular concern in game design is that a player may play in a style different from the play styles that a game is designed for. The play style goals of a game design can be expressed explicitly as a basis for deciding not only what styles to accommodate in the game mechanics, but also if and how to create the freedom for players to improvise around the mechanics if their play preferences are not strongly accommodated.

An influential scheme for categorising play styles has been developed by Richard Bartle (1996, 2004). Bartle’s scheme\(^2\) is derived from discussions between highly experienced MUD\(^3\) players on the topic of “What do people want out of a MUD?”. Bartle’s categories represent forms of player enjoyment identified in these discussions. The categories are:

- **Achievers** driven by in-game goals, usually consisting of some form of point gathering (eg. experience points, levels, money).
- **Explorers** driven to find out as much as they can about the virtual world, including mapping its geography and understanding the game mechanics.
- **Socializers** use the virtual world to converse and role-play with their fellow gamers.
- **Killers** use the virtual world to cause distress to other players, and gain satisfaction from inflicting anxiety and pain on others.

Bartle notes that these categories are fuzzy and that players may cross over, although one play style tends to dominate the preferences of any given player. The categories represent differences in preferred activity, and these differences are reflected in the language and discourse patterns of the different respective player types. Bartle suggests that the categories derive from two dimensions of distinctions, one ranging between *acting* upon (killers and achievers) and *interacting* with (explorers and socialisers), and the other between *players* (killers and socialisers) and the *world* (achievers and explorers). Bartle also identifies specific

\(^2\) Bartle (2004) proposes a third dimension for this scheme and discusses alternative categorizations; this discussion focuses on the initial four category system, both for simplicity and due to the added validation and refinement supplied by Yee’s (2002) study.

\(^3\) MUD is an acronym for Multi-User Dungeon, a text-based form of shared virtual world.
game features favouring each category while suggesting that achieving a balance between the play styles is an important factor in the ongoing success of a virtual world.

John Kim (1998) has examined player style in the context of live-action and table-top role-playing games (RPGs). This has led to the development of what he refers to as the Threefold Model, regarded as a way of grouping many aspects of “group contracts” into logical categories. The group contract is a kind of collective agreement between a specific group of players covering every facet of how a game is to be played: mechanical rules, how scenarios are constructed, what sort of behaviour is expected of player characters, how actions not covered by the rules are resolved, the allowance of outside distractions, etc.. The categories of the Threefold Model are:

- **Drama.** The dramatist style values how well the in-game action creates a satisfying storyline.

- **Game.** The “gamist” style values setting up a fair challenge for the players (as opposed to the player characters). The challenges may be tactical combat, intellectual mysteries, politics, or anything else. The players will try to solve the problems they are presented with, and in turn the game master (GM) will make these challenges solvable if they act intelligently within the contract.

- **Simulation.** The simulationist style “values resolving in-game events based solely on game-world considerations, without allowing any meta-game concerns to affect the decision. Thus, a fully simulationist GM will not fudge results to save PCs or to save her plot, or even change facts unknown to the players. Such a GM may use meta-game considerations to decide meta-game issues like who is playing which character, whether to play out a conversation word for word, and so forth, but she will resolve actual in-game events based on what would "really" happen.”

As noted in Lindley (2005b), these categories have both similarities to and differences from Bartle’s. In particular, Bartle’s system does not have a category corresponding to the dramatists. Kim’s gamer (or gamist) category appears to be the same as Bartle’s category of achievers, while Kim’s simulationist category appears to be loosely analogous to Bartle’s explorer category. Bartle’s socialisers and killers are missing from Kim’s system. Although Bartle includes role-players within the socialiser category, all of Kim’s categories cover role players, and hence are socially oriented, and, as seen below, role playing cannot be simply equated with Kim’s dramatist category. These differences may be indicative of a different purpose behind the systems, largely resulting from the different form of games involved. Live-action and table-top RPGs require social agreement in order to effectively realise the game, since the rules are implemented manually, imaginatively and socially. However, it is plausible that the socialiser and killer categories could equally well provide the foundations of the social contract required for manual implementation of game mechanics. Bartle is dealing with computational worlds in which the social contract is generally implicit and enforced by the software mechanics of the virtual (game) world engine. In this case the categories become ones of play preference within the space of possibilities supported by a software system, and the dramatist style becomes a plausible category omitted from Bartle’s scheme.
Yee (2002) has built upon Bartle’s scheme, adding just such a category (the immersionist), modifying the other categories and also dropping the explorer category. Based upon empirical data provided by questionnaires answered by 6700 players (at the first time of reporting in 2002), followed by statistical factor analysis, Yee identifies the following categories representing the primary high level grouping of responses:

- **Relationship** (socialisers): This factor measures the desire to develop meaningful relationships with other players in the game - usually in the form of a supportive friendship. Players who score high on this factor usually make good friends online, and tend to have meaningful conversations with their online friends, that involve talking about real-life personal issues. In times of need, these players can usually count on their online friends for emotional support. These players also tend to feel that they have learned things about themselves from playing the game, as well as gaining a better understanding of real-life group dynamics.

- **Immersion**: This factor measures the desire to become immersed in a make-believe construct. Players who score high on this factor enjoy being immersed in a fantasy world they can wander around and explore. They tend to role-play their characters, and use their characters to try out new personalities and roles. They enjoy being in the company of other role-players. They also appreciate the sense of being part of an ongoing story, and oftentimes will think up a personal history and story for their characters.

- **Grief** (killers): This factor measures the desire to objectify and use other players for one's own gains. Their means may be overt or subtle. On the overt side, they may enjoy dominating other players by killing them on the battlefield, or by taunting and annoying them. On the more subtle side, they may enjoy manipulating other players for their own gains, such as deceiving other players through clever scams, or begging for money and items. In either case, satisfaction comes from some form of manipulation of other players for personal gain.

- **Achievement** (achievers): This factor measures the desire to become powerful within the construct of a game. Players who score high on this factor try to reach the goals defined by the game. They try very hard to accumulate rewards. For example, they try to optimise their experience point gains to reach the next level as quickly as possible, they may try to accumulate as much high level gear as possible, or they enjoy doing massive amounts of damage to non-player characters (NPCs). The underlying theme is a desire to get bigger numbers, but the satisfaction comes from feeling powerful.

- **Leadership** (which can be regarded as a subcategory of socialisers): This factor measures the gregariousness and assertiveness of the player. Players who score high on this factor prefer to play in a group rather than alone. They are often assertive individuals and usually drift to leadership positions when in a group. Because a group led by an indecisive leader often gets fragmented, the assertiveness of these players probably allows them to be effective group leaders in the game.
A game provides an important context underlying successful engagement and immersion for players with all of these motivations. It is in particular the presence of gameplay and unfolding stories that provide a sense of depth and purpose for socialisation, as well as the immediate input and play mechanics for achievers, killers and immersionists.

Interestingly, Kim’s categories of Drama (story and narrative), Game and Simulation as driving principles for social gaming contracts also underlie the independent isolation of these factors as formal systems within computer games. Aarseth (1997), Frasca (1999) and Juul (2001) focus on the question of the relationships between narrative and gameplay in computer games. Frasca (2001) focuses on the nature of a game as a simulation. Lindley (2003, 2004) brings these elements into a three-way relationship and highlights the three formal systems in terms of existential dependency, a hierarchy of temporal design concerns, and different and complementary sets of methodologies for design. The mechanics of a computer game may realise the designed formal structures at all three levels, but players may be more or less free to play creatively in a style of their preference, in tune or at odds with the design emphasis in the computer game artefact.

This freedom also underlies the many roles that a player may have in relation to their character and the game world, discussed by Pohjola (2004) in the context of live-action role-playing as a question of identity and immersion. Different strategies for identification and immersion suggest very different strategies for narrative and story construction in computer-based role-playing games. Based upon and extending Pohjola’s discussion, it is possible to propose at least the following four attitudes towards drama/story/narrative within a game:

- the audience: preferring passive reception of a narrative, i.e. being told a story; this is the model implicit within the use of predefined cut scenes in commercial computer games to convey story elements designed by the game developers

- the performer: preferring active performance of a character role within an unfolding story; further distinctions here might be made in terms of the degree to which the role and/or the story are predefined, as opposed to being created by the performer prior to or during the performance

- the immersionist: preferring immersion of the player in the character, i.e. the player/character distinction is dissolved into a unified persona within the game world; here too there is a question of the degree of character predefinition required to encourage immersion

- the director: preferring not to self-identify with a game character or to be told a story, but rather to direct the action of one or more characters from a distance, as in so-called ‘god games’ like The Sims or Sim City.

While Bartle (1996) has proposed specific game features supporting and encouraging the different play styles in his system, since he had no dramatist/immersionist category, the features required to support this play style remain unspecified. Bartle’s later work (2004) presents a model of the degree of immersion of a player with their character along a continuum ranging from the avatar at one extreme to the persona at the other, reflecting the performer/immersionist distinction. The avatar is a dramatically empty shell, being an
instrumental vehicle for the player within the game world. The persona, on the other hand, is the immersionist state of total player identification with their character, representing the player’s being within the game world. Between these extremes lies the performed character.

Bartle’s (1996) categories of play style emerged from what he describes as heated discussions about what makes a game good, the resulting distinctions accounting for differences of taste underlying player conflict. Similar controversies around the use of cut scenes in computer games can be seen to reflect different player preferences in relation to the story aspects of games, not only between gamers who are not interested and others who are interested in the story, but also between the different tastes for how story elements are manifested, a conflict between preferences for being told a story (the audience play style), performing a story (the performer play style), immersion within a story (the immersionist play style, specialised here from Yee’s use of the term in order to align the term with its use in role-playing theory), and directing virtual characters within a game world without any strong identification with them (the directorial style).

These distinctions are based upon analyses of (often strongly expressed) differences among players in their preferences for how games should be played, how conflicts should be resolved, what represent good games, immersive games, etc.. Notably the distinctions do not yet have any validated interpretation in terms of other measures for assessing personality. Of course, characterisation of players can also proceed by standard psychological tests, such as NEO (measuring Openness, Conscientiousness, Extraversion/Introversion; Agreeableness and Neuroticism), impulsivity, risk-taking tendencies, aggressiveness, etc. (e.g. see Weiner and Greene, 2007). Mapping game affects to game design features and personality traits and gameplay preferences is a complex task, perhaps with questionable validity given the scope of social and cultural changes that occur over the time scale required for generating large bodies of data (a process that by necessity involves numerous research teams over many years).

1.6 Learning Theories and Digital Games

Learning theories and game-based learning have been reviewed in a broad way in the xDELIA deliverable D6-61. Project-Wide Multi-Disciplinary State-of-the-Art. A serious game is most widely understood as a digital game having purposes other than pure entertainment. Learning is the most common of these purposes, based upon the belief that learning through gameplay can be an enjoyable experience that stimulates or encourages players to more intensely engage with educational content than traditional learning media, often delivering situated and action-based learning in simulated environments where physical environments are inaccessible, unavailable, too expensive, or dangerous (Ritterfeld et al., 2009). The analysis of 600 games by Ratan and Ritterfeld (2009) showed that most (63%) of those games emphasised academic content, followed by games for social change (14%), health and occupationally oriented games (8% and 9 %, respectively), games for military training (5%) and games for marketing (less than 1%). Interestingly though, defence organisations use simulations very often for training, with up to 90% of officers studied by Sennertsen (2010) having trained in simulation environments, although this is not considered to be part of the academic context. In academia, simulation-based training is hardly used at all outside of specialised contexts of mathematical modelling, despite computer games being the dominant form of entertainment for contemporary students.
Ratan and Ritterfeld (2009) find that the games they surveyed fall into a small number of categories in terms of the learning outcomes they pursue:

- **Practical skills** (48%), characterised by repeating tasks and activities, with relatively limited information content

- **Cognitive problem solving** (24%), e.g. puzzles and games with complex task patterns

- **Knowledge gain through exploration** (21%), where declarative knowledge is of secondary concern. Players instead focus on exploring problem spaces and learning by doing

- **Social problem solving** (7%), where players collaborate in teams to acquire social, emotional, and decision making skills to prevent problem behaviour

These figures suggest that, as we have broadly characterised the concepts, games have been applied more for cognitive learning (emphasising practical skills learned by repetition, and cognitive problem solving) than for social constructivist learning (emphasising learning by creative and social interaction).

Four frameworks for identifying learning objectives, processes and outcomes are applicable in the context of xDELIA:

- Bloom’s revised taxonomy (Anderson, 2005, derived from Bloom, 1956), is a two-dimensional classification scheme. The cognitive process dimension has six levels of activity: remember, understand, apply, analyse, evaluate and create. These are learning activities that may apply in the overall design of learning interventions. The second dimension in the model is the knowledge dimension, which represents types of learning, including: factual knowledge, conceptual knowledge of classifications, theories and models and so on, procedural knowledge of how to do things by applying methods, techniques and skills, and meta-cognitive knowledge of cognition in a broad-spectrum, comprising strategic knowledge, task knowledge, and self-knowledge (Anderson, 2005).

- Kolb’s experimental learning cycle (Kolb et al., 2001), includes the stages: 1. concrete experience (feeling), 2. reflective observation (watching), 3. abstract conceptualization (thinking) and 4. active experimentation (doing). The conflict between different ways of learning, between concrete and abstract, active and reflective, is resolved by the learner’s learning style, which may be: 1. Diverging: the learner combines concrete experience and reflective observation, 2. Assimilating: merges abstract conceptualization and reflective observation, 3. Converging: a combination of abstract conceptualization and active experimentation, and 4. Accommodating: the learner uses both concrete experience and active experimentation.

• Baker and Mayer’s CRESST learning model (Baker and Mayer, 1999) defines five families of cognitive demands required for learning: the problem-solving task itself, self-regulation, communication, collaboration and content understanding.

These models can potentially be applied to learning in the xDELIA domains of stock trading and investing as shown in Table 1. However, in using these models we notice that they pay little explicit attention to the role of emotion in learning and need adaptation to do so. The exception is the role of self-regulation in the Baker and Meyer model. Here we note that emotion regulation fits well into broader models of self-regulation. (for a more detailed account of our approach to integrating emotion and emotion regulation into our learning approach for investors see Deliverable 23: Pedagogic Framework). Of course, any mode of learning can be simulated and provided in the form of an immersive, 3D virtual world, especially if avatars are provided for multiple students and teachers. Currently there are vast numbers of virtual education tools, and contemporary universities typically have a high dependence upon web-based educational resources (e.g. Online-Educa, www.online-educa.com, is a rich source of concepts for virtual learning systems). Here, however, it is possible to consider game-based learning interventions meeting specific requirements of the trading and investing application scenarios, including the requirements noted in the section “Application to xDELIA Learning Interventions” above, together with the following factors:

• Training for traders is conducted in an environment of intensive interpersonal interaction, contacts and communication, with a heavy use of mentorship and on-the-job training extending over many years. In this context, highly immersive virtual training systems are not desirable, since they would remove trainees from their primary sources of knowledge, understanding and practice.

<table>
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<tr>
<th>Author</th>
<th>Learning Category</th>
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<th>Games for traders</th>
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Table 1. Mapping of learning constructs to games and learning interventions.

- Investors tend to be physically isolated (during investing interactions) and heavily immersed in the investing software platforms that they use, as a focus of intensive emotional and/or attentive investment. It is not desirable to break this immersion with the provision of rich ancillary training systems beyond the training and simulation functions already provided.

Table 1 has been constructed with these factors in mind, together with the previously mentioned focus upon emotion regulation as the target of learning. Degree of relevance is indicated on a scale of: - (not relevant), L (low), M (medium), and H (high).

The relevance of different modes of learning is the same between investors and traders. However, modes of delivery, involving detailed learning intervention design, will be significantly different, due to the very different environments within which learning takes place.

1.7 Eyetracking

Eye gaze tracking is a method that has been used commonly over the last 40 years to study how visual attention is distributed when carrying out different tasks (Sennersten et al, 2007). While there are several different eye movement measurement methodologies (see Duchowski, 2003), here we are concerned with the non-contact method of video-oculography (VOG), which is the basis of readily available commercial eyetrackers. Video-based eye tracking can be used to measure eye-point-of-gaze (EPOG), also called point of regard, i.e. where someone is looking and what they are looking at, if the absolute orientation of the eye in relation to surrounding objects is known. Also, pupil size can provide an indication of intense emotions, concentration/attention and negative valence, blinking can provide an indication of intense emotions, stress and concentration, and gaze movement characteristics can provide an indication of attention and arousal (Andreassi, 2007). Overt attention, via the fovea, plays the major role in visual attentional selectivity, so eye point of gaze indicates the current object of visual attention (Findlay and Gilchrist, 2003).

Eyetracking techniques have been used in many fields, including neurology, cognition, linguistics, branding, advertising, car design, art, media communication, security, etc.. For example, Graf and Krueger (1989) used eye movement data as a performance measure for evaluation of an alphanumeric display, as well as a measure of the cognitive load on the user.
Holsanova et al (2006) have investigated gaze behaviour on newspaper layouts, while Lankford et al (1997) have used eye gaze tracking in the design of telecommunications software. The most commonly used eyetrackers for human-machine interaction research, studies of vision, attention, etc. are screen-based systems (e.g. Tobii T60 or T120, SMI RED/RED250), limited to a user looking at a screen in a fixed location and with a limited range of possible head movements. Another solution for gaze analysis or gaze-directed interaction with flat surfaces (e.g. a larger screen or projected video display) involves separation of the eyetracking unit from the flat surface (e.g. MangoldVision, Tobii X60/X120). These systems are designed for a user in a relatively fixed location, with a fixed target screen, and are not effective during the performance of tasks requiring significant head or whole body movement or mobility. These latter scenarios are more suited to the use of head-mounted eye tracking systems (e.g. ASL Mobile Eye, EyeSeeCam, eyesee cam.com, ISCAN VisionTrak, SMI IVIEW X HED, SR Research Eylink II, Tobii Glasses) that capture video of the scene in front of the wearer and also have one or more cameras observing the eye(s) of the wearer so the eye gaze positions can be superimposed over scene video to show where the wearer is looking.

Eyetracking has been used extensively to study visual cognition in games, for example, providing a foundation for testing specific hypotheses about the influences of visual design upon visual cognition, for modelling gameplay decision processes of players, and for studying the relationship between internal, subjective experiences and self-reports of play in relation to externally observable behaviour. Sennersten (2004) investigated gameplay in a Counterstrike tutorial. In this study, it was found that: 1. slightly more than 50% of gaze behavior fell within the left of the game display, where a priori an even distribution between left and right might be expected, and 2. approximately 50% of players visually fixate on the far end of the graphical representation of the barrel of the gun, that actually has no functionality in the performance of shooting tasks, and in the region in between the end of the gun and the actual aiming cross sight. In this study it was also found that while questionnaire data indicated that players looked at the face of the virtual hostage 90% of the time and at their hands 10% of the time, eyetracking data indicated that the opposite was actually the case.

These results led to further tests of three hypotheses concerning visual attention in close combat tactics as simulated by a first-person shooter (FPS) computer game (Sennersten and Lindley, 2009; see also Sennersten, 2009, 2010). Firstly, the cuing effect of the player’s gun graphic on visual attention was tested, but no evidence was found to support this. Data supported the second hypothesis, that a player attends to the target opponent while shooting at them, in most cases, while in a small percentage of cases this is achieved in peripheral vision. Finally, in most cases, a player targets the nearest opponent. These results provide a baseline for further investigations in which the stimulus game design may be modified to provide more detailed models of the visual cognitive processes involved in gameplay. These results also document the learning outcomes of game interaction and provide a basis for improvements, such as the optimization of combat survival tactics. Sennersten and Lindley (2010) present an analysis of the interrelationship between externally measured gaze behavior (strongly defined measures) and subjectively reported data based upon questionnaires (weakly defined measures), exemplified by the FPS combat simulation task. Sennersten et al (2010) use eye gaze data to extend the Belief, Desire and Intention (BDI) model of cognition to create several new models addressing levels from the individual to the organization, and going from education environments to mission critical operations (these models are described in more...
detail below). The cognitive models and architectural solution models presented are proposed for measuring cognitive and physiological processes when interacting in a simulation or game, or in actual operations. The models presented are derived from data obtained in two field studies of simulation-based training in preparation for ISAF missions in Afghanistan.

1.8 Psychophysiological Affective Analysis

Developing games for emotion regulation requires methods for detecting and responding to emotional, or affective, states as a foundation for the definition of game mechanics and player interaction. *Psychophysiology* is the study of (measurable) physiological manifestations of emotional states (see Andreassi, 2007, and Cacioppo, Tassinary, and Berntson, 2007, Larsen et al, 2008, xDELIA, 2010, and Calvo and D'Mello, 2010). Emotions include subjective feeling, expressive behavior, and physiological arousal, while some models also include motivational state or action tendency and/or cognitive processing. This leads to a degree of ambiguity in the interpretation of emotions, since subjective feeling, expressive behavior, physiological changes and cognitive states may not be synchronised (Larsen et al, 2008). E.g., one may act differently from how one feels, and a given psychophysiological change can be associated with more than one subjective state or experience. Methods of resolving these ambiguities include the cross-correlation of subjectively reported states (via the use of questionnaires) with multimodal psychophysiological measures, where the use of multiple measures may lead to less ambiguous interpretations of corresponding subjective states. Ambiguities remain, however, since the causality of the relationships between somatovisceral activity and experienced emotion is disputed, and different experienced emotions may occur with the same somatovisceral activity. The nature of the context and stimuli evoking emotions also influence the nature of their physiological correlates; e.g. real-life fear is correlated with larger heart rate increases than real-life anger, where these reactions for images are the same, while sadness is generally associated with increased heart rate, although heart rate decreases in response to sad music (reviewed in Larson et al, 2008).

These and other factors discussed by Larson et al (2008) suggest that the use of physiological measures as indicators of subjective emotional experience is far from being fully systematized and must take into account issues of context, stimuli, current tasks, goals, and cognitive appraisal. This amounts to the question, not of what emotion-specific physiological indicators of autonomic activations may occur, but under what conditions emotion-specific autonomic patterns may occur. Hence in the context of the xDELIA project, the subjective emotional correlates of physiological measures must be validated for the target user and application/task environments, validating the use of physiological measures as an input to game mechanics.

The psychophysiological measures of particular interest for xDELIA, based upon interpretive clarity and the availability of accessible measurement systems compatible with the application scenario, are facial EMG, GSR, EEG and EKG.

*Facial electromyography (EMG)* measures voltage levels on the surface of the skin above the locations of facial muscles involved in the generation of affective facial expressions, as an indication of emotional valence (pleasure to displeasure). Increased activity over the cheek (*zygomaticus major*) and periorcular (*orbicularis oculi*) muscle regions increase with positive valence, while EMG activity over the brow (*corrugators superciliii*) muscle region increases with negativity and decreases with positivity (Larson et al, 2008). A study by Janke (1996)
showed substantially reduced EMG activity associated with inwardly-directed anger and a neutral control group, compared with a group expressing induced anger. Janke interpreted this result as providing support for the view of Fridlund (1991) that facial expressions of emotion express information rather than necessarily reflect all felt emotion.

**Galvanic skin response (GSR)** measures skin conductance as an indication of emotional arousal, attention, alertness and effort. GSR measurements are taken from the surface of the skin, where electrical conductivity is affected by sweat released by eccrine sweat glands in response to physiological and emotional arousal. GSR includes short term *phasic* responses to specific stimuli, and relatively stable, longer term *tonic* levels. GSR may be measured in terms of resistance, conductance, or absolute voltage (Andreassi, 2007). Measurements are typically taken from the palm of the hand, the fingers, or the soles of the feet, where eccrine sweat glands are most densely distributed, providing the strongest signal variations. One drawback with the use of GSR in the field is its susceptibility to influences of temperature, humidity and mechanical pressure at the points where sensors are attached.

**Electroencephalography (EEG)** measures electromagnetic radiation emission from the scalp, indicating cognitive/conscious states of attention, alertness and drowsiness. The interpretation of EEG data has largely been framed in terms of specific frequency bands associated with different cognitive and emotional states (Andreassi, 2007): *alpha waves* (8-13 Hz) with relaxation, reflection and inhibition; *beta waves* (14-30 Hz) with alertness, anxiety, concentration, mental and physical activity; *delta waves* (0.5-3.5 Hz) with deep sleep; *theta waves* (4-7 Hz) with drowsiness, pleasure, displeasure, idling and inhibition; *kappa waves* (10 Hz) with thinking; and *gamma waves* (resting frequency around 40 Hz, modulated by 3-5 Hz) with cross-modal perception and perceptual recognition. Evidence suggests that stronger alpha waves in the right frontal hemisphere are associated with withdrawal (negative emotions), while those in the right frontal hemisphere are associated with approach (positive emotions) (Larsen et al, 2008).

EMG and GSR/EEG are especially interesting when interpreted according to a *dimensional* theory of emotion, e.g. the *circumplex* model proposed by Russell (1979, 1980). In the circumplex model, *arousal* is represented as a vertical dimension, and *valence* is represented as a horizontal dimension. There are other dimensional models based upon alternate dimensions of positive/negative affect (Watson et al., 1999), tension/energy (Thayer, 1989), and approach/withdrawal (Lang, Bradley, & Cuthbert, 1998). For all of these models, affective experiences are regarded as a continuum of highly interrelated and often ambiguous states composed of varying degrees of the factors corresponding to the dimensions of the models, where each dimension is attributed to a largely independent neurophysiological system. The circumplex model proposed by Russell (1979, 1980) includes dimensions of valence and affect, that are of interest in biometric interfaces, e.g. due to the availability of low cost EMG and GSR/EEG instruments providing plausible measures of these factors. The circumplex model proposes that any affect word can be understood in terms of its degree of arousal and valence, placing it upon the two dimensional plane mapped according to these dimensions. E.g., fear is interpreted as a state of high arousal and high negative valence, while happiness is a state of moderate arousal and high positive valence. The subjective experiences of fear or happiness may be understood as consequences of cognitive interpretations of these patterns of physiological activity that occur in the context of eliciting stimuli (Posner, Russell, and Peterson, 2005). Cognitive interpretations are employed to identify neurophysiological
changes in the valence and arousal systems and conceptually organize these physiological changes in relation to the eliciting stimuli, memories of prior experiences, behavioral responses and semantic knowledge (Russell, 2003).

The circumplex model has been used research in studies of computer game interaction, and for modifying gameplay automatically in response to the measured emotional states of a player (see, e.g., Ravaja et al, 2006, Nacke, 2009, Nacke, Grimshaw, and Lindley, 2010, Nacke, Stellmach, and Lindley, 2010, Nacke, and Lindley, 2009, Nacke et al, 2009, IJsselsteijn et al, 2008, Grimshaw, Lindley and Nacke, 2008, Nacke and Lindley, 2008a, Nacke and Lindley, 2008b, Nacke, Lindley and Stellmach, 2008, FUGA, 2009). Within xDELIA, this system can be used as a basis for classifying human emotional responses, e.g., as measured by GSR/EEG and EMG, providing emotional data for use by a game for automatically modeling affect states of the player. This can then be used as a foundation for assessing emotional biases in decision making, and to provide feedback to players about where and how their emotions are implicated in, and impact upon, cognitive decision making. However, this use must first be validated in the target applications in relation to contextual, personal and task-related factors influencing the meaning and interpretation of physiological measurements.

Electrocardiography (ECG) measures heart rate, which can be used to assess heart rate variability (HRV). Heart-rate variability yields information about autonomic flexibility and thus regulated emotion responding. HRV can be considered a proxy for the central autonomic network’s regulation of the timing and magnitude of an emotional response via inhibition, in response to context (Appelhans & Luecken, 2006; Moses, Luecken, & Eason, 2007; Utsey & Hook, 2007; Geisler & Kubiak, 2009; Hansen, Johnsen et al., 2009). Higher levels of high frequency HRV have been associated with constructive coping in university students and lower high frequency HRV with the use of repressive coping strategies, anxiety, depression and rigid attentional processing of threat (Appelhans & Luecken, 2006). Recent studies have demonstrated the utility of HRV in providing a task-related, moment by moment, assessment of regulation (Moses, Luecken, & Eason, 2007) suited to field studies of task performance (Segerstrom & Nes, 2007). An xDelia study has demonstrated an association between the expertise of traders in two investment banks and effective emotion regulation as measured by high frequency HRV during trading episodes around market news releases (Fenton-O’Creney et al, 2011). Further detailed of HRV are presented in Part 3 of this document.

1.9 Modelling Higher Orders of Social Cognition

In this document we have presented a cognitive framework for analysing gameplay, as a congitivist perspective (with associated methods of measurement) especially suited to situations where gameplay is highly repetitive and the contexts of play are highly stable. We have proposed that decreasing contextual stability leads to decreasing usefulness of a congitivist perspective as characterised, and an increasing applicability of social constructivist perspectives. However, this is not to say that all knowledge pertaining to larger scale social structures cannot be modelled using congitivist modelling techniques. For larger scale social structures, those having stability and persistence may be amenable to cognitive modelling. This presents a range of levels of cognition, where problem solving and decision models may be encapsulated at different scales, from the individual to the organisational, and with
differing degrees of explicit representation, from the wholly implicit and unconscious to the explicit and textual/declarative.

This perspective is here exemplified with a case study involving two exploratory field studies of simulation-based training sessions held for military staff before leaving for ISAF in Afghanistan (Sennrsten, 2010, from which this material is derived). Study methods include eye gaze tracking, video and audio recording, behavioral observation and retrospective questionnaires. The field studies were conducted at the Swedish Life Guard Regiment sub-departments: International Training Unit (IntUtbE), that conducts pre-deployment training for Peace support operations, and the Swedish Armed Forces International Centre (SWEDINT), involving simulation-based training sessions carried out with their Simulation, Modeling and Practice Platform.

Based upon data obtained in the field studies, cognitive models of decision processes involved in operational task performance were developed, using cognitive modeling methods beginning with the Belief, Desire and Intension (BDI) model. This model was then modified in several steps to cover different levels of decision making revealed by the field studies, including an intrapersonal and organizational layer, an educational layer, a layer where objects are built into decision algorithms as a basis for purposive behavior, and finally a team competency layer built largely during debriefing sessions. The outcome of the pilot study was the identification of the abstract form of models (more accurately, the cognitive modelling metamodels) required for comprehensive modelling of decision processes within this domain.

The cognitive modelling methodology and software called Beliefs, Desires and Intentions (BDI, Wooldridge, 2000) functions as the starting point for cognitive modelling in the pilot study. However, BDI was found to be insufficient for modelling all aspects of decision processes in the military application domain. Hence a series of metamodel variants were produced, based upon BDI and interpreting it from points of view of: the military organization, education, instructors, simulation-based training, operational scenarios in the field, teams, and debriefing situations. The resulting BDI-derived cognitive modelling methods (Fig. 2) include:
Figure 2. BDI, a cognitive reasoning model, and its modification over several steps from individual and organizational points of view, education through operational missions in teams, to retrospective performance evaluation. The last step is gathered competency that can feed back into the high level BDI model of the system and organization. From Sennersten (2010).

- the original BDI model and its framing
- the A<sub>KS</sub>GA model for training in military education
- OGA, a simulation-mediated perspective
- OPA/OP<sub>D</sub>A and OP<sub>D</sub>A<sub>T</sub> emphasizing object perception and taking advantage of rapid eye gaze
- IDC<sub>TO</sub> where shared imperfect experience and debriefing are major cornerstones

The models are interrelated and are understood to operate in parallel where many levels of operational and training environments and systems are considered. Note in particular that these are not implementation models; the question of the best architectures and/or languages for the implementation of the models is not within the scope of the pilot study. Rather, the models are abstractions of distinct decision processes within the application domain, derived from the field studies. Computational implementation of the models is proposed by Sennersten (2010) to contribute to decreasing gaps in training, and/or increasing safety and security in simulation and operational worlds, or a mix of both.

In the pilot study it was found that the original BDI model can be used to represent the organizational framework within which simulation-based training is conducted. The framework and rules of the organisation are formed over many years, representing the values and rules that an organization stands for, that all individual activities within the organization are supposed to conform to. So the BDI level is an intrapersonal and an organizational model. Desire in this case is about motivation of goal-oriented behavior that leads to action. Desires were not found to have a functional place when it comes to fast action in operational
tasks in a changing environment, since fast action responses are reflexive, prebuilt during training; the routines and the intentions of a BDI framework are worked out beforehand and discussed so they should not need elaboration while performing varied tasks in the field that are not necessarily routine, but at least anticipated. Beliefs, desires and intentions are therefore perceived here as a model that lies as a background for an organization, where frameworks are developed over long periods of time and also where documentation and negotiation are important processes for forming a stable framework. This belief-desire-intention framework is what an individual is ‘accepting’ when deciding whether to join an organization or not. Hence the BDI organizational layer frames the whole organization and mission, and mission training includes training in the values of this layer. The BDI model has constraints if it is used for operational purposes where fast paced decisions are required, and these constraints motivate the definition of complementary models.

AKSGA stands for Ability, Knowledge and Skill(s), serving Goals and generating Action. In the military application domain this represents abilities that officers are required to practice and that have to function as background knowledge, a backbone plan, for use in most activities carried out in an international operational mission. AKSGA includes the ability model used in military education in Sweden (Försvarsmakten, 1988, 2006). The ability model is used for educating military staff both for national and international missions, with the aim of making education effective at least in part by having people use the same concepts and having a collective language for goal formulations in qualitative terms. The ability model is used to shape a comprehension of simulation-based training sessions for upcoming missions. Bratman’s BDI model (Bratman, 1999/87) is captured in IntUtB’s principle of HOW TO DO which could be said to be based in Belief plus Desire which then gives the Intention to perform or to do something. However, the result of the training process is to combine APPLICATION (ability) as KNOWLEDGE and SKILL with educational goals so the trainees know how to act in different situations, e.g. how to stop blood pumping out from an artery or how to shoot, how to use a vehicle, a weapon, a system, etc.. The educational model means that a trained person has done an action before and can do it independently and also that time pressure can come into the picture without being a problem. Hence these learning outcomes are more suitably modelled using AKSGA as an extension of the BDI model, more directly stressing operational competence.

On a group level, AKSGA models collective action of people with different experiences following formal education about a certain area or context. From an educational point of view, the aim is to have trained for common collaborative action at the lowest level in/for a context. So with AKSGA, we move from the organizational and intrapersonal BDI level to personal and group training outcomes concerning action-oriented abilities and skills. The AKSGA model in its context helps to clarify performance qualities and quality levels for an individual as well as for a team. The description and use of the ability model “...is especially useful in goal formulations as well as planning, performance, analysis and evaluation of education” (Försvarsmakten, 1988). AKSGA is an abstraction of the structure and functions of the ability model.

The Object, Goal (in context) and Action (OGA) level from Sennersten’s (2010) study operates in a training or adjustment phase where there are no real world consequences. The original BDI model does not include perception, while in OGA this is lifted into the model as “O”, the perceived object layer. This layer replaces Belief with tangible object perception.
Goal development then involves typically long term interaction and a bridge from ability training and long term negotiations into every day operations, a state of peacekeeping operations where the OGA can be a prolongation of the BDI and where also both models can work in parallel. From BDI via $A_{KS}$GA to OGA (Object, Goal and Action), Belief is replaced with Object as the source of information, Desire is replaced with Goals and Intention is replaced with Action. In simulation-based training this model is more accurate for modelling another, faster pace for exercising decisions than for the BDI or $A_{KS}$GA models. The officer observes the world (VBS2 simulation scenarios in the case study) and its constituent objects, and an OGA model represents the mapping from these observations to chosen (and potential) actions according to relevant goals. This is far too much detail for higher level concerns of the organization, which are therefore better modelled using BDI, while $A_{KS}$GA is more concerned with learning social collaboration and providing a map of different kinds of abilities, knowledge and skills as training targets, without necessarily going into the details.

The question arises of how committed an agent should be when the agent has selected an action. This may involve two questions: 1) how committed, and 2) for how long? There are different kinds of commitments (Wooldridge, 2000): i) blind commitment/fanatical commitment, ii) single-minded commitment, and iii) open-minded commitment. The OGA level allows for some extended deliberation in order to resolve these kinds of issues and obtain a decision.

Some actions have purposes that may not drive deliberative action selection by individuals or teams, for example, routines, such as reporting reaching waypoints to local command and control centres. Routines are trained for and performed often enough that they are performed automatically and with little deliberation, and without being driven by detailed conscious goals. They relate to specific objects, have purposes, and consist of highly familiar actions. This can be modelled using Objects (O), Purposes (P) and Action (A). This is referred to as an OPA model.

It is also necessary that at least some training aims for direct and rapid action selection under circumstances that are not routine (although they may be heavily trained for) without any extended deliberation. Hence, while an action in OGA can be regarded as a deliberatively chosen behavior in response to certain stimuli, interaction (as in $A_{KS}$GA) is more of a dialog, and direct action, $\rho_A$, is more or less reacting with highly automated responses and little or no deliberation. To accommodate this we introduce the Object, Purpose, (direct)Action, or OP$_d$A, model. (Actions in OPA have less urgent time requirements than in OP$_d$A.) OP$_d$A, stands for a level of direct action that may be modified by a deliberative context.

In the field studies reported by Sennersten (2010), statements were observed that were about scenarios testing cognitive decision-making and judgment rather than skills, which should eventually lead to the capacity for skill-based direct action when there is no room for cognitive decision-making in the actual moment, or direct action responses may be trained in a way that does not rely upon higher level cognitive processing other than an understanding of the context. In direct action, cognitive procedures and allocations have been trained and built up over many hours and possibly years, resulting in the capability for rapid reaction that can be critical for survival. The object triggering rapid reaction and its value are what an agent sees (O), the information about the world, and the purpose (P) of direct action ($\rho_A$) is to meet that object and its value in a way that achieves higher level goals, but without deliberative
action selection. From a BDI organizational perspective the information about the world and its framework is quite stable, while the need to make rapid decisions under pressure (at the OPDA level) raises the question of how to quickly process the information at hand to arrive at an action while staying within a framework of higher level rules and negotiations. This requires the kind of multi-level cognitive framework proposed in the study (Sennersten, 2010).

OPA and OPDA provide models of how Object(s), Purposes and Actions function at an intrapersonal level. These models have been derived from observations of individual roles, but it is also necessary to consider how teams may function. This leads to a team extension to the OPDA model, leading to $OP_{DA^T}$, where $T$ stands for Team. There are different kinds of teams and here the term team is used with the meaning of “A group organized to work together and on the same side (as in a game)”. $OP_{DA^T}$ captures training for the ability to constitute a team in relation to operational tasks. The team participants are required to understand individual roles and their prerequisites, leading to a cognitive team model. As a result of this training, “job performance (task performance) is related to cognitive ability and not to personality” (LePine and Dyne, 2001). $OP_{DA^T}$ allows modelling of individual and possible collective “observation” tasks that can result in a common cognitive model for specific kinds of decisions. Direct action here means to act and know what to do in a coordinated way among team members without long thought processes or individual or collective deliberation. Coordination among team members may involve terse verbal or nonverbal signs.

The final level of Sennersten’s (2010) model is that of Information, Debrief and Competency within Team and Organization ($IDC_{TO}$), which refers to collective cognitive processing where, after training and debriefing, the team has developed an imperfect competency together that can be of further use for later team collaboration in improving understanding. The competency is an interpersonal shared mental model based upon common experience of situations. It is important here to understand the difference between imperfect post-experiential information and information needed in ongoing task performance in the present. Debriefing is about role- and team-shaped postscripts in relation to former initial prescripts. The pre- and postscripts form learning/comprehension outcomes. The simulation-based training scenarios carried out provide a basis for case studies in debriefing and also provide a ground for in-simulation team dialog.

The cognitive (meta) models presented above identify different levels and forms of cognitive decision processes involved in military simulation-based training. Detailed models at these levels can provide a basis for: i) analysing and understanding cognitive processes both within training environments and real operational environments, including evaluation of the effectiveness of different operational decision models, ii) expressing target cognitive processes for training, and iii) evaluating the effectiveness of training systems by comparison of target models with models achieved via training systems. These three uses represent a development sequence, of first identifying cognitive decision model variants and possibilities, then prioritizing and selecting from these to specify detailed cognitive training targets, and then using these targets for evaluating and improving training processes. Of course, fully developing comprehensive models at all levels for a given operational environment would be an enormous and perhaps impossible task, so actual use of the models will require more selective application.
1.10 Application of the Cognitive Framework to xDELIA Games

The xDELIA deliverable D17-4.1 Part 1, ‘A Cognitive Framework for Understanding Gameplay’, presents the approach to developing pedagogical games within xDELIA, including theoretical bases and methodological approach. This material presents a central characterization of cognitivist and social constructivist understandings of cognitive learning (section 1.3), as a basis for deciding upon an overall design approach for a specific game within xDELIA. Specific practical consequences of the cognitive framework thus described include:

1. D17-4.1 section 1.4: explanation of the relevance and nature of cognitivist and social constructivist paradigms of game-based learning interventions for the applications addressed by xDELIA (investors and traders, and youth and young adults, respectively)

2. D17-4.1 section 1.4: for WP2, the identification of cognitive schemata manifesting learning biases as targets for the design of games that diagnose and/or provide feedback to players about the occurrences of biases.

3. D17-4.1 section 1.4: the formulation of 5 hypotheses regarding emotional bias schemata, that are in principle possible to provide empirical evidence for or against.

4. Game design principles motivated by social constructivism (see especially D17-4.1 section 1.3, p. 18) for WP3 games, including:
   - the games are multi-player games embedded within social media, to facilitate community building and active reflection upon and discussion of financial capability issues by their players
   - players operate a semi-autonomous avatar, encouraging reflection upon behaviour and its consequences
   - the game world and avatar operation are highly open, encouraging active exploration and experimentation by players
   - external, social and community experience is in focus, rather than internal cognitive processes
   - potential schema development is not prespecified and is not highly constrained by game design
   - experimentation, exploration and results may be very different for different players, player groups or communities
5. The design approach to learning interventions that, for social constructivist reasons, that games based upon emotional bias schemata need to be contextualized by a broader learning intervention design including significant non-game elements (see this document, D18)

Within the cognitivist paradigm, the material also presents a broad methodology for game analysis that includes articulating description spaces for design features of games (D17-4.1 sections 1.2.1, 1.5.2 and 1.5.3), player typology, motivations and affects of gameplay (D17-4.1 sections 1.2.2 and 1.5.4), together with methods for measuring game interaction (D17-4.1 sections 1.2.3, 1.7 and 1.8) including event and command logging, eye gaze tracking and psychophysiology. Application of these constructs and methods is determined within the design of specific studies. Constructs describing players and game design features include much more material than it is feasible to use within xDELIA, but this material is presented in D17-4.1 to facilitate game analysis and design in broader contexts than the xDELIA project, and also to contextualize xDELIA game design within a broader space of possibilities and to present constructs that may prove to be relevant in the analysis of results from studies.

The application of the cognitive framework specific xDELIA games is summarised in Table 2 below. Part 2 of this document describes the development of the games. More detailed descriptions of some of the games can be found in D18.

<table>
<thead>
<tr>
<th>Game</th>
<th>Purpose</th>
<th>WP</th>
<th>Approach</th>
<th>Description</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance Cards</td>
<td>FINCAP themes: planning ahead + balancing</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>the player can either try to enhance their own status or bring down their</td>
<td>2 player card game</td>
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<tr>
<td></td>
<td>life quality</td>
<td></td>
<td></td>
<td>opponent</td>
<td></td>
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<tr>
<td>Evil Spouse</td>
<td>FINCAP themes: making ends meet + keeping</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>player 1 aims to save as much money as possible, player 2 tries to spend</td>
<td>2 player board</td>
</tr>
<tr>
<td></td>
<td>track</td>
<td></td>
<td></td>
<td>as much money as possible</td>
<td>game</td>
</tr>
<tr>
<td>Wife and the Baby</td>
<td>FINCAP themes: making ends meet + keeping</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>player strives to get married and have a child, but in order to do</td>
<td>1 player board</td>
</tr>
<tr>
<td></td>
<td>track + planning ahead + balancing life</td>
<td></td>
<td></td>
<td>that good finances are required, eight turns, each with costs. Eight</td>
<td>game</td>
</tr>
<tr>
<td></td>
<td>quality</td>
<td></td>
<td></td>
<td>categories of financial factors relevant to financial capability (life/family,</td>
<td></td>
</tr>
<tr>
<td>Game of Life Financial</td>
<td>FINCAP theme: planning ahead</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>college loan, house, luxury, transportation, investment, job path,</td>
<td>Multi-player</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>insurance), player must choose how to spend income wrt a long-term goal.</td>
<td>board game</td>
</tr>
<tr>
<td>First Person Shopper</td>
<td>FINCAP themes: planning</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>multi-player struggle over who can buy the most property first, income +</td>
<td>1 and 2 player</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>expenses each turn</td>
<td>digital shopping</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>virtual shopping center with various products. Items rated by hedonic value</td>
<td>simulation</td>
</tr>
<tr>
<td>Game</td>
<td>Description</td>
<td>WP</td>
<td>Cognitive Map</td>
<td>Task</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------</td>
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<tr>
<td>MicroGames</td>
<td><strong>The Iowa Gambling Task</strong> – test of persistence of system 1 apprehension with different media representation = unconscious awareness of payoff probabilities</td>
<td>WP2</td>
<td>Cognitivist</td>
<td>Player has four decks of cards. Pick cards from the different decks until the game is over. Each card earns a small sum of money. But sometimes a card presents loss of money greater than the normal gains. Players eventually realize that some decks are better than others and then stick to those decks. GSR shows a clear reaction of stress by hovering over the “bad decks”, long before players are consciously aware of the fact that the decks are “bad”. Variants: 2 x with, 2 x without total scoring feedback, 1 represented as mouse searching cheese avoiding cats, 1 represented as picking apples from 4 trees.</td>
<td>1 player digital card game</td>
</tr>
<tr>
<td>FinBoard</td>
<td>Different aspects of managing finances</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>a player tosses a dice to advance across game tiles. Tiles are colored differently and when the player stops on a tile s/he has to take a corresponding card. The colored tiles have various meanings: event tiles (e.g. life improvement), temptation tiles (e.g. shopping mall appears) or an action a player can make (e.g. take a bus, rent a car.</td>
<td>table top game + an iPhone game</td>
</tr>
<tr>
<td>Banking Game</td>
<td>elicit FINCAP Framework from xDELIA partners, + FINCAP theme: secure your financial future</td>
<td>WP3</td>
<td>Soc. Constr.</td>
<td>Simulate assisting customers with financial problems and thus learn about financial issues through the eyes of the customers. Player has to deal with many different problems related to financial capability with different levels of difficulty and ambiguity together with social aspects such as being a part of a corporation.</td>
<td>Digital simulator that can accept many minigames</td>
</tr>
<tr>
<td>LineRacer</td>
<td>cognitive go/nogo task reimplementation to assess impulsivity, + game features</td>
<td>WP2</td>
<td>Cognitivist</td>
<td>player's actions are to react to arrows; a black arrow pointing up or down, + another arrow. If second arrow is green AND pointing in same direction player is supposed to press &quot;left ctrl&quot; as</td>
<td>1 player digital game</td>
</tr>
<tr>
<td>Project</td>
<td>Description</td>
<td>Cognitive/emotional skills</td>
<td>Game mechanics</td>
<td>Game interaction in game design and evaluation</td>
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<tr>
<td>MINDswap</td>
<td>platform to learn about different elements of impulsivity and learn strategies to resist temptations related to impulsive behavior</td>
<td>WP3 Soc. Constr.</td>
<td>Players follow young people, implemented as non-player characters (NPCs), getting along with their everyday life consisting of temptations and obstacles that have to be dealt with. The player helps their NPC through informed decision-making in regards to financial capability issues, knowledge which is hypothesized to be transferable to real world settings.</td>
<td>Persistent multiplayer Facebook game</td>
<td></td>
</tr>
<tr>
<td>Aiming Game</td>
<td>arousal (heart rate) input to verify whether emotion regulation can be trained using a game</td>
<td>WP2 Cognitivist</td>
<td>a two dimensional shooter game where the player tries to aim and shoot down airplanes while avoiding distractions in the form of similar airplanes. Biofeedback creates noise in aiming, rewarding low arousal levels and punishing high arousal levels, facilitating learning of emotion regulation</td>
<td>1-st person shooter computer game + biometric feedback</td>
<td></td>
</tr>
<tr>
<td>Auction Game</td>
<td>tool for Investors, using the Saxo Bank trading platform, to train in Emotion Regulation and Disposition Effect</td>
<td>WP2 Cognitivist</td>
<td>player is an auctioneer; buying or selling goods/stocks. With every round of the game a stock has a different price. Player’s goal is to buy and sell stocks according to the correct price that round. Every round the player receives three stock price estimations from consultants. The true price of a stock = mean of the three estimations. Biometric data: true price estimation deviates from the mean more the higher the player’s emotional arousal, making it harder to buy and sell at the right price when emotionally aroused.</td>
<td>1 player digital auction simulator + biometric feedback</td>
<td></td>
</tr>
<tr>
<td>Two Index Game</td>
<td>improve understanding of the emotional</td>
<td>WP2 Cognitivist</td>
<td>Two indices: one = current prices and one predictor index, which partially determine tradable stock value. Player tries</td>
<td>1 player digital stock index simulator + biometric feedback</td>
<td></td>
</tr>
</tbody>
</table>
processing in economic decision making by making traders aware of the disposition effect + train them to regulate such biases | to predict the price based on predictor index chart + buy and sell assets at appropriate times in order to maximise profit. Indices give indications of when it may be a good time to sell, but depending on the present market value the player may deviate from their personal trading rules. The game logs the player data in order to determine if, and how severely, the player is suffering from the disposition effect. | feedback

Table 2. Application of the cognitive framework

1.11 Discussion and Conclusion

The framework presented in Part 1 of this document presents a combination of theoretical perspectives on game development from a cognitive science perspective, together with broad methodological approaches representing both cognitivist and social constructivist conceptions. Taxonomies for describing players and game features developed in game studies have also been presented, which can be used as a source of constructs in experiment design and analysis. These taxonomies present a very large combinatorial space of possibilities that it is impossible to explore comprehensively from a cognitivist perspective within any individual research project. The difficulty of this task is compounded by the need, not just for the validation of constructs used to characterize gameplay affect within laboratory settings, but also to explore the boundaries of validity in ongoing reliability and predictive validity studies. In stable contexts, a cognitivist approach can be used to explicate learning affects of gameplay, but the conditions and scope of this stability must be understood in order to understand where these affects apply and where they do not, a key issue in the question of the transfer of learning effectiveness of games. Moreover, games continue to develop and evolve in form, which means that these taxonomies must also continue to develop. This includes taxonomies for describing players derived from clustering studies of player behaviours and communications, since play styles, motivations and preferences evolve in tandem with new opportunities provided by evolving game forms.

From a social constructivist perspective, games provide accessible and safe environments for the social construction of meaning and the development of knowledge and skills by action, and offer the possibility of new environments for learning that cannot exist in the physical world. This is not to say, however, that these games provide a simple alternative in the face of the difficulty of exploring the combinatorial space of game/player features from a cognitivist perspective. For learning highly stereotypes skills that are well defined in stable contexts, the social constructivist approach is too open. Hence these paradigms present different methods suited for different purposes.
Part 2: Game Design Process

2.1 Introduction: Game Design

Blekinge Institute of Technology in Sweden has had the role of being the game developer and main provider of stimuli for experimental studies in xDELIA, to satisfy specifications to address research questions given and been formed by other xDELIA partners. This is not a conventional game development process by the terms of the entertainment game industry, the latter generally following heavily established genre conventions regarding all aspects of game design. The major theoretical domains in xDELIA lay within economics, investment and financial competence. Hence for the game development team, not being specialists in these areas, the development process has taken a form that is less typical for commercial game development and more common in project engineering contexts. This has meant a strong focus on iterative prototyping and participatory design methods, to shape a comprehension of the possibilities in game design for the partners with application domain expertise, and to shape a collective understanding among the game developers of the requirements upon viable game components within leaning interventions. A major challenge in this systematic approach has also been in the different time frames of the activities of various partners. A game designer is always in immediate need of detailed requirements in order to explore and fine tune gameplay, and in xDELIA this must be designed in relation to requirements of learning in emotion regulation and mindfulness. At the same time, detailed studies are required in the other work packages to validate the premises relating to emotion regulation within the application domains. Application specialists must also understand the process of game design and development and to be able to think in terms of the application of games to learning as part of the development of mutual understanding needed in order to create games that are effective within learning interventions.

2.2 Game Design and Development

The definition of design is “plan: make or work out a plan for; devise; plan something for a specific role or purpose or effect; purpose: an anticipated outcome that is intended or that guides your planned actions…”4. The definition of a process is a “procedure: a particular course of action intended to achieve a result; …work: shape, form, or improve a material…”5. Game design is the process of designing the form and content of a game during the pre-production stage of development, and designing detailed gameplay, the game environment, storyline, and characters, etc. during the production stage. The term is also used to describe both the design embodied in a game as well as documentation that describes such a design.


5 http://www.google.se/search?hl=sv&biw=1258&bih=821&q=define%3Aprocess&btnG=S%C3%B6k&meta=, accessed 12 March 2011.
Here we are concerned with the design *per se*, rather than its documentation, when we refer to ‘a game design’. To create a game design there are six major questions that must be answered:

1. ‘What’ object(s) to include in a game/simulation session.

2. ‘How’ to achieve the desired gameplay interaction. This can include everything from software issues to hardware devices needed (e.g. sensors and interfaces, computers), software components and middleware accessed via Application Programming Interface’s, API’s, networks connecting and transferring data flows, etc.

3. ‘Why’ concerns the usefulness of the game and/or simulation as such.

4. ‘When’ is then a question of particular times the game and/or simulation is useful in a context and

5. ‘Where’ brings up the question of the place or places at which the game or simulation has its greatest impact, i.e. in a formal learning context, the workplace, at home in the living room, or in a public place, etc..

6. ‘Who’ is the target group, i.e. who are the customers or/and the learners intended for a particular gameplay and their context or situation, which may suggest needs for supportive solutions and specific design features.

In the production of a game design, it can be useful to use the metaphor of language structure terms, see Figure 3 below. If we take the ‘What’ question, we call for a specification of the objects in the game/simulation world. This is a specification of the nouns referring to objects in the world. The verbs are the actions that will be supported, implementing player decisions in relation to the nouns. This addresses the ‘How’ question, which can also be extended from manipulation into a continuum with the adjectives that describe feelings, behaviors, emotions, states…, about how something is.

The design process as characterized above can also be applied to any other design for activity, constituting design of mental processes that call for cognitive and embodied resources to be able to execute actions (Norman, 1998). In the context of xDELIA, the nouns, verbs and adjectives of a design must serve specific research questions, either to provide game stimuli for studies in order to generate data, or to constitute elements of validated learning interventions, where validation can also proceed via empirical testing in which the game components serve as stimuli. The questions of ‘when’, ‘where’ and ‘who’ relate to broader intervention design and must be specified as a foundation for the design of games within those interventions. The question of ‘why’ must address the role of games contributing to improved decision quality in trading and/or investing tasks, especially via learning techniques of emotion regulation and ‘mindfulness’.
Game design within xDELIA must also consider the balance between cognitivist and constructivist approaches to game design, as characterized and discussed in Part 1 of this document. Overall we aim to create games within a cognitivist paradigm, which are delivered as part of broader learning interventions developed from a more strongly constructivist perspective (see also Figure 3). This approach is justified in Part 1 in terms of the requirements derived from the application domains, resources available for game development, and maximization of the impact of focused gameplay experiences within the general, intensive, decision environments of trading and investing.

Figure 3. An overview of the game design process in context within xDELIA.

The game designer is responsible for the play experience. A commercial as an academic game designer has to collaborate closely with all the people in a team to be able to create gameplay, because the gameplay is “so intricately linked with how the play is programmed, visualized and supported by music, voice-over, etc., the game designer must collaborate closely with just about every other team member” (Fullerton, Swain and Hoffman, 2004).

Figure 4. An overview of how to approach the actual design of the system.
The main responsibilities of a game designer are to brainstorm concepts, to create prototypes, play test and revise those prototypes, write concepts and design documents and update these through production, and to communicate effectively both with the development team and with the customer(s) of a game. Prototyping is a commonly used design method in game development (Fullerton et al., 2004). Prototypes can be used to test, improve and communicate game concepts in the preproduction phase of the game development process (Koivisto and Palm, 2005). 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).

A key question for game development within xDELIA has been to identify the customers. Game development started with the understanding that the customers are the application domain experts and academic participants in the project, the Erasmus Centre for Neuroeconomics, UNIVBRIS, Saxo Bank, OU and, to some extent, FZI. In the early stages of the project, OU, Erasmus and FZI have primarily been scientific customers seeking games to function as stimuli in experimental studies. UNIVBRIS and Saxo Bank have been application domain stakeholders seeking games to function as prototypes for eliciting requirements to inform later learning interventions, and then as consumers of the deliverable games as components of learning intervention demonstrators. The role of CIMNE was that of knowledge facilitator between the financial capability domain (UNIVBRIS) and game development.

The need to address these ambiguities has led to a process of producing small scale game demonstrators. The purpose of these demonstrators has been to communicate the nature and requirements of game development among the project participants, to inspire and elicit concepts and requirements for games as stimuli for studies and as potential elements of learning interventions, and to test technical issues. Early in the project a game workshop was arranged to elicit what xDELIA partners regarded as important and what questions could be of major concern in refining the focus areas of the project. Several board games were conceptualized, implemented and play-tested with participation from all of the organizations in the project. An analog game is different from a digital game, but the logical design of elements such as the game concept, game rules, game objects and the game space can be demonstrated, iterated, experienced and discussed in a way that can lead directly to software implementation if a concept proves to be suitable and successful. Physical tabletop game prototypes are a standard practice in the commercial development of computer games, and within xDELIA the process functioned to start the project group thinking in terms of games and to elicit and stimulate game ideas from the project partners as early as possible in the project. Some of the major ideas that were created from that first workshop included: rules of economy in a game, how to shape awareness about financial capability, when in life we have to make choices and make well grounded decisions are that have a financial impact (shaping a family, buying a house, changing jobs, marriage, buying a car, etc.), teenage/adult spontaneous consumption, how to think in an economical calculation as in an auction situation, how to use already established gameplay in a new setting like the FirstPersonShopper concept, and also if, how and when to use bidding. The less polished prototypes are useful for generating ideas. When a prototype does not look like a finished product, it is easier not to comment on its looks but to concentrate on the design of the core gameplay instead (Snyder, 2003). The boardgame situation may not reach all its prerequisites...
but in the dialogue and discussions formed within the workshop, everybody starts to develop an understanding and shared mental models of what the group as whole must solve in relation to the development of games for addressing research questions, their design aspects, clarifications, and how to proceed in the ongoing collaborative development process.

A potential misinterpretation of tabletop prototyping is that the board game workshop may seem to be an old-fashioned and non-technical start by those not used to the process, a misunderstanding of what such a workshop tries to shape in the form of developing first-hand understandings of what people want to achieve in a particular context, and of the challenges of reaching desired outcomes especially in the form of games. This is a process of “physical prototyping” by board and paper prototypes, a method for development of very rapid prototypes that are thrown away in game development and sketching, but that nevertheless provide very valuable contributions to the development of games eventually implemented in software (Augustin et al, 2007). This technique is also well established in academic and research game development. For example, Ballagas and Waltz (2007) used several prototyping methods in their location-aware city exploring game, REXplorer. They used a board game prototype to successfully demonstrate the game, and noted that it was particularly useful for getting a feel for travel times, expressing spatiality, judging proximity of sights, and ensuring that the game was fun to play. Like Lacucci et al. (2000), they used event cards for simulating a more realistic environment.

Wright (2004) states that all of the members of a development team benefit from experimenting with physical prototypes when designing games. Ehn and Kyng (1992) demonstrated how combining prototyping and games can be used to improve communication of the concepts to the end users. Iacucci et al. (2000) developed the method further by using the approach for testing mobile applications and services. Iacucci et al. (2000) found that playing the prototype as a game enhanced the user’s understanding of contextual charges and the context of other users. Ollilla et al (2008) report finding agile methods useful for game prototyping because they make it possible to change the functionality of the prototype quickly when needed. This is especially true when using participatory design, when all of the product development team members are brainstorming and developing. Moreover, for development projects including inexperienced game developers (as in the xDELIA project when non-game designer partners are contributing to design specifications), these methods are even more useful, since the more inexperienced the game designers are, the more difficult is for them to imagine what kind of gameplay will emerge when the players, and potentially the environment, interact with a design (Ollilla et al, 2008).

### 2.3 Design Approach

The development of prototypes in the xDELIA project involves three different process models: SCRUM, Participatory Design, and Constructive Development.

#### 2.3.1 SCRUM

Scrum is a working method especially used in software development projects and is “an agile approach to software development. Rather than a full process or methodology, it is a framework. So instead of providing complete, detailed descriptions of how everything is to be
done on the project, much is left up to the software development team.”⁶ In Scrum, software development progresses through iterations of what are called ‘sprints’. The so-called sprints are 2-4 weeks long and are suited towards processes with rapidly changing requirements. There are two specific roles that are pointed out and they are the ScrumMaster and the Product Owner, the latter here in the form of the owner of the research question. The ScrumMaster functions more or less as a coach for the team and the Product Owner is the customer and will express or communicate needs and requirements so the ScrumMaster and the development team know what to build for and why. All work items are prioritized and added into what is called a backlog, which describes all tasks for the coming iteration. Scrum meetings are held daily and centre around three primary questions: What have you done since yesterday? What are you planning to do today? and Do you have any problems that would prevent you from accomplishing your goal?⁷

2.3.2 Participatory Design

Computer Professionals For Social Responsibility (CPSR) define Participatory Design (PD) as “an approach to the assessment, design, and development of technological and organizational systems that places a premium on the active involvement of workplace practitioners (usually potential or current users of the system) in design and decision-making processes”⁸. The PD approach traces its roots to Scandinavia and the work trade unions in the 60's and 70's. The way of designing has also been called Cooperative Design. The purpose is to involve everybody who will use a system in the design phase so that needs and usefulness can be met and considered from an efficient work point-of-view.

2.3.3 Constructive Development

“Constructionist learning is inspired by the constructivist theory that individual learners construct mental models to understand the world around them.”⁹ Constructivist Research relies essentially on constructionist or design thinking (Crnkovic, 2010). In learning, we would like to know how people construct knowledge and how we may be able to predict how learning and its outcomes are structured. Crnkovic bases Constructive Research in the Computing field in Software Engineering and Cognitive Science, where she and others describe its typically multidisciplinary and cross-disciplinary nature where an Info-Computational Paradigm of knowledge production is addressed. Constructivists contend that knowledge is constructed, emergent, and grounded in action or experience (Jonassen, Peck and Wilson, 1999). Constructivist research is characterized by Crnkovic as follows: “The construction proceeds through design thinking that makes projection[s] into the future envisaged solution (theory, artifact) and fills conceptual and other knowledge gaps by purposefully tailored building blocks to support the whole construction. Artifacts such as models, diagrams, plans, organization charts, system designs, algorithms and artificial languages and software development methods are typical constructs used in research and engineering. Constructivist solutions are designed and developed and not in the first place discovered, even though a lot of inspiration for many artifacts comes from nature, today especially evident in Natural and Organic Computing.” Hence we might say that

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⁷ [http://www.scrum.org/scrumguides/](http://www.scrum.org/scrumguides/)
constructionist research characterized in this way includes the kind of prototyping and agile development methods described above, contextualized by constructivist learning theories of the kind summarized in Part 1 of this document.

Prototype development in xDELIA has used these methodologies and applied them in varied combinations as appropriate. SCRUM has been implemented in the design process, first with daily meeting but then progressing to weekly meetings, thus reformulating the three questions to involve previous and coming work on a weekly basis instead of daily. The xDELIA prototype development process has adopted the Participatory Design approach in the sense that it was vital that all partners had a say in the direction of game development. However, once a decision was made and a basic outline of a prototype was formed, the development turned towards an agile methodology more similar to SCRUM. This has been necessitated by limited access to professional traders and investors for reasons of commercial confidentiality.

### 2.4 Game Prototypes Completed

Game prototypes completed within xDELIA up to the time of writing are presented in this section, together with their purpose, description, development method(s) used and a discussion of outcomes.\(^\text{10}\)

Development methods will be summarily illustrated with the help of diagrammatic components as shown on Figure 5.

![Diagram](image)

Figure 5. Three illustrative shapes to explain the design process in the following explanations.

#### 2.4.1 Board Games

![Diagram](image)

Figure 6. The design process of the Board Game(s).

Purpose: WP3 - The board games were created in order to find a common understanding of the different aspects of xDELIA, to agree on concepts to look further into, to elicit early requirements for games, and to facilitate the acquisition of hands-on knowledge about game development among the xDELIA-partners. To focus the concepts, designs were intended to create learning about themes of financial capability, including: planning ahead, balancing life quality, making ends meet, and keeping track, themes promoted by UNIVBRIS in order to help people from getting into financial problems.

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\(^{10}\) Further design details of WP2 games are presented in D18-2.4.1 Intervention package – specification and development.
Description: Four board games were created: finance cards, the evil spouse, the wife and the baby, game of life financial.

**Finance Cards**
Finance Cards is a two player game that addresses the issue of *planning ahead* and *balancing life quality* with money income and outcome. The game is played with cards, where the player can either try to enhance their own status or bring down their opponent.

**The Evil Spouse**
The Evil Spouse is also a two player game where the goal of one player is to save as much money as possible while the other player tries to spend as much money as possible. The players have common finances, thus they need to compete over why and why not to spend money. They train on *making ends meet* through arguing about what to do with their money and also *keeping track* in order to keep score on which of them is winning.

**The Wife and the Baby**
This game is a single-player game in which the player strives to get married and have a child, but in order to do that good finances are required. The game is divided into eight turns and during each turn an upkeep is required. Eight different in-game categories of financial factors relevant to financial capability exist (life/family category, college loan, house, luxury, transportation, investment, job path, and insurance) and the player must choose how to spend the income with a long-term goal.

**Game of Life Financial**
This game is a multi-player struggle over who can buy the most property first. The buying of property is represented by moving forward on the board. Incomes and expenses are given each turn, randomly picked out of a population. Incomes are generally higher than the expenses, but the players need to plan for unforeseen expenses.

Method: an initial round of brainstorming was done to find some initial concepts, then these were presented and a subset chosen to be developed further in different groups. All groups had a brainstorming leader, and at least one researcher each from work packages two, three, and four. Several brainstorming methods were tested in order to encourage participants to think about the problems in different ways.

Outcomes: Project members got an idea of what is required in order to create a playable game. Further ideas were born which later resulted in ongoing conceptualization and development of the first person shopper and several micro games.

**2.4.2 First Person Shopper**

![Figure 7. The design process for the 1st Person Shopper.](Image)

D17-4.1 – Cognitive/emotional skills, game mechanics, and game interaction in game design and evaluation

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Here we saw that we also needed a formalized evaluation method, and in particular a heuristic evaluation process. We realized that we had to capture opinions from our xDELIA partners early in the design process and especially the research questions in mind and of interest.

Purpose: WP3 - Act as means for discussion about the different learning outcomes and their manifestations within WP3.

Description: The logical game space is a fictional shopping center with various products. Before the player enters this area the different items that are available for purchase are rated, by hedonic value, by the player. When the player enters the area there are four different stages. In the first stage the player may simply buy whatever they want. In the second stage an amount of money is given to the player and they need to prioritize and plan for what to buy. The third stage requires the player to wear a galvanic skin conductance-sensor, because arousal level is used in order to buy items. This also means that the player has to avoid being aroused when closing in on items that are not wanted. A fifth stage involves two players playing at the same time. Some items have a false price tag for one player but a correct one for the other, so the players need to cooperate in order to complete the stage optimally.

Method: BTH constructed a mock-up in order to communicate with partners. This was later presented as a basis for discussion during an xDELIA project meeting.

Outcomes: Consumer research was postponed and instead the direction of small micro games was prioritized for implementation.

2.4.3 Micro Games

Purpose: WP2 - To take a well defined cognitive task and implement it as a game through the efforts of participatory design. The Iowa Gambling Task is a well-known psychological task which is thought to simulate real-life decision making. Participants are presented with four virtual decks of cards. They are then asked to pick cards from the different decks without interruption until the game is over. Each picked card will earn the player a small sum of virtual money. Sometimes, however, the picked card will present a loss of money, a loss greater than the normal gains. As the game continues, players will eventually realize that some decks are “better” than others and should then stick to those decks. Interestingly, players also show, with the help of measurement of galvanic skin response, a clear reaction of stress just by hovering over the “bad decks”, long before they are consciously aware of the fact that the decks are “bad” (Bechara et al., 1994). The aim of the prototype variants produced in WP4 was to test the persistence of the Iowa Gambling Task GSR effect across varying media representations of the same logical gameplay and underlying scoring system, and with varied feedback of the scoring. The Iowa Gambling Task also suggests the possibility of unconscious awareness of payoff probabilities that might occur in trading and investing task performance and therefore be a target for learning interventions based upon psychophysiological measurements during task performance.

Description: Four different implementations were made of the game, two without total scoring feedback and two with total scoring feedback. The original appearance was kept for one game with feedback and one without. In addition, one prototype was represented as a mouse.
searching for cheese, but avoiding cats, without score feedback. The last prototype involved picking as many apples as possible from four trees, in this case with score feedback.

![Micro Games Diagram](Image)

**Figure 8. The Micro Game design processes.**

Method: A participatory design method was used, where some participants were physically present while others participated through the Internet-based communication program Adobe Connect, while various the brainstorming methods (see Löwgren and Stolterman, 2004) were used.

Outcome: It was agreed that although some valuable input could be given from people through Adobe Connect, this was very limited and would have been impossible to have brainstorming of the same quality if all participants would have been attending this way. The game implementation was time consuming and should in the future not include partners during implementation and after the specifications are sufficiently agreed. Regarding the results from the test of the games they were inconclusive, total score did not seem to have any difference between the two games with the original card representations, but people scored better and with a different learning pattern when they were presented with the apple version that did have continuous feedback. The players received their worst score in the mouse version, but they followed the same learning curve as in the versions with cards.

We understood that we needed more rigorous and detailed task descriptions so we were able to meet the wishes and requirements from xDELIA partners without spending too much time on circular discussions about requirements and design features.

### 2.4.4 FinBoard

**Purpose:** WP3 - The FinBoard game was created in order to explore different aspects of managing finances, e.g. long/short term savings, and impulsive buying. The target audience was youth.

**Description:** The FinBoard game exists in two versions, a table top game and an iPhone game. The iPhone game served the purpose of exploring the potential for extending a web based game with a mobile application. In the game a player tosses a dice to advance across game tiles. Tiles are colored differently and when the player stops on a tile s/he has to take a corresponding card. The colored tiles have various meanings: event tiles, temptation tiles or an action a player can make. For example, if the player steps on a beige tile, a life improvement event occurs. In the case of a red tile, a shopping mall is revealed and the card will challenge the player to agree to different temptations. Other cards force the player to evaluate different offers or agreements. An orange tile is a bus stop where a player has to decide if s/he wants to take a bus, walk or maybe spend some money on renting a car; which will give a player a certain advantage for a price.
Method: The FinBoard game design was developed using Participatory Design where xDELIA partners at BTH in met and discussed viable design solutions. A board mock-up game was constructed in order to test the working prototype as soon as possible. The tested and balanced playable game prototype was then mirrored onto the iPhone platform, since the game was intended to be player by youth online.

Outcome: The direction of the FinBoard prototype was unclear so repeated brainstorming meetings became too long and unproductive. There were deviations from the initial plan and the xDELIA focus eventually shifted to other areas; thus further development of this prototype was stopped. But the findings and the developed FinBoard framework was implemented and upgraded in the subsequent Banking Game.

2.4.5 Banking Game

Purpose: WP3 - The purpose of the Banking Game was to assist customers with their financial problems and thus learn about financial issues through the eyes of the customers. The game development process was also intended to elicit an initial Financial Capability Framework from our xDELIA partners so we could understand how to design for those requirements. A particular focus of the game was to provide a platform for discussion with other partners to establish a possible response to the vital financial capability theme “Secure your financial future” which is a part of WP3.

Description: By advancing on a career ladder, the player has to deal with many different problems related to financial capability with different levels of difficulty and ambiguity together with social aspects such as being a part of a corporation. The idea was for the game to take "an evil approach", meaning that the player should experience banking strategies from a purely financial (non sympathetic) stand point.

Method: The Banking Game concept was constructed by xDELIA partners at Blekinge Institute of Technology, and derived from FinCap frameworks seen in FSA/BSA (2004) and NSG-FC (2009).

Outcome: Since partners became involved rather early, they were able to identify flaws in the design of the Banking Game, specifically towards the concept of the "evil approach" resulting
in the game concept not being implemented. The main idea however of having an umbrella game concept in which smaller games could be added to was carried forward in a new game concept called the MINDswap game (see below).

2.4.6 LineRacer Prototype Series

Purpose: WP2 - In order to assess impulsivity, a cognitive go/nogo task has been used (Vocat et al., 2008). The LineRacer prototype is a reimplementation to assess impulsivity, but adding more game features in order to make it more enjoyable.

Description: In the go/nogo task, the player's actions are to react to arrows; first there is a black arrow shown pointing up or down, then another arrow is shown. If the second arrow is green AND pointing in the same direction as the first arrow the player is supposed to press "left ctrl" as fast as possible (go). If not, the player is supposed to not press (nogo). In addition to this standard version, another variant was also made, called LineRacer. LineRacer has the same logic structure as the go/nogo game, but also has a moving character which reacts according to the player’s performance. Also, versions including background pictures and music (and both these combined) have been created for both the standard go/nogo and LineRacer, in order to test the effect of these factors on impulsiveness measures.

![Diagram of Prototype Series]

Figure 11. The Prototype Series process when designing these studies.

Method: There were suggestions from xDELIA partners to implement impulsivity assessment with the go/nogo task. Additional brainstorming within BTH was held in how to add game features to create more interesting gameplay without interfering with impulsivity assessment. During the implementation, information was given to the partners in xDELIA in order to get feedback on progress and also to gain input on new research variants including pictures and music.

Outcome: The go/nogo task was assigned to be implemented into MINDswap (see section 2.4.7) and feedback from the LineRacer could be used as a valuable source of information in this subsequent development. The most important implications were that the LineRacer series had worse assessment power than the go/nogo task with regards to attentional impulsivity, but better with regards to motor impulsivity. This was probably due to that it is easier to keep a higher attention level when there is an animated character to look at, thus should animated characters be avoided when implementing the task in MINDswap. Also, in the go/nogo task, the assessment became more powerful when negative inducing music was added to the task, which means that this kind of music could be played when the task is performed to make inter-player differences larger. The implementation was successful, but it was found that contact with the partners needed to be more specified and requirements made more firm, as they subsequently were for the Aiming Game and the Auction Game (both described below).
2.4.7 MINDsway

Purpose: WP3 - Mindsway was developed as a persistent world, a virtual world existing even after the player exits the game, through Facebook. The idea was to provide a platform for young people to learn about the different elements of impulsivity and learn strategies of how to resist temptations related to impulsive behavior. By improving one's skill and knowledge in terms of impulsive behavior, the player is rewarded by increased performance and attributes.

Description: MINDsway is a game built around a variety of financial capability themes, that set the scene for the main challenges in the game and provide the backdrop against which the player will apply knowledge and skills to steer the avatar through the world and towards the final goal. In the game the players follow young people, implemented as non-player characters (NPCs), getting along with their everyday life consisting of temptations and obstacles that have to be dealt with. The player helps their NPC through informed decision-making in regards to financial capability issues, knowledge which is hypothesized to be transferable to real world settings.

![MIND SWAP Diagram](image)

Figure 12. The Design Process for the game MINDsway.

Method: Developing this game involved an increased need for initial documentation, or a formalized process, from the xDELIA partners. We had frequent iteration and a discussion with partners generally three times a week for collaborative or participatory development.

Outcome: The development of MINDsway has been a close collaboration between the developers and product owner with joint meetings usually held three times a week. The development adopted the methodology of participatory design and has generated extensive experience in how to carry out this method in a multidisciplinary research environment. Developers have also gained experience in how to let participatory design permeate the whole design process from game design to implementation and evaluation. It has become apparent that a close and continuous collaboration between the work packages, or more generally the partners, are required to make games relevant for the application areas. We believe that MINDsway can become a viable learning intervention for young people regarding financial capability issues.\(^\text{11}\)

2.4.8 Aiming Game

Purpose: WP2 - The Aiming Game was developed to provide a tool for Investors, using the Saxo Bank trading platform, to train in Emotion Regulation by making a direct link between states of arousal and game phenomena that have a direct effect upon the player’s performance in meeting game challenges.

\(^\text{11}\) Note that ongoing development of MINDswap has been cancelled in line with the recommendations of the xDELIA project reviewers and project office.
Description: The game is a two dimensional shooter game where the player tries to aim and shoot down airplanes while avoiding distractions in the form of similar airplanes. By also being connected to the game via a bio-feedback system, the player’s psychophysiological state affects the game by rewarding low arousal levels and punishing high arousal levels. In particular, arousal levels are linked to perturbation of aiming accuracy and blurring of the targets. Later iterations include the possibility to reward increased arousal and to reward maintaining arousal in a specified zone.

Method: We worked mainly according to the SCRUM methodology, with influences from Participatory Design. We had weekly meetings, for iterative cooperation with partners and also standardized tests/evaluations\textsuperscript{12}. Initially the partners came together to discuss how best to create a game which trained emotion regulation. The discussion led to ‘concept art’ which developers used to create a backlog (see 2.3.1 SCRUM). A product owner, a SCRUM Master and a development team were assigned. The backlog was then presented and approved by the product owner which led to a sprint period of two weeks. After two weeks the prototype was presented to the product owner in order to ensure that the progression was headed in the right direction. Adjustments were made accordingly which resulted in another two weeks development period, and this process iterated until a well developed prototype was completed.

Outcome: The development of the Aiming Game clearly showed that iterative development can be beneficial in the sense that it ensures that the development stays in line with the product owner’s and project's desired outcome. In addition, iterative development is not particularly vulnerable to changes because of frequent update meetings. Using a combination of participatory design and scrum proved to be beneficial in the case of prototype development when the methods are structured properly, i.e. they do not interfere with each other but rather succeed each other.

Initial results from play testing sessions, interviews and data analysis show that the Aiming Game can be a successful platform for learning of emotion regulation strategies. The game is however in need of further development to increase the experience it provides. Currently players report a sense of boredom, because of the repetitiveness of the game, and the length of the game. Because of the focus from the first iteration being solely aimed towards making the

\textsuperscript{12} see the studies and development documentation on Google Docs.
game a viable platform for training, the second iteration must shift its focus towards providing a meaningful and engaging experience.

2.4.9 Auction Game

Purpose: WP2 - The Auction Game was developed to provide a tool for Investors, using the Saxo Bank trading platform, to train in Emotion Regulation and Disposition Effect.

Description: The game is a stock exchange simulator where a player is in the position of an auctioneer; buying or selling goods/stocks. With every round of the game a stock has a different price and the player’s goal in the game is to buy and sell stocks according to the correct price of that round. Helping him in his decision are his trusted consultants; thus every round the player receives three stock price estimations from them. The true price of a stock can be calculated by the mean of those three estimations. Moreover, the player is connected to the game via a bio-feedback system, and the player’s psychophysiological state affects the game in such a way that true price estimation deviates from the mean more the higher the player’s emotional arousal, making it harder to buy and sell at the right price when emotionally aroused.

![AimNG Game Diagram](image)

Figure 14. The Auction Game development and its design process.

The SCRUM methodology was used for developing the Auction game, but modified to include weekly meetings, iterative cooperation with partners and also with the development of developed standardized tests/evaluations. Hence the development of the Auction Game is based on the SCRUM methodology with influences from Participatory Design. At the end of every iteration, partners came together to discuss how best to create the next cycle game prototype for training emotion regulation. The discussions led to concept art which developers used to create a backlog (see 2.3.1 SCRUM). A product owner, a SCRUM Master and a development team were assigned. The backlog was then presented and approved by the product owner which led to a sprint period (see 2.3.1 SCRUM) of two weeks. After every two weeks the prototype was presented to the product owner in order to ensure that progress was heading in the right direction. Adjustments were made accordingly, which resulted in the following two week development period.

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13 See see studies and development on Google Docs.
Outcome: The development of the Auction Game provide further evidence that iterative development can be beneficial, in ensuring that development stays in line with the product owner’s desired outcome, and in being resistant to changes because of frequent update meetings. Using a combination of participatory design and scrum can be beneficial in the case of prototype development if the methods are structured properly, i.e. they do not interfere with each other but rather support each other. Requirements discussed and negotiated between the product owner and developer have been put in time perspective, after which they have been approved by the Scrum Master. This way product owner participates in the design as stated in Participatory Design methodology, while Scrum Master plans the time table and requirements during the coming iterations.

2.4.10 The Two Index Game

Purpose: WP2 - The Two Index Game (TIG) is a serious game for game-based learning as an intervention technique relating to the role of emotions and emotional regulation in financial decision making. In particular, it emulates decision making processes within investment and trading, in a non-specific manner, and can perform diagnostics about exhibited cognitive biases, as well as incorporate feedback derived from these into gameplay in real-time.

Description:

The game is played by a single player, either on one or multiple levels, in a fast-paced environment with a high amount of uncertainty and constructed risk.

Gameplay is through interaction with a single interface by simple mouse-clicks on action buttons and requires no other degree of mobility or dexterity.

The game interface also provides a rich setup environment for fine-tuning parametrization, according to the requirements of experimental studies.

In the Two Index Game, a player is presented with information in the form of two indices: the Value Index and the Predictor Index. In the original version of the game, both indices are presented as a one dimensional signal indexed in time with changes of value plotted against the ordinate axis. In the “Trading Mastermind” variant of the TIG, the Predictor Index is presented as a serious of abstract symbols with reference to the time series of changes in value in Value Index.

Both of these indices are presented as time series, plotted as a vector of values against units of time-steps on the abscissa axis.

Other information is presented to the player in the form of various scalar values and plotted time series relating to the outcomes of game play, explained further below.

The object of the game is to use the information available in the two indices in order to make as much profit as possible on buying and selling assets while the clock is counting down. Each game level allows for more possibilities for taking risk and ways of transacting.
Method: Due to important aspects of game mechanics for the Two Index Game, particularly the requirement for relatively complex mathematical design relating to the time series and computations for detecting disposition effect on high frequency data, it was...for development by Saxo Bank’s Quantitative Research department, which is responsible for developing the most complex financial engineering and artificial intelligence within the bank’s primary trading systems, both in terms of the required science and programming of machine learning.

The department applied several of its standard key protocols for research and development, particularly “Protocol for research and experimentation in Quantitative Analysis” (Lins, et al., 2007a), “Protocol for test and release of implementation deliverables from Quantitative Analysis (describes the delivery requirements of testing specification, when binary code, code specification or prototype code are delivered as part of the work product of the Quantitative Research department) (Lins, et al., 2007b),and “Reproducibility requirements in Quantitative Analysis” (Lins, et al., 2007c).

Although, typically, Scrum methodology is not orthodoxyally applied in this setting, especially due to the high level of scientific activity that is involved, there are many “Scrum-like” attributes to the process by which the department researches and develops its solutions and normally the department interacts in the development phases of software engineering for many other applications used within the bank and its clients, where individuals from the department act as “product owner” directly in the Scrum process. Hence, it is appropriate to indicate that Scrum methodology underlies much of the development philosophy.

We may describe the actual process applied in the development of the Two Index Game as essentially bipartite. Initially, top level design ideas and functional requirements were translated into relevant requirements with respect to mathematics and logic. The result of this phase is a set of thoroughly consistent equations game processes, pseudo-code and prototypes of algorithms (Yee, J. T. & Lins, J. 2011a). Subsequently, the player interface, with controls and graphical displays was produced in a rapid application development process, wherein daily and even sub-daily scrums were part of following progress, confronting challenges and trouble-shooting obstacles.

Outcome: The development of the Two Index Game demonstrated that a combination of participatory design and Scrum can be beneficial in the case of prototype development if the methods are structured in accordance with the overarching requirements for the research and development environment. In this case, the product owner carried an initial role of very adequately creating mathematical and algorithmic specifications, which were “burned in” before further development. All subsequent development may then be made from a clear backlog of coding tasks and tested iteratively against the specifications. This reduces the propensity for interruptions and delays due to intermittent “re-design” and “feature creep” that may arise when less structured approaches are applied.

2.5 Discussion & Conclusion

The Design Process in xDELIA has been, and continues to be, a journey of trying to find the most suitable method for game prototype development in a multi-disciplinary project such as this. For the workpackage responsible for creating viable stimuli in response to different
research questions provided by xDELIA partners, having a generic method for the development process can save time, energy and costs. It is also important to have a systematic approach when dealing with requirements coming from third parties, making sure that these are assessed and implemented accordingly.

Through the different phases of the design process, methods such as SCRUM, Participatory Design and Constructive development have been tried out and validated in regards to their effectiveness and efficiency in leading the development further. Ultimately, in the development of prototypes, the process has converged into a balance between these methods. The concept of when and how to involve partners into the development process is a rather complicated matter. This has proven to be either valuable or impractical depending on the timing of the involvement. The conclusion drawn from this experience is that a combination of the methods described in this chapter, together with partner/stake-holder involvement at critical stages where decisions outside of developers expertise are needed, has proven to be the most beneficial.

In xDELIA, Participatory Design and Constructive Development have proven to be the most suitable methods for initial phases when concepts are not yet fully and congruently understood between partners. SCRUM, however, is a more development-oriented method in that it allows for a development structure that is suitable when a main direction can be formalized. The use of specific tools for development and evaluation of developed content aims is to detect and correct faulty designs as early as possible. This idea resulted in the development of a standardized Evaluation Methodology elaborated on in chapter 3.

From the viewpoint of the cognitive framework presented in this document, the primary cognitive schemata motivating the development of the prototype games are those representing emotional biases in decision making noted in section 1.4 Application to xDELIA Learning Interventions in this document.
Part 3: Game Evaluation Methodology

This section describes the game Evaluation Methodology developed and assembled by xDELIA partners at Blekinge Institute of Technology. The methodology consists of several different tools used to analyze both entertainment games and serious games in regards to their efficiency in performing their original respective purposes.

3.1 Introduction

During the development of game prototypes and concepts in the xDELIA project, there has been a growing need for a systematic way to evaluate produced content. Individual subjective measurements are important but in the end, a more robust and trust-worthy approach is required to ensure viability in a game prototype, in regard to its purpose. Different methods and tools have been adopted as game development has progressed, which have provided assistance in the verification and validation of the game prototypes. The Evaluation Methodology is a collection of those tools.

The purpose of the Evaluation Methodology is to provide a broad, easy-to-use framework for the assessment of both existing games and game prototypes in the development. The aim is to identify game design and implementation flaws at a variety of levels, both technical and game experience-oriented.

3.2 Background

Methodologies for evaluating Game Mechanics and Game Experience are largely drawn from Software Engineering and Game Development fields and their respective testing processes. They are often explicitly included in the game development process (at least by larger companies) to make sure that the functional level on which the game mechanics operate is correct. Gameplay is also evaluated through Game Experience evaluation; defined as the subjective experience of interaction of a player with the game (Sennersten, 2004, Lindley & Sennersten, 2006). The different iterations of prototype development in the xDELIA project have generated much insight in regards to the importance of evaluation as well as its execution and implementation, especially in a multi-disciplinary project such as this one. Already from the initial development of the Board Games prototypes, there was a congruent understanding that the development process had a need for a systematic evaluation model. As the prototypes progressed one after the other, the vision of the evaluation model was becoming clearer which ultimately resulted in the Evaluation Methodology.

3.3 Evaluation Framework

The Evaluation framework is meant to be used as a methodology in the sense that it should provide a variety of different tools which can be applied to assess and correct design issues. It is not the intention that one should apply all tools in the kit each time a game is to be evaluated, but rather that appropriate tools are selected to assess whether or not the specific game fulfills its original purpose. Depending on the purpose and current state of a game, the assessment will most likely differ. An entertainment game, with its sole purpose of being enjoyable and engaging might not need to be evaluated with respect to its transferability, while a simulation game for training might benefit from this type of assessment much more. In the same manner, a serious game meant to teach some specific financial skill might benefit
much from being assessed with respect to its ability to teach, but may not necessarily need to undergo substantial unit testing to assess its demand of processing power. Functionality testing should also occur early in the process while transferability cannot be tested until a completed game prototype is made.

In an attempt to cover as many aspects of game development as possible, the Evaluation Methodology grew to include several very different evaluation concepts. It currently consists of five main sections as seen in Figure 15, concepts to the left can be tested earlier in the design process than the concepts to the right, creating a natural flow in the framework.

<table>
<thead>
<tr>
<th>FUNCTIONALITY</th>
<th>GAME STRUCTURE</th>
<th>GAME EXPERIENCE</th>
<th>COGNITION</th>
<th>TRANSFER</th>
</tr>
</thead>
</table>

Figure 15. A representation of the Evaluation Methodology at the highest abstraction level.

Most of the elements described in Figure 15 are broad, generic concepts which cover much content in each section. Several sections can be divided into sub-sections that are evaluated differently and independently. The sub-sections seen in figure 16 are elaborated in the following sections.

<table>
<thead>
<tr>
<th>VALIDATION</th>
<th>USABILITY</th>
<th>GAME EXPERIENCE</th>
<th>COGNITIVE PROCESSES</th>
<th>TRANSFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERIFICATION</td>
<td>GAME MECHANICS</td>
<td></td>
<td>LEARNING</td>
<td></td>
</tr>
</tbody>
</table>

Figure 16. A representation of the Evaluation Methodology with its main sub-categories.

### 3.3.1 Functionality Evaluation

The evaluation of functionality is a vital part of quality assurance and can consist of several different tests depending on the type of software one is developing. Fayad and Cline (1996) discuss three concepts of testing that are important when evaluating software: Validation, Verification and Future Support. These concepts align well with the sought evaluation methodology of game prototypes for the purposes of the xDELIA project since they cover initiation, development (implementation) and several aspects of post-development.

Validation can simply be described as “building the right thing” which refers to accurately understanding requirements and the player’s needs. Verification is loosely described as “building it right” and refers to the implementation and the actual content. Future support is a matter of reusability and the ability to create generic code which can easily be reused in later, similar settings or implementations.
3.3.1.1 Validation
In order to validate the game prototypes developed in the xDELIA project in relation to their original purpose, the development phase follows a model similar to that of SCRUM. Each prototype has a product owner who is responsible for making sure the product stays in line with the intended use. This is done by initially having the developers present a backlog (see 2.3.1 SCRUM) to the product owner, representing their interpretation of the product, which has to be either accepted or declined, depending on its alignment with the purpose of the product. Should the product backlog be accepted, the developer will implement its content after which a follow-up meeting will occur to further validate the product. If the backlog is denied, a new backlog has to be specified and presented to the product owner to again be accepted or declined.

3.3.1.2 Verification
As long as a computer program contains errors or bugs, it will be unreliable. In order to increase the reliability of the program, it is important to qualitatively describe these errors and their nature so that they can be systematically eliminated (Rubey, 1975). In the context of this chapter, errors in implemented game content are referred to as bugs and defined, as in Beizer (1995), as:

“A design flaw that will result in symptoms exhibited by some object when another object is subjected to an appropriate test.”

Beizer (1995) goes on to define the criteria for such a test as:

“A test is passed if it is executed, the validation criteria are correctly applied, the actual outcome matches the predicted outcome, and there are no symptoms.
A test is thus failed if it is executed and the actual and predicted outcome does not match and/or there are symptoms.”

In game development, bugs can be categorized in four different levels depending on the severity of their condition (Levy & Novak, 2010), according to:

- Low Priority Bugs
- Medium Priority Bugs
- High Priority Bugs
- Critical Bugs

While High and Medium Priority bugs are prioritized in such a way that they should and will get fixed soon, critical bugs demand the immediate attention of the developer and are prioritized above everything else. Meanwhile, low priority bugs are bugs which can be fixed later, if ever at all.

For the development of game prototypes in xDELIA, the system must not contain errors which would interfere with the main purpose of the game. While certainly not preferred, there is room to have what Levy & Novak (2009) refer to as Low Priority Bugs which do not directly affect psychophysiological measurements or interfere with gameplay to such an extent that they become an element of annoyance for the player.
Verification of a prototype is mainly up the development team. Developers have to ensure that the product is implemented in a way that guarantees its viability to perform the task it is meant for. In xDELIA, the game prototypes mainly concern psychophysiological measurements in real time, feeding this information into the game and then using the information in some way. It is therefore vital that there are no errors which affect this process.

Weyucker and Labs (1998) suggest that software systems should go through at least three stages of correctness testing: unit testing, in which individual components are tested, integration testing, in which the subsystems formed by integrating the individually tested components are tested as an entity, and system testing, in which the system formed from the tested subsystem is tested as an entity.

Unit testing is a fundamental practice in Extreme Programming (Beck, 1999), and is the testing of the smallest part of an application that can actually be tested conveniently (Beizer, 1995). Components that are calling or are called by a specific unit are assumed to work properly, or are replaced by simulators. Beizer (1995) suggests that unit testing is a valuable testing method but states that it eventually should be upgraded to component testing. Component testing differs from unit testing in the sense that it involves the testing of integrated components and not just the unit or component itself.

Integration testing explores the relationship or interaction between components and the self-consistency of the aggregate.

System testing attempts to analyze elements which cannot be caught by previously mentioned testing methods. Elements such as reliability, performance or security are all examples of system testing and can be done by either developers or external testers.

3.3.1.3 Future Support
The concept of Future Support concerns the reusability of the created product and its components (Beizer, 1995). Writing generic code and solutions will obviously have a positive effect on the efficiency of future developments, in the sense that generic solutions already exists which can be directly inserted into an appropriate place.

In terms of future support in the xDELIA project, the production of prototypes has led to generic frameworks for reusing psychophysiological feedback, such as the Emotiv EPOC, galvanic skin response and heart rate variability. It is now a matter of minutes to connect such a device to a game engine and use the data gathered from it as bio-feedback and thus alter a game accordingly.

3.3.2 Game Structure Evaluation
Jordan (2000) 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. Game experience is what the player perceives emotionally and cognitively during a game session. The supporting level below game experience is the game structure, here divided into usability and game mechanics. By concentrating on evaluating the game as such and not focusing on the player’s experience of
the gameplay, many design flaws can be found and corrected, thus strengthen the creation of a good game experience.

In this section, two main aspects of a game are discussed, usability and game mechanics. Usability concerns the interaction technology used to play a game, and how easy that is to use. Game Mechanics are defined as the parts of the rule system of a game that covers the interaction that takes place during the game (Lundgren and Björk, 2003). A player should experience a challenge in the game world, not struggling to get through the interface. Usability is concerned with the interface issues, which should be intuitive and smooth; while game mechanics focus on the challenge the player has in the actual game world.

### 3.3.3 Usability

Usability is defined in ISO 9241-11 (1998) as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. In a game context the goal is to play the game, not completing it, and the game should still put up a challenge in order to be meaningful to play. There are several ways to measure and assess usability, such as user interviews, user questionnaires, user observations, heuristic evaluation, cognitive walkthrough, and talk-aloud protocols. This methodology focuses on usability testing by heuristics, user interviews and observations. Perceived Game Usability can be measured with a modified System Usability Scale (SUS) (Brooke, 1996).

### 3.3.3.1 Usability Heuristics

A Heuristic evaluation is an informal method born in the Human-Computer Interaction community. It was originally made popular by Nielsen & Molich (1990) and has since then been developed further by several researcher for various kinds of purposes (e.g. Nielsen, 1994; Schneiderman, 2004). It is used by experts to evaluate systems in an early stage of development to find usability problems. Despite being a limited method in that it cannot replace empirical evidence, as much as 40%-90% of early problems can be found in an early stage and can be corrected to a lower cost (Nielsen & Landauer, 1993).

The Usability Heuristics used in this methodology are seen in Table 3 (see Appendix A for a detailed description), and are adapted from Isbister and Schaffer (2008).

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Feedback</th>
<th>Easy-to-understand terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize memory load</td>
<td>Avoid errors</td>
<td>Provide help</td>
</tr>
<tr>
<td>Simple and clear menus</td>
<td>Separate interface from operation system</td>
<td>Screen layout and visually pleasing</td>
</tr>
<tr>
<td>Supportive audiovisual</td>
<td>Convenient and flexible game controls</td>
<td></td>
</tr>
<tr>
<td>representations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Summary of the eleven usability heuristics used in the methodology.

Generally when performing a heuristic evaluation, several experts analyze a system with the heuristic categories in order to find usability problems. More experts mean that more usability
problems can be found and corrected. An estimated optimal number (maximum cost-benefit ratio) for a middle-sized project is 4-5 usability experts (Nielsen & Landauer, 1993). This number is subject to change and will be decreased if the size of the project is smaller, the experts have great domain knowledge, and/or the experts’ usability knowledge is high.

3.3.3.2 Process
Because of the small size of each prototype, it is enough that three people with domain knowledge in game design perform the heuristic evaluation (Nielsen & Landauer, 1993). The process of evaluating a game prototype in xDELIA by using heuristics is described as:

**Step 1:** The list of Nielsen’s (1994) heuristics is distributed to the evaluators. Each evaluator evaluates the game separately, without any collaboration, at least three times in order to find problems that might arise when the initial threshold of understanding the system is achieved. The evaluators describe issues violating each heuristic in the list.

**Step 2:** When the first step is completed, the evaluators meet and coordinate their lists of problems, ranking the importance of the problems by how many evaluators found each problem and also how severe possible consequences could be.

**Step 3:** A report is prepared, describing the issues in more detail. Screen shots can be used to clarify the issues when needed.

**Step 4:** The evaluators, together with the developer, discuss possible solutions and the suggestions are compiled into recommendations and added to the documentation.

**Step 5:** After the heuristic evaluation has been conducted and documented, the result is presented to the product owner. Then, in collaboration between the development team and the product owner, decisions regarding what to do with the recommendations and also if a new development iteration should start or if play testing should be conducted, are taken.

3.3.3.3 Bio-Feedback Heuristics
The standard heuristics do not refer to external equipment such as the various sensors used within xDELIA. In order to make testing more systematized, heuristics were developed to quickly test out games with the sensors to see if any problems existed. The customized heuristics address face validity of the sensor, game balance, equipment and expert need.

**Sensor Face Validity**
The experienced emotional state, or sub-part of the emotional state, must correspond with the feedback given from the game. If the player feels that the game does not react to the bio-signals in an intuitive way, immersive play and thus learning is less likely.

**Game Balance**
In order for the player to have an enjoyable experience, the variations in sensor input and game difficulty must be meaningful and in balance. The game should become harder when sensor stimuli move towards unwanted levels of arousal, but this does not mean that the game should become impossible to manage. As an example of good design, the screen becomes
increasingly blurred when the player reaches undesirable levels of arousal. An example of a bad design would be that the screen turns black, rendering gameplay impossible.

**Equipment Convenience**

The sensors are tested for the intended period of time they are supposed to be worn. They should be comfortable to wear for that period. Otherwise sensors used, sensor placement, or game length will need to be adjusted.

**Expert Need**

It must be determined if a knowledgeable person is required in order to set up the sensors or if it is something everyone can do. Additionally, it must be determined how hard it is to adjust the sensor if the signal for some reason is lost (e.g. if it slips off).

### 3.3.3.4 Heuristics Results

The results are sorted based on their category. Each finding will get an identification number, marked with the category, the usability problem report and also a possible design solution, is seen in Table 4.

<table>
<thead>
<tr>
<th>H_ID13_SCREEN_LAYOUT</th>
<th>Text on introduction menu isn’t fitted on screen. It gets cut off.</th>
<th>More time will be spent on making texts and GUI items more visually pleasing.</th>
</tr>
</thead>
</table>

Table 4. An example of one usability problem found with the heuristics.

The feedback from the results of heuristic evaluation feeds into the Scrum process for the next iteration. Findings are discussed with the product owner and a decision is made how to address issues arising.

### 3.3.3.5 Usability Interview and Observation

Interviews are conducted after the game session in a semi-structured manner in order to get information regarding the players’ usability problems during play. The interviews concern open-ended questions about the overall usability and possible difficulties foreseen by the development team. Questions are directed towards specific parts of the game where the interviewer observed anomalies during the play testing session.

### 3.3.4 Game Mechanics

The concept of Game Mechanics is the fundamental building block for the game structure of any immersive and engaging game. Lundgren & Björk (2003) define the concept of Game Mechanics as the parts of the rule system of a game that covers the interaction that takes place during the game. Game Mechanics can be identified and qualitatively described by the use of
gameplay heuristics. This allows the evaluator to extract and analyze game concepts and make changes accordingly.

### 3.3.4.1 Gameplay Heuristics

Gameplay heuristics are used in order to quickly assess whether the gameplay offers adequate and well-designed challenges to the player. These heuristics are not as common and are much younger than usability heuristics, but several sets exist and research is starting to grow in the field of gameplay heuristics (e.g. Federoff, 2002; Desurvire et al., 2004; Pinelle et al., 2008). For the xDELIA game prototypes the gameplay heuristics from Korhonen and Koivisto (2006) are used. The different categories can be seen in Table 5 and more detailed explanations can be found in Appendix B. Other sets of heuristics were considered (Desurvire et al., 2004; Federoff, 2002; Pinelle et al., 2008), but were considered irrelevant because of their respective domain foci. In addition, two of these heuristic frameworks were considered too complex to use, with 43 heuristics in Desurvire et al. (2004) and 35 heuristics in Federoff (2002). Most of what was done by Pinelle et al. (2008) is covered by the usability heuristics described previously, rendering the addition of this framework redundant.

<table>
<thead>
<tr>
<th>Clear goals or supports player-created goals</th>
<th>Progress can be seen and compared</th>
<th>Meaningful rewards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player in control</td>
<td>Challenge, strategy, and pace are balanced</td>
<td>First-time experience is encouraging</td>
</tr>
<tr>
<td>Game story supports gameplay</td>
<td>No repetitive or boring tasks</td>
<td>Different playing styles are supported</td>
</tr>
<tr>
<td>Game does not stagnate</td>
<td>Consistent game mechanic</td>
<td>The game uses orthogonal unit differentiation</td>
</tr>
<tr>
<td>Hard-won possession are not lost</td>
<td>The players can express themselves</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. The eleven gameplay heuristics used in this methodology.

### 3.3.4.2 Gameplay interviews

Interviews are conducted after the game has been played in a semi-structured manner in order to get information on the players’ opinion about motivation, if there is something missing and if there was something that kept them especially motivated during gameplay. Suggestions for improvements are collected in order to be discussed within the development team. Interviewers should pose questions regarding gameplay that might have been missed by the generic questionnaires.

### 3.4 Game Experience

Game Experience evaluates how a user perceives a game. Usability and Game Mechanics are a necessary part and these factors in interaction with the nature of the player produce the Game Experience, as described in Part 1 of this document. A great deal of research has been conducted into developing measures of gameplay experience using and cross-correlating...

Some researchers have also tried to address game experience from perspectives derived more from usability. For example, Fernandez (2008) proposes a rather complex model of digital game experience, built around temporal influences before (antecedents), during (processing) and after (consequences) the gameplay experience. The model regards fun as the major outcome of game experience, constructed from emotional and cognitive player responses; furthermore, he proposes that game evaluation follows from this. Hassenzahl (2005) introduced a model (supplementing simpler and older models, e.g. Logan, 1994), which views user experience from a designer and a user perspective. Furthermore, Hassenzahl makes 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. His model implies that the experience is formed from the iconic value and prior memories the product triggers.

All of the game prototypes developed in xDELIA are aiming to be fun in nature, and thus provide high quality Game Experience. Game Experience supports the goal of the prototypes as learning platforms, both emotionally and regarding knowledge content. Thus it makes sense to carefully evaluate all of the prototypes regarding Game Experience. Data gathered during such an evaluation is analyzed to ensure that the game is used and perceived as intended, from the player and designer perspective. Following the proposal of Fernandez (2008), the Evaluation methodology includes methods for gathering data before the game starts (questionnaire), during gameplay (in game sensor logging) and after the game finishes (questionnaire and interview).

Game Experience research sets out to answer the question of what experiences the player has, how the game mechanics are perceived and how these relate to game design features. A closely related field is that of User Experience, which evaluates if an application provides the user with desired emotional and cognitive experiences. Garrett (2003) proposed a User Experience (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. Overall, User Experience has also recognized fun as an important factor for people to interact with products. Hassenzahl & Tractinsky (2006) outline
three important threads for UX research: addressing human needs beyond the instrumental, affective and emotional aspects of interaction, and the nature of the experience. These three directions also inspired the three layers of our methodological framework: Usability Evaluation, Game Experience and Cognition and Learning, respectively.

Research efforts are beginning to unravel the epistemological, ontological, and methodological nature of User Experience to foster a better general understanding of this concept (Law et al. 2008, 2007). Digital games have been in the focus of some of these efforts, specifically related to broader UX research (Bernhaupt, 2010; Bernhaupt, Eckschlager, & Tscheligi, 2007; Bernhaupt, Ijsselsteijn, Mueller, Tscheligi, & Wixon, 2008; Isbister & Schaffer, 2008).

A lot of User Experience research (in games or in general) utilizes qualitative approaches such as usability evaluations, playtesting, interviews and focus groups, and surveys (Pagulayan et al, 2002). For entertainment systems, the same success metrics as for desktop systems are not applicable, so regular usability metrics (e.g., task completion time, errors; Law, Hvannberg, and Cockton, 2008; Tullis and Albert, 2008) would have to be adapted to work as metrics of in-game behaviour; for an example see (Tychsen & Canossa, 2008). This is because the main usability issues in games concern evaluation of the emotional and cognitive experiences provided by game technology and virtual environments; not so much on performance measures.

In the game prototypes developed in xDELIA, a greater need to evaluate User Experience arose when games needed input from biosensors to feed data back to the player. User Experience evaluation sets out to explore the design quality of such an interaction and whether it provides the intended Game Experience. Evaluation is base on the affective and emotional aspects of interaction, just as Hassenzahl & Tractinsky, (2006) discuss, as well as, emotional and cognitive experiences provided by game technology and virtual environments (Tychsen & Canossa, 2008). As proposed by (Pagulayan et al, 2002), we used qualitative approaches such as usability evaluations, playtesting, interviews and focus groups, and surveys to evaluate User Experience with our prototypes.

3.4.1 Play Testing

Play Testing is a valuable asset in the evaluation of games since it allows different players to analyze the game from different subjective perspectives. This may reveal novel aspects of experience which have not previously been discussed or evaluated by the development team. Different components of game experience can be measured using the game experience questionnaire (GEQ) (IJsselsteijn et al., 2008).

3.4.1.1 Play Testing Procedure

For the Play Testing Evaluation of a particular game version, six arbitrarily chosen people play the game. Before playing the game, demographic data considering gender, age and experience with similar digital games are collected before the test starts. In order to objectively determine which game elements the players are paying attention to, the game can be played using an eye tracker device (as exemplified by Sennersten 2004, 2008, 2010). Eye Trackers measure the saccades (fast movements) and fixations (dwell times) of human gaze (Duchowski, 2003). Due to the relationship between eye fixations and attention focus, we are able to infer cognitive processes in virtual environment exploration (Sennersten, 2008). The
The purpose is to be able to tell how important different objects are, and in interviews afterwards, receive indications on how to improve the visual representations of the game.

**Step-by-Step Process**

The process of Play Testing of game prototypes can be described in 11 specific steps as listed below:

1. Recruit participants
2. Set up
   - Six players are used for the Play Testing session, following Pernice & Nielsen’s (2009) suggestion that this is enough for statistical significance regarding eyetracking gaze measurement. The game and the sensor software should run on the eye tracker computer.
3. Introduction (Purpose + in-game-description)
4. Questionnaire (Appendix C). Check that the questionnaire is properly filled in.
5. Play - During the play session the test leader observes the player and makes notes of the players behaviour. (Pernice & Nielsen, 2009)
6. GEQ (Appendix B) and SUS (Appendix C) (IJsselsteijn et al., 2008) (Brooke, 1996)
7. Closing questions. The interview section is recorded and the test leader also takes notes.
8. Analysis
   - The results from the GEQ and SUS are arranged and analyzed.
   - The gaze replay is analyzed and summarized. Gaze replay provides the best understanding of what goes on in the players head compared to other eye tracking analysis methods with 6 players ((Pernice & Nielsen, 2009). Areas of Interest may also be a good tool if there are specific elements that the experimenters want to explore.
   - The closing questions are summarized.
   - A final summary draws conclusions from the results from A-C to answer the question “What does this mean for the game design?”
   - Analysis of the logged data. Analysis seeks to answer the questions: “Does the players’ performance improve from play session to play session?” and “How well did the players manage their emotions/biases from play session to play session?”
9. After the play test is conducted and documented the result is presented to the product owner and the pedagogue, and in collaboration decisions regarding what to do with the results are discussed.
10. The discussion results in a prioritized product backlog.

**3.4.1.2 Play Testing Questionnaire**

Different components of game experience were measured using the game experience questionnaire (IJsselsteijn et al., 2008). IJsselsteijn et al theorized that immersion, tension,
competence, flow, negative and positive affect, and challenge are important elements of gameplay experience and developed the game experience questionnaire (GEQ) to assess these elements, which will be used in our user study. 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. Perceived Game Usability can be measured with a modified System Usability Scale (SUS) (Brooke, 1996). Brooke states that the SUS has proven to be a valuable evaluation tool, being robust and reliable. To evaluate the results Tullis & Albert (2008) argue that an average SUS score under 60% is relatively poor and one over 80% can be considered as good.

**Game Experience Questionnaire**

The alternative answers are “Not at all”, “Slightly”, “Moderately”, “Fairly” and “Extremely”. The questions are:

1. I felt content
2. I felt skillful
3. I was interested in the game’s story
4. I could laugh about it
5. I felt completely absorbed
6. I felt happy
7. I felt tense
8. I felt that I was learning
9. I felt restless
10. I thought about other things
11. I found it tiresome
12. I felt strong
13. I thought it was hard
14. It was aesthetically pleasing
15. I forgot everything around me
16. I felt good
17. I was good at it
18. I felt bored
19. I felt successful
20. I felt imaginative
21. I felt that I could explore things
22. I enjoyed it
23. I was fast at reaching the game’s targets
24. I felt annoyed
25. I was distracted
26. I felt stimulated
27. I felt irritable
28. I lost track of time
29 I felt challenged
30 I found it impressive
31 I was deeply concentrated in the game
32 I felt frustrated
33 It felt like a rich experience
34 I lost connection with the outside world
35 I was bored by the story
36 I had to put a lot of effort into it
37 I felt time pressure
38 It gave me a bad mood
39 I felt pressured
40 I was fully occupied with the game
41 I thought it was fun
42 I felt competent

System Usability Scale
A Likert scale from 1 to 5 (strongly disagree to strongly agree) is used. The questions are:

1 I think that I would like to use this game system frequently.
2 I found the game system unnecessarily complex.
3 I thought the game system was easy to use.
4 I think that I would need the support of a technical person to be able to use this game system.
5 I found the various functions in this game system were well integrated.
6 I thought there was too much inconsistency in this game system.
7 I would imagine that most people would learn to use this game system very quickly.
8 I found the game system very cumbersome to use.
9 I felt very confident using the game system.
10 I needed to learn a lot of things before I could get going with this game system.

3.4.1.3 Interview
In addition to the play testing questionnaires, semi-structured interviews are conducting in order to catch additional information about the gameplay and the players’ experience. The players are questioned about specific game elements that caught their attention, if anything was lacking, motivational factors that were present (or missing), and game strategy. These are conducted after the questionnaires, when the player has had time to reflect on their gaming experience. This can then be fed back into the design process, both as things the players are uncomfortable with but also as suggestions to improve gameplay.

3.4.1.4 Play Testing Results
Play Testing results consist of questionnaire data from the GEQ, SUS and qualitative answers from the conducted interviews. The GEQ results are categorized into immersion, tension, competence, flow, negative and positive affect, and challenge. The concepts are presented in diagrams that visualize the distribution of participant answers, as seen in Figure 17.
Figure 17. An example of answer distribution among several GEQ result categories, from Play Testing of the Two Index Game.

Besides the hints from the combined categories regarding the gameplay, answers from the individual questions can give valuable information as well.

All results are compiled and discussed within the development team, as well as communicated to the product owner. Design changes go into the backlog after careful consideration regarding value and priority.

### 3.5 Cognition

The Cognition aspect of the Evaluation Methodology is separated into two sections; Cognitive Processes and Learning. In Cognitive Processes, the evaluator defines the cognitive biases that the game is trying to measure, assess or train against. In the case of the xDELIA project, Cognitive Processes involves the concepts of the disposition effect as well as emotion regulation. Learning involves the defining of learning outcomes for a specific game as well as the method or achieving them.

#### 3.5.1 Cognitive Processes

Norman (2004) makes a distinction between affect and cognition; he also explains that both are information-processing systems with different functionalities. Cognition refers to making sense of the information that we are presented with, whereas affect refers to the immediate gut reaction or feeling that is triggered by an object, a situation or event a thought. Furthermore, he 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.

When facing difficult and stressful tasks, people tend to use one of two main strategies to deal with the corresponding emotion (Wallace, 2009), suppression and reappraisal. Suppressors generally tend to push down emotions, ignoring the fact that they exist and are continuously affecting them. Reappraisers however tend to positively re-evaluate situations. Both emotion regulation strategies exhaust cognitive resources for the person affected by the emotion (Wallace, 2009). Generally it is preferred to apply reappraisal strategies when encountering unwanted emotions.

Making the players aware of emotions arising while making financial decisions sets the stage for learning how to effectively regulate emotions using the reappraisal emotion regulation strategy, supporting the central hypothesis of xDELIA that improved emotion regulation will improve decision quality.

### 3.5.1.1 Emotion Regulation

As described in Part 1 of this document, emotions can generally be classified by the independent components of arousal and valence (Russell, 1980), where arousal represents excitement level and valence defines whether the arousal is positive or negative. This implies that emotions can be visualized in a diagram where arousal and valence define each axis, as seen in Figure 18.

![Figure 18. Emotions in the valence-arousal space](image)

When attempting to measure emotions, one is thus actually measuring a combination of valence and arousal. There are methods for extracting and interpreting valence from...
Electromyography (EMG) measuring devices (Cacioppo et al., 1986), but since there are several technical difficulties here such as accessibility and extensive setup procedures, the learning intervention in xDELIA will not be concerned with valence. Instead the focus lies on arousal as the primary attribute of interest. Since arousal is vital in the definition of emotion, emotion regulation is basically the attempt to change state of arousal and valence, and we address emotion feedback via feedback about arousal.

As noted above, when facing difficult and stressful tasks, people tend to use one of two main strategies to deal with the corresponding emotion (Wallace, 2009). These strategies are suppression and reappraisal.

Gross and colleagues (Gross & Thompson, 2007) have developed a staged model of emotions, which distinguishes between strategies for emotion regulation which intervene at different stages of the emotion process. In particular they distinguish the intentional cognitive reappraisal of a situation (to change emotions) from suppression of emotion expression. A self-report measure, the Emotion Regulation Questionnaire, identifies two habitual approaches to emotion regulation: reappraisal, in which an intentional cognitive reappraisal of the stimulus affects the emotion response; and response modulation (or expressive suppression) in which expression of an experienced emotion is effortfully modulated. Other questionnaire measures (eg the Mainz Coping Inventory, Krohne, Egloff, et al., 2000) can be used to identify defensive approaches to emotion regulation which prioritise avoidance of threatening information over realistic situation appraisals.

Such self-report measures are easy to administer and have been successfully linked in research to important outcomes. However, they depend on subjects’ awareness of their habitual strategies (which may be pre-conscious) and on subjects’ motivation to be honest in their self-report. Thus physiological measures are a highly desirable adjunct to such measures since they do not depend on the accuracy of subjects self-assessment and may encompass pre-conscious as well as conscious emotional states.

One important physiological measure which has recently been linked to emotion regulation is heart rate variability (HRV). The autonomic nervous system can be subdivided into the (excitatory) sympathetic and (inhibitory) parasympathetic sub-systems (SNS and PNS respectively). These interact, often antagonistically, to produce variation in physiological arousal. During periods of stability and low stress the PNS is dominant and maintains a lower degree of physiological arousal and lower heart rate. During physical or psychological stress the SNS becomes dominant, increasing physiological arousal and heart-rate. Effective emotion regulation requires the ability to adjust physiological arousal on a moment-by-moment basis (Gross & Thompson, 2007). Heart-rate variability provides a measure of the moment-by-moment interaction of the SNS and PNS yielding information about autonomic flexibility and thus regulated emotion responding. HRV can be considered a proxy for the central autonomic network’s regulation of the timing and magnitude of an emotional response via inhibition, in response to context (Appelhans & Luecken, 2006; Moses, Luecken, & Eason, 2007; Utsey & Hook, 2007; Geisler & Kubiak, 2009; Hansen, Johnsen et al., 2009). Higher levels of high frequency HRV have been associated with constructive coping in university students and lower high frequency HRV with the use of repressive coping strategies, anxiety, depression and rigid attentional processing of threat (Appelhans & Luecken, 2006).
While early studies have focused on resting HRV as providing a global assessment of regulatory capacity, recent studies have demonstrated the utility of HRV in providing a task-related, moment by moment, assessment of regulation (Moses, Luecken, & Eason, 2007) suited to field studies of task performance (Segerstrom & Nes, 2007). xDelia studies are aimed at evaluating both questionnaire measures and physiological measures such as HRV as feedback mechanisms in learning intervention design. An xDelia study has demonstrated an association between the expertise of traders in two investment banks and effective emotion regulation as measured by high frequency HRV during trading episodes around market news releases (Fenton-O'Creevy et al, 2011).

By playing a game, the player’s emotional state is monitored, and fed into the game to make difficulty adjustments accordingly. By receiving real time bio-feedback, the player should eventually become aware of his or her emotional state. In addition, if the player receives instructions on how to manage emotions; it is hypothesized that this may lead to lower average arousal state when playing the game.

### 3.5.1.2 Disposition Effect

The disposition effect is the tendency to hold assets which would sell at a loss for longer than assets which would sell at a gain. In colloquial terms an investor who suffers from the disposition effect cuts their wins and runs their losses. This bias arises out of the desire to avoid the emotional pain of realising a loss. So long as the investor does not convert a paper loss into a realised loss they can console themselves that ‘it will probably increase in value again’. We have chosen to focus on the disposition effect since it fits well the criteria outlined above: a) there is robust evidence for the effect in both laboratory and naturalistic settings; b) there is good reason to believe that emotion processes are important in the operation of the bias; and c) it is tractable to detection in individual trading patterns. It can also be shown that the disposition effect tends to cause investors to have a different risk profile to that intended and tends to reduce performance.

The disposition effect can be reliably demonstrated in laboratory experiments but there is also a very significant body of research which shows the disposition effect to be remarkably robust and to characterize trading patterns across a wide range of financial decision-making contexts and at different decision-making time horizons (Barberis & Xiong, 2009). The disposition effect is a member of a class of biases which are framing effects; that is effects on decision-making and judgement which arise out of the contextual framing of a decision by elements which are not strictly relevant to the decision (Bazerman, 2002). That is trading decisions which are framed as involving losses lead to different behaviours than trading decisions which are framed as involving gains. There is strong evidence that framing effects are robust across situations and have been demonstrated to be important both in the lab and in the field. There is increasing recent evidence for the role of effective emotion regulation in ameliorating such framing effects; for example a laboratory study (Sutterlin, Herbert et al., 2010) showed effective emotion regulation as measured by higher task based Heart Rate Variability to be associated with lower susceptibility to framing effects.

The disposition effect is widely understood to be mediated by emotion processes. Thaler (1999), for example, explains the disposition effect in terms of the emotional impact of realised gains and losses versus paper gains and losses. In particular, the emotion of regret and
the higher weighting attached to negative emotions than positive emotions in decision-making play an important role (Shefrin & Statman, 1985; Lee, Kraussl et al., 2009).

Given a sufficiently large trading record, it is possible to analyse the trading record of an individual investor to characterise their propensity to a disposition effect. However, most studies in this field are concerned with the demonstration of the disposition effect in a given population of investors. Existing approaches to measuring the disposition effect thus are not well suited to characterising individual investors. A significant contribution of the xDelia project is the development of an innovative approach to measuring the disposition effect of individual investors both through analysis of trading data and in gameplay (Yee and Lins, 2011a,b).

A study in the domain of losses has been conducted in xDElia, by Karlsruhe Institute of Technology, measuring investors experienced regret and (dis)satisfaction during incurring various sizes of gains or losses over multiple periods, and linking these emotions to their subsequent hold/sell decisions 14(Lee, Kraeussl, & Paas, 2009). It has been found that in the loss domain, only regret has significant impact on investors’ subsequent hold/sell decisions. Furthermore, high experienced regret and pride are linked to a larger probability to sell; anticipated pride leads to a larger probability to sell; while anticipated regret links to a smaller probability to sell (the Disposition Effect).

Lee, Kraeussl, & Paas (2009) demonstrate in their findings that investors’ subsequent hold/sell decisions are simultaneously affected by their experienced and anticipated emotions. In a similar study it has been found that alternative outcomes may affect evaluation of decisions (Fogel & Berry, 2006). Anticipation of regret may lead investors into the trap of holding losing stocks too long. All of the respondents in this study reported regret for investment decisions, either for not selling a losing stock soon enough, or for selling a winning stock too soon. Emotions have a powerful impact on our lives: they shape our behavior, and their influence is so pervasive that no decision theory could be complete without taking their role into account. When markets are as volatile as they currently are, then there is no doubt that emotions play even more of a role. This has been confirmed in a research study where it was found that investors tend to feel sorrow and grief after having made an error in judgment (Yahyazadehfar, Ghayekhloo, & Sadeghi, 1985). This study found that investors deciding whether to sell stock are typically emotionally affected by whether the stock was bought for more of less than the current price. Therefore, the investor must recognize this fact and try to practice some mechanism to control his/her irrational behavior. As Summers & Duxbury (2007) found that emotional response is clearly important in explaining behavior in disposition effect and that manipulating emotions changes behavior. This provides evidence of the importance of emotion in economic behavior.

The psychology of emotions, however, offers a further set of influences to consider, and Elster (1998) advocates that economic theory should take account of their impact too. He concludes “we need a better understanding of how emotions actually influence behavior” and

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14 See discussion of studies RS-1 and RS-2 in Deliverable 9.
how they “affect the ability to make rational choices”. Elster's (1998) call has been heard and there is a move in the economics literature to recognize that emotions (e.g. Loewenstein, 2000) and feelings (Romer, 2000) have important roles to play in understanding economic behavior. Regret is a prominent example for the impact of emotions in financial decision making (Engelbrecht-Wiggans & Katok, 2008).

3.5.1.3 Learning

In order to assess if players are learning within each game, first a target learning outcome must be specified. The methods of test-retest and to randomize the order of game phases are used in order to determine if the learning outcome is met. Test-retest is a within-subject method in which the player plays the game several times in order to determine if the learning factor increases, decreases or stays the same. This method has the disadvantage that it requires the player to complete the game several times in order to correctly assess if the skill level is affected. Randomization of game phases is a between-subject method that makes it possible to determine if the players learn or not. If a game, for example, has two phases, one group of participants plays phase one first and then phase two, while the other group plays the game in the reversed order. This makes it possible to dissociate phase sequencing effects from learning design effects. A disadvantage with this method is that it requires many players in order to account for individual differences among them. In addition, it is difficult to implement if the game itself is path-dependent and requires one phase before another can happen.

For each game it is important to map the learning curve. This can provide a basis for assessing how much each player needs to play before a difference is observed, but also when a player no longer seems to learn more of a desired skill from the game. The latter is not the same as to not proceed any further in the game, but refers to the case when the desired learning outcome is no longer increasing. For example, a player might reach greater scores each time the Aiming Game is played, but no more emotion regulation effects are seen after the game has been played seven times, which may imply that the learning taking place thereafter is not related to emotion regulation but rather to increasing gameplay skill.

As an example of learning, in the LineRacer prototypes the goal is to have as fast a reaction time as possible. As seen in Figure 19, learning in the Go/nogo(S) game is rapid, and in phase 3 there is relatively stable performance (just differing by a few milliseconds) through the rest of the game. Go/nogo(S) is therefore learned within one single play session (consisting of six phases). Go/nogo(M) on the other hand has much more variance and has not stabilized after six phases, thus concluding that it takes longer to learn to have solid performance in the game.
Figure 19. Mean reaction times for two different version from the LineRacer series.

3.5.2 Transfer

The Evaluation Methodology was initially developed to assist in the development of serious game prototypes in the xDELIA project. Therefore, it contains methods which explicitly analyze the effectiveness of transfer between the game setting and real world settings. The concept of transfer of learning was first introduced by Thorndike and Woodworth (1901) and concerns how performance in one task influences performance in another. One way to test for transfer is to establish a baseline with one task, train on another and then retest the first task, to see if they are targeting the same underlying skill. Transfer can also occur and be tested for between different game settings. This chapter is thus defined by the evaluators themselves in order to cover the methods which are to be used to test the effectiveness of the game in transferring knowledge and skills between settings.

In xDELIA, the cognitive bias that is evaluated is the disposition effect (Summers & Duxbury, 2007) in relation to emotions and emotion regulation. The relationship is that anticipated feeling influences the behaviour of selling winning stocks early and riding losses for a longer time, i.e. the disposition effect. By training emotion regulation, the anticipation of emotions might gain a reduced role, thus reducing or eliminating the disposition effect. Therefore, transfer between emotion regulation training and testing of the disposition effect in the game environments is hypothesized to be of great importance. The first step is to test for the disposition effect, the next to train emotion regulation and lastly to retest for the disposition effect. This is done by firstly playing the Two Index Game, developed at Saxo Bank, and then train emotion regulation using the Aiming Game, and lastly play the TwoIndex game again. A control group is also tested that plays the Two Index Game but does not receive the training by using the Aiming Game.
3.6 Platform
The Evaluation Methodology is a generic set of tools meant to be used in many different evaluation sessions. As a way to define what parts of the methodology are of importance in the evaluation of a specific game, the evaluation platform is defined as a list of features where each feature needs to be covered by a specific evaluation tool. If the evaluated game, for example, includes bio-feedback, the evaluation of the game must include tests that validate the use and implementation of this feature. Should the evaluated game be a learning game in an online social setting, the methodology must account for this by analyzing the game experience and social interaction.

A feature from the evaluation platform list may require several evaluation tools in order to be covered completely. Sensor technology would for example require both Functionality testing of the implemented software and input, as well as Heuristics that generate specific discussions regarding sensor technology and usability. The platform is thus basically a list of requested evaluation methods that need to be used in order to fully evaluate a specific game.

3.7 Example of the methodology in the Design Process

The Evaluation Methodology has been continuously revised and improved during the development of game prototypes by xDELIA partners at Blekinge Institute of Technology. Certain parts of the methodology have been used multiple times to assess the viability of the prototypes and have provided valuable information on how to proceed with the development most effectively.

In this section, an example of how the Evaluation Methodology has been used during the development of xDELIA game prototypes is presented. The purpose of the example is to elaborate on the effectiveness of each of the different aspects of the evaluation that were used. In this example the development and evaluation of a prototype called the Aiming Game is presented. The different evaluation aspects are divided into sub-chapters and discussed independently.

3.7.1 Aiming Game Development Process
The purpose of the Aiming Game is to provide a platform for learning emotion regulation skills and strategies. Specifically, the game targets investors using the Saxo Bank trading platform. The initial development of the Aiming Game aimed mostly at meeting the requirements provided by xDELIA partners, which focused on making the prototype a viable tool for teaching these emotion regulation skills. The first version of the Aiming Game therefore consisted of game mechanics to support skill training but lacked somewhat in entertainment value. Since the game eventually should be used as a platform for learning with frequent revisits by members of the target user group, there was a strong need for the game to provide a more enjoyable experience than it initially did. In order to solve this issue, several evaluation methods were applied to the game. A Heuristic evaluation was applied to the game to identify critical design flaws and to suggest solutions to the major issues of the prototype, as well as Play Testing sessions using uncontaminated participants.
3.7.2 Heuristics

The Heuristic Evaluation of the Aiming Game covered two very important areas of the game, namely Usability and Game Mechanics which are the building blocks of the Game Structure Evaluation in the methodology.

Usability Heuristics uncovered many faults in the graphical design of the game and while Usability issues are crucial, they were not the main focus of the evaluation. Since the developers first sought ways to improve the quality of the game content rather than correcting interface issues, it was in the Game Mechanics domain that most effort was put. The Heuristic evaluation generated much content in terms of issues, congruent with the opinions of the developers, which were beneficial to discuss further.

The game design of the Aiming Game did not allow for many key concepts, making up an engagement and immersive game. Below is a list of the most crucial problems with the Aiming Game found after the first iteration:

- The goal in the game is not motivating enough for a 10 – 12 min game and it becomes very dull after a while.
- The game doesn’t support player-created goals (like a high-score list).
- Players are not rewarded at all. Achievements should be provided related to the score to motivate the player.
- Level progression in between levels is too slow. Make level progress dependant on player performance
- There is no support for different playing strategies. For example, for players who control emotions very well, increase the sensitivity of the emotion detection measurements, and for the good shooters, increase the speed of the aircraft.
- Tasks in the game are too repetitive. Introduce random events to break the repetition and introduce disturbance.
- The player has no feeling of progression; with no feedback on how the game is developing.

The Heuristics clearly point at an obvious outcome of an iteration which merely focused on implementing content which supported the main purpose of the game, i.e. emotion regulation. It became clear that the game needed to adopt game design patterns and ideas which could increase the game experience and make the game more compelling in the long run.

3.7.3 Play Testing

The Play Testing evaluation of the Aiming Game generated much valuable data which can be used in order to improve the Aiming Game both as an entertainment platform and as a learning tool. In addition to answering the generic questionnaire regarding Game Experience (GEQ), participants were also interviewed regarding specific topics which the experimenter/developer needed answers for. The interview questions usually became open discussions regarding the specific topics which in turn generated additional useful data. The topics discuss with participants were:
- Arousal bar and Bio-feedback
- Aiming Mechanics
- Flow and Progression
- Difficulty
- Music
- Other (open discussion to let participants speak freely regarding the game)

An observation regarding the Arousal Bar was that five out of six participants claimed to have had awareness of their own arousal with the help of the arousal bar. Eye Tracking results however indicated that none of the participants paid any (or very little) direct attention at all to the arousal bar during the game. This finding might indicate that players are able to perceive the arousal bar in their peripheral view while playing the game and that direct attention focused on the bar itself is unnecessary. Another possible explanation for the participants claiming that they at most times had full awareness of the level of the arousal bar might be that they received this information in other forms. This hypothesis is based on the fact that players receive several indications of their arousal in the form of air plane blurring and crosshair offsets as well their own gut feeling. This phenomenon will have to be investigated further.

In general participants answered uniformly in the discussion of the Aiming Mechanics. All participants experienced the aiming as being somewhat rough and several participants drew the analogy to an old mouse with wheel-mechanics. It turned out that there was a bug in the aiming class update section of the software preventing smooth movement in certain arousal levels. This issue has been completely encapsulated and will be resolved in the next iteration.

Most participants (five out of six) also had a problem with the delay between shots fired and actually hitting the targets. Because of this game element, players had to learn how to compensate for the delay before being able to hit targets correctly. Since the game does not explicitly explain the phenomenon, this caused much confusion among participants. In a new version of the Aiming Game this effect would be removed and replaced by an instant shoot/hit mechanic.

Several participants described the development of tactics throughout the game and how these changed in accordance with the changes between phases. The most common tactic seemed to be to focus attention towards the middle of the screen where evidently the most planes eventually appeared. This tactic was shattered however when the second phase was initiated and red distraction airplanes appeared. Since these come in greater numbers with the same generation procedure as the targets, the red airplanes swarm in the middle of the screen making it very hard for the player to separate the targets from the distractors in this region. This led to players completely switching tactics and focusing their attention on the borders of the screen instead, something that can be seen relatively clearly in the Eye Tracker data of some participants during the last phases of gameplay.

When asked for their suggestions to make the game more interesting to play, all participants talked about the repetitiveness which eventually leads to boredom in the game and suggested
different ways to vary the game content. Suggestions to decrease repetitiveness were to provide:

- additional airplanes with different features such as blue planes which rewarded with more points.
- reaching new levels by performance instead of time to increase the incentive to achieve better.
- several graphically different levels
- a variation of many games with the same mechanics but different game manifestations, e.g. click-and-drag items to different places.

From the Game Experience Questionnaire answers, it was possible to extract uniform trends regarding several components, but in order to gain statistical significance from the GEQ one would preferably need approximately 20-30 participants. Here, several components can be discussed despite the lack of a larger sample group.

Participants generally answered that they felt tense during the game (Average: 4, Standard deviation: 0.89) as well as having to constantly focus on the game (Average: 4.17, Standard deviation: 0.41). They also congruently answered that they were not allowed to explore things (Average: 1.5, Standard deviation: 0.84) and did not feel very imaginative (Average: 2, Standard deviation: 1.09). Participants answered that they did not feel happy during the game (Average: 2, Standard deviation: 0.63) at the same time as stating that they were not particularly bored (Average: 1.83, Standard deviation: 1.17).

### 3.7.4 Results and backlog

The results and conclusions discussed above were categorized and prioritized, and eventually inserted into a backlog. The backlog serves as a requirement list for the next development iteration, which means that it has to be approved by the product owner. While game design decisions are mostly up to the developer, the product owner must ensure that the prototype still stands aligned with its original purposes.

### 3.8 Discussion

The Evaluation Methodology is a continuous work in progress, evolving iteratively by each game prototype developed in xDELIA, from the initial Board Game prototypes where a need for a systematic Play Testing model was conceived, up to the latest Aiming and Auction games where it was expanded into its current state.

Through the development of prototypes in xDELIA, there has been a need for a systematic way to evaluate elements concerning game design choices, as well as technical aspects such as the handling of bio-sensors and the impact of bio-feedback. The development of customized heuristics for this type of technology made the Evaluation Methodology much more viable when evaluating such games.
3.9 Conclusion

The Evaluation Methodology is a tool specifically used to solve issues regarding the development of prototypes in the xDELIA project. Its generic structure, however, allows for effective evaluation of other types of games as well. It does not cover all aspect of game evaluation, such as the mental processes of the player while playing a game. What strategy is the player using to solve problems? What method of reasoning does the player use in certain contexts? These are better assessed by detailed interaction data in relation to game features, including command logging, eye tracking studies, and more general psychophysiological measures, as discussed in Part 1 of this document. Evaluation methods such as talk-aloud sessions as a part of the Play Testing sessions could be additions to the methodology in future versions. When games become more complex, they also call for additional and more sophisticated functionality testing. Software validation methods and tests will therefore most certainly need to be revised.

While several sections of the Evaluation Methodology are more or less standardized, the sections regarding Cognitive Processes, Learning and Transfer are more domain-specific in that their content are depending on the type of game that is evaluated as well as the setting it eventually should transfer skills to. In later versions of the methodology, it might be possible to elaborate these areas in an attempt to increase the generic content of the Methodology and provide more systematic and structured ways of dealing with different cognitive biases, as well as the learning and transfer of their respective skills.

With the intention of being able to rapidly create prototypes using existing components, there is a demand for a systematic component repository structure. Currently, there is no such structure involved in the project, but because of the limited number of reusable components so far, it currently does not really affect the development process.
Appendix A - Usability Heuristics

In this section there is a description of the usability heuristics used in the evaluation methodology. These heuristics were taken from Nielsen (1994), but adapted by the work of Latinen (2008), Korhonen & Koivisto (2006), Federoff (2002), and Desurvire et al. (2004).

**Consistency**
The user interface should be consistent within the game and also with other games. Consistency reduces the learning curve of how to play the game and also decreases the number of usability errors. Consistency within the game means that similar functions work in a similar manner. It is the behaviour of the game that is consistent, not necessarily the interface. Consistency between games means to follow game conventions and standards. An example could be the controls in a first-person shooter; normally the player navigates through the game with the WASD-scheme (W – forward, A – left strafe, S – back, D – right strafe), it would be very inconsistent to implement it as a RDFG-scheme instead.

**Provide feedback**
Feedback should be immediate, appropriate, and easy-to-understand after each action in the game. This applies both to menus and in-game. Feedback is important in order to reduce insecurities in the game so the player will think things like “Did I, or did I not, perform the action?”.

**Use easy-to-understand terminology**
The language should be clear and non-ambiguous and also relevant to the domain of players intended.

**Minimize players’ memory load**
The current state of affairs should always be visible, such as health and time left on level.

**Avoid errors**
Errors should be prevented and relevant feedback should be given if a player commits an error. Also, all errors should be reversible.

**Provide help**
The player will generally not read any instruction material so all information needed to play have to be included in the game.

**Simple and clear menus**
As well as clear and simple menus, if they are in several layers they should follow a logical, easy-to-understand pattern in order to make them easier. Shortcuts should be used when it is suitable.

**Device user interface and game user interface are used for their own purposes**
The game style should be separated from the style of the operating system, to not confuse user if the game is running and also to not break the immersion.

**Screen layout is efficient and visually pleasing**
The information that is required should be the one that is present, without any additional unnecessary information. The layout should not appear cluttered with information, but rather neatly organized. Screen, display items, and menus should all be visually pleasing.

**Audiovisual representation supports the game**
There should be no dissonance between the style of the game and the visual and audio representations. Visual and sound elements can be used to provide feedback to the user. Feedback should not be provided by sound exclusively, since some players keep the volume down or off.

**Game controls are convenient and flexible**
Controls should be easy to learn, convenient and flexible. Navigation should be consistent with industry standards and logical, controls should be customizable, and mapped in a intuitive and natural way.
Appendix B - Gameplay Heuristics

This section contains the gameplay heuristics, adapted from Latinen (2008), Korhonen & Koivisto (2006), Desurvire et al. (2004), Federoff (2002), and Isbister & Schaffer (2008).

**The game provides clear goals or supports player-created goals**
The player should always be aware of the next goal and also what the long-term and short-term goals are. Goals should be clear and the long-term goal introduced early, and short-term goals when they are needed. If no clear goal is stated, it is important that the game supports player created goals.

**The player sees the progress in the game and can compare the results**
In order to keep players motivated it is important to give them feedback on the progression in the game. Therefore, the game should give feedback on how the progression is proceeding, both score achieved and how far it is left until the end of the task. It should also be possible to compare results with other players, boosting motivation further.

**The player is rewarded and rewards are meaningful**
The rewards should be experienced as fair and meaningful. Increasing in-game capabilities, customizable looks, and better skill in playing the game are categories of rewards. Although, the game should be well balanced between challenges and rewards.

**The player is in control**
Players should feel like they are in control, that it is actually a game and not a lottery. The game should be easy to turn on and off, without losing progression. Skills are taught early that are used later or directly.

**Challenge, strategy, and pace are well balanced**
The game should strive for “the golden middle way”, that is, not to be too difficult or too easy. The pace should pressure, but not frustrate, the player

**The first-time experience is encouraging**
The first five to ten minutes of the game must be encouraging, since it is here the player decides if the game should be played further. The game should thus have an easy way of getting the player immersed. Tested ways of doing this is tutorials and/or progressive or adjustable difficulty levels. It should also follow general trends within the game community.

**The game story supports the game play and is meaningful**
If there is a story line it is important that the player understands it as a single consistent vision. The player should spend time thinking about different outcomes of the story, and get the feeling that the game world continues even when the player is not present. The story should progress as a natural part of the game play.

**There are no repetitive or boring tasks**
Tasks should not have to be repeated all the time, and when they have to, it should be meaningful to do so. In order to avoid player’s fatigue it is important to vary the tasks the player has to do.

**The game supports different playing styles**
If the game is complex enough, there should be multiple ways to play it. Multiple paths, and winning conditions, should exist in order to keep the player interested.

**The game does not stagnate**
Game progression must be perceivable at all times.

**The game is consistent**
The game mechanics should be consistent with industrial standards, as well as consistent between game elements inside the game, giving the player the perception of a fully functional, non-ambiguous, world.

**The game uses orthogonal unit differentiation**
Different objects in the game should serve different purposes, allowing players to use different strategies. The difference between a hunting rifle and a shotgun could be an example. The hunting rifle requires great accuracy but can shoot at a long distance without losing effectiveness, whereas the shotgun will hit the target even though the player is bad at aiming, but cannot be used on a long distance because power is lost.

**The player does not lose any hard-won possessions**
If long time has been put into the game to win a certain item, this item should not be lost easily. Committing the same failure in the game should not be equally punished every time.

**The players can express themselves**
The player’s character should be customizable in order to get more involvement in the game. Also the feature to be able to build own content is helping people to get more immersed.
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