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TNO report

TNO-DV 2011 B142

Transfer of Gaming: Transfer of training in serious gaming

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Copy no	
No. of copies	20
Number of pages	52 (incl. appendices)
Sponsor	Netherlands Organization for Scientific Research (NWO)
Project name	Transfer of Gaming: Transfer of training in serious gaming
Project number	032.13301

Summary

Serious gaming for learning purposes exploits characteristics of play to help people learn by using computer games. The combination of play, learning and simulation may explain the popularity of the concept of serious gaming. Furthermore, PC based games may have great learning value because they offer the opportunity to create dynamic an elaborate learning environments where learners can actively work on authentic problems. Following the introduction, Chapter 2 to 6 cover the most crucial aspects of serious gaming, i.e.: play, motivation, learning, and transfer. Central to Chapter 2 will be the questions 'what constitutes play' and 'why do we like to engage in games'. These topics are discussed from a developmental, psychological and evolutionary perspective. We conclude that play has a firm foundation in evolution and individual development. It not only drives the physical, social and cognitive development of animals and man, but also functions as a behaviour generator that stimulates the development of new types of behaviour and skills. In Chapter 3, motivational aspects and individual differences with respect to gaming are discussed. In this chapter we identify three major influences on the internal motivation of people to undertake or like an activity, i.e.: competence, autonomy and self-realization. In addition, we describe external conditions that may affect a person's feeling of autonomy and competence such as rewards, feedback, meaningful goals and rules. Furthermore, in this chapter we present the results of an empirical study that we have carried out investigating whether or not individual learning characteristics may be a good predictor of gaming as preferred learning tool for individuals. Subsequently, Chapter 4 describes the benefits of gaming from a didactical viewpoint and offers a new educational approach that is relevant for serious gaming. This so-called JOT approach is based on constructionist theories of education and discovery learning. Chapter 5 explores the topics of effectiveness and efficiency of learning in games (Transfer of Gaming, ToG) borrowing from knowledge built up in the areas of modeling and simulation and didactics.
An overview is provided of the different transfer measures and some positive aspects of serious games that are not considered in these measures are discussed. These positive aspects relate to motivation, engagement, explorative behaviour, and the fact that the "cost" of serious gaming for professionals may become very low when it is done in leisure time. In addition, a task-taxonomy is invoked showing that, serious gaming may allow people to learn many kinds of relevant skills, despite large differences between playing PC games and real tasks. The taxonomy can be useful as a grip to predict ToG, to design games and to evaluate games.
In Chapter 6 we present a stepwise reference framework that can be used by game designers to develop serious games from an instructional and cost-effectiveness point of view. In the final chapter, we discuss our findings of the previous chapters. We conclude that serious games should resemble the operational environment on the key (critical) aspects of the task to be learned. This resemblance not only concerns the physical and synthetic environment, but also the information processing operations, which are determined by the underlying (mathematical) models, scenarios, objects, characters, and storylines. If there is sufficient validity in the physical, synthetical, and informational world that carries the game, games may teach relevant skills and enrich existing training curricula making learners more inspired, motivated and engaged.

Contents

1 Introduction

Games are increasingly gaining acceptance as valuable training tools within the education and training community. Besides being a cheap, and maybe a cost-effective, alternative for the expensive high-end simulations, there is another reason educators are turning to games: most people prefer playing over learning. Still, in a way, people always learn. In any day-to-day activity (higher) animals get feedback on their behaviour, leading to the selective modifications of neuronal connectivity (e.g. Hebb, 1949; Engel et al., 1991, Engel, Konig & Singer, 1991). In other words: they gain understanding and tend to change their behaviour to better adapt to the world around them or to mimic someone else. This is no different in play. During play, people perform new activities and learn the “rules” of the game. This type of learning is usually characterized as informal, incidental and unconscious. Serious gaming simply exploits this characteristic of play to help people acquire skills, knowledge, or attitudes by using computer games (live-simulations or virtual environments). The combination of learning, simulation, and play may explain the popularity of the concept of serious gaming. It fits in with modern theories of learning and instruction such as discovery learning (i.e., Gerven, 2003) and experiential learning. Such theories advocate an active, central role for the learner and using authentic (realistic, practical) learning environments that minimize the need for (human) guidance. Even though these approaches have received their share of criticism (e.g. Kirschner et al., 2006, Sweller et al., 1998) their attractiveness remains. They are often contrasted to traditional classroom education and are expected to increase learner motivation.

Serious gaming focuses at computer games that model certain aspects of reality with a didactical goal. As can be seen in Figure 1 this effort can be positioned at the heart of the three intersecting circles. The combination of these three elements is relatively new although overlapping areas of the circles have been explored earlier.

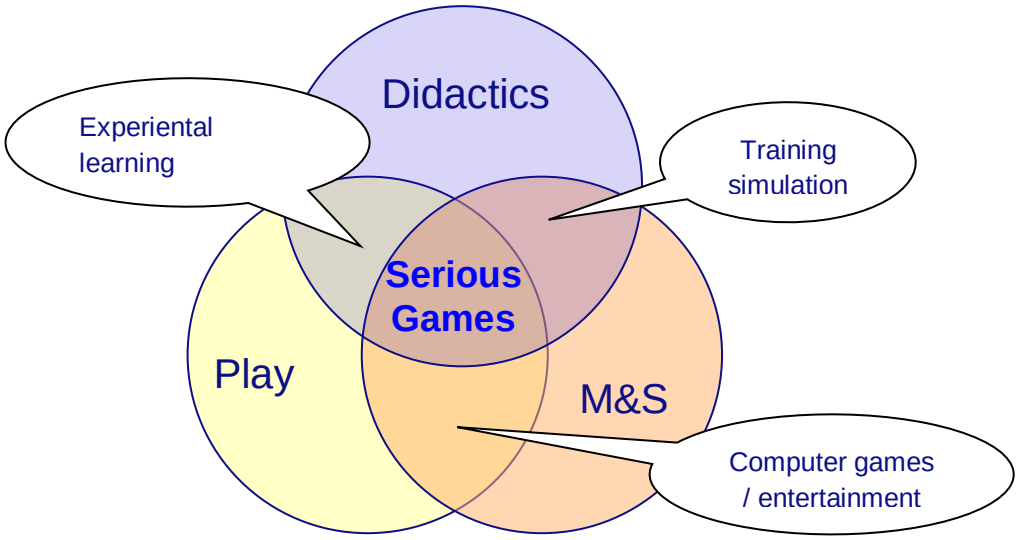

Figure 1 Three circles defining play, didactics, and modelling and simulation (M&S). At the respective intersection of each pair of circles we can distinguish between computer games for entertainment (Play / M&S); training simulation (Didactics / M&S); and new learning approaches (Didactics / Play).

Each of these circles (domains) presents its own perspective to the field of serious gaming and could be used as a starting point for writing a different text on the same topic. In the current document we will set out from the perspective of play. Following this introduction three sections (Chapter 2-4) will each cover parts of the interconnecting circles as depicted above. Central to Chapter 2 will be the questions 'what constitutes play' and 'why do we like to engage in games'. These will be discussed from a developmental psychological and evolutionary perspective. This is related, in Chapter 3 to motivation and individual differences. In this chapter we identify major influences in the internal and external motivation of people to undertake or like an activity. Chapter 4 describes modern insights into learning and education and a new educational approach that is relevant for serious gaming. Chapter 5 presents the topics of measuring the effectiveness and efficiency of learning in games (i.e. Transfer of Gaming, ToG) borrowing from knowledge built up in the areas of modeling and training simulation (validity, fidelity, transfer).
In addition, a task taxonomy is invoked showing that, serious gaming may allow people to learn many kinds of relevant skills, despite large differences between playing games and real tasks. The taxonomy can be useful to predict ToG, to design games and to evaluate games. In Chapter 6 we present a stepwise framework that can be used by game designers to design, specify and develop serious games from a didactical point of view. In the discussion and conclusions, we will wrap up these findings and relate them to the domain of serious gaming.

2 A functional view on play

2.1 Definitions

What constitutes play is not easily answered. According to Huizinga (1938) “play is an activity which proceeds within certain limits of time and space, in a visible order, according to rules freely accepted and outside the sphere of necessity or material utility”. Dewey defines play as ‘actions not consciously performed for the sake of any result beyond themselves’ (Dewey, 1910). However, many of us might disagree with such a definition when observing children being engaged in play: how much of their behaviour is to be identified as ‘not consciously performed for the sake of any result beyond themselves’? Children seem to use their play to establish the social status of different members of the group. Smith and Volstedt (1985) have attempted to define play by its most salient criteria, and found that flexibility, nonliterality and positive affect were most commonly used to define play. Other definitions may include aspects such as players, rules, goals (Smed & Hakonen, 2003.)

2.2 Function

Although trying to come up with a definition of play helps us to understand what play and playful behaviour is, it does not explain the function of play. Sutton-Smith (1997), in his book the Ambiguity of Play, proposes that play serves an evolutionary purpose, to introduce variability into behaviour patterns that are set once one is adapted to new environments. Furthermore, many scientists agree that play is paramount in the development of a child. It may be beneficial for development of language skills (Roskos & Christie, 2001), social skills (Howes, Unger, & Mathesen, 1992) or the development of the ‘theory of mind’ (Lillard, 1998).

There has been a longstanding debate on the function of play, and more specific, the role of play in learning. Play is hard to grasp. Wittgenstein (1953), for instance, refers to play as a ‘very confusing phenomenon, including a great variety of behavioural patterns’. The current popularity of games and especially ‘serious gaming’ shows a similar complexity. Some seem to suggest that games will provide the solution for all learning problems (e.g Prensky, 2001, Stapleton and Taylor, 2003), whereas others say that gaming can never provide real learning experiences (e.g.: *I would not like to be a passenger in an airplane with a pilot that learned flying in Microsoft Flight Simulator*, Cannon Bowers, 2005). In relation to learning, play can be considered as a developmental aid or catalyst in achieving a more advanced cognitive state, in which play is less useful (e.g. Piaget, 1951).
Some say that play primarily affords juveniles practice towards the exercise of later skills (Smith, 1982), whereas others state that the only thing play prepares you for is more play (Sutton, 1998). In the next chapters, we will approach potential value of games in learning from a more fundamental point of view, but first we will ask why we play in the first place.

The question why people play may have two answers (Chick, 1998). The first is that people play because there are certain endogenous or environmental stimuli that trigger playful behaviour. Play is fun, play is engaging, play triggers ‘flow’ (Csikszentmihayli and Csikszentmihayli, 1988), and it can be competitive and inspiring, as will be argued in the next chapter. The second answer is more related

to the playful behaviour itself. Why do we (and almost all mammals and birds) have playful behaviour at all? Why do we show this envelope of behavioural patterns in play and in gaming? The answer to that question is related to development and evolution: play may exist because playful behaviour has somehow evolutionary benefits to the species (e.g. Smith 1982, Poirier, 1982, Lewis, 1982). Evolutionary biologists have attributed numerous functions to play, which nearly all fall in three categories (Bekoff & Beyers, 1981, Fagen, 1981, Smith, 1982, 1995):

- play as physical training,
- play as social training,
- play as cognitive training.

Play seems to aid educational, developmental and evolutionary goals. Evolutionary biology also offers an explanation for the non- goal directed behaviour in play: i.e., a key processes generating random variation in behaviour (Gregory, 1987, p. 239). According to the evolutionary approach, play prepares the organism for physical, social or cognitive challenges it will face. The non-goal directed aspect of play may be useful to explore and possibly extend this behavioural envelope (e.g., a monkey may not be able to think through the cracking effect of a stone thrown on a nut, but may stumble upon this effect when 'just playing around' with some stones. This newly discovered strategy may be refined and/or generalized by 'useless' repetitions. So, playing is an important aspect in the development of an organism. This is supported by the finding that play behaviour peaked during periods of maximal cortical development (Chick, 1998, Lawick-Goodall 1968).

From the viewpoint of the development of the individual, there is debate on the function of play. For Piaget (1951) play helps to generate mental representations of the world and its objects, thus providing a means to develop abstract thought. In analogy, Leslie (1987) claims that play does not improve understanding of objects and events as such, but rather forms the beginning of a capacity to understand cognition itself. It is an early symptom of the human mind's ability to characterize and manipulate its own attitudes to information and the ability to understand someone else's attitudes to information, a competence that is called *theory of mind* (Premack & Woodruff, 1978). Support for these claims comes, among other things, from Leslie's studies of mental retardation and autism. These studies show that autistic children, even those with average IQs, do not display any form of pretend play. This is not the result of general mental retardation, since for example Down's syndrome children pretend play at a level that is expected given their mental age. In the absence of this specific form of play, autistic children do learn a suite of real world or practical skills. However, there is evidence to suggest that a large proportion of autistic children have a specific deficit in *theory of mind*, leaving them unable to comprehend or predict a lot of the behaviour of others (Leslie, 1987). Thus, apart from having a function in the cognitive development of a child, play also seems to be important in social learning. Ghiselin (1974) supports the social function of play but not from the perspective of social learning or any developmental theory. He suggests that play inhibits children to engage in genuine competitive interactions and thereby play supports peace within a group. Within this view, the seemingly dysfunctional aspects (e.g. loss of time and energy) of play that pose a problem for many other theories on the function of play, are apparently not dysfunctional but keep us from hurting each other (Ghiselin 1974, p. 261: "So long as everyone continues playing, nobody gets hurt").

The random aspects of playful behaviour are at odds with much of traditional learning theory. Siegler's (1996) model of cognitive development assumes that individual cognitive change is predisposed to operate through goal sketches that are limited to domains in which evolutionary history has specially prepared children to learn. Thus, play remains subordinate to the imbedded structural characteristics of preformed learning 'channels' (Myers, 1999). Whether imbedded or imitation, Chick (1998) stresses that play involves mainly behaviour patterns adopted from their usual context, derived from adult behaviour. Therefore, it may be that play generates random behaviour only within very limited boundaries. Within these boundaries play prepares the individual for many different functions. In their review of the hypothesized functions of play, Bekoff and Byers (1981) mention skill development, social bonding, learning, cognitive development, development of behavioural plasticity and problem solving. However, hard empirical evidence for any of the hypothesized functions of play is still scarce.

With the increase of mass education and structured learning, the significance of internally motivated playful behaviour for the individual's development may be diminished. Studies that have compared play with training for children in the 3 to 7 year age range show that, although training and play are equally effective, training can be much more efficient: 2 minutes of training a solution principle equalled 10 minutes of undirected free play with the same tools (Sylva, 1977). However, structured training and external goal-setting can have detrimental effect on the motivation of children and hence negatively affect learning. And there is also evidence that for some tasks, e.g. non standard and innovative tasks, play experience can be superior to training experience (e.g. Smith & Dutton, 1979).

3 Motivation and individual differences

In Chapter 2, we noted that there are two kinds of answers to the question why people play. One answer has to do with the evolutionary, developmental and social benefits play has for the species, as was concluded in Chapter 2. The other answer concerns the rewarding experiences and positive stimuli an individual receives during play. We will focus on these motivational aspects of games and play in the first section of this chapter. Then, we will discuss individual differences and how psychological characteristics may affect learning value of games.

3.1 Motivation and engagement

Games and playful activities can be fun, engaging, satisfying, exciting or challenging and motivate the player to continue their playful activities without any external values or real-world goals (i.e. intrinsically). Csikszentmihalyi (1999) calls this *autotelic* characteristic *flow*. Flow is described as a state of deep concentration and involvement in an activity. It is one of the most enjoyable experiences, and people report feeling active, alert, happy, strong, concentrated and creative during the experience (Csikszentmihalyi & LeFevre, 1989). Because of the intense, alert and concentrate nature of flow, it may be expected that, when a subject is in a state of flow, his brain is active showing a high degree of metabolism. Since brain activity leads to changes in structural neuronal interaction patterns and connectivity, we suppose that flow enhances learning processes. Flow can be experienced during many activities, such as work, play, car driving, or exercise. Flow theory predicts that experience will be most positive when a person perceives that the environment contains high enough opportunities for action (or challenges), which are matched with the person's own capacities to act (or skills). Other theoretical approaches to intrinsic motivation such as the cognitive evaluation / self-determination theory (Deci and Ryan, 2002) or the eudaimonistic theory (Waterman, 1990) also recognize the importance of balancing the (relatively high) challenge of an activity and the skill level of the individual (Schwarz and Waterman, 2006). According to the theory of cognitive evaluation/self determination theory, two important predictors of intrinsic motivation are the fact that an individual perceives the activity as chosen (i.e. self-determined) and feels successful in carrying out the activity. The eudaimonistic identity theory builds on and incorporates elements from cognitive evaluation / self-determination theory and the flow theory. Beyond the self-determination and the balancing of challenge and skills, the theory posits that self-realization values serve as an additional important predictor of intrinsic motivation. Self-realization is understood as the activity of people to strive to realize their best potential.

These theoretical approaches offer an explanation as to why activities may or may not be intrinsically motivating because they account for individual differences in experiences (why do some people find some activities intrinsically motivating and others not?) and for changing interests of the individual throughout time. However, although intrinsic motivation exists in the nexus between the person and the task, there is considerable practical utility in focusing on task properties and their potential intrinsic interest, as it may lead to improved task design to enhance motivation (Ryan and Deci, 2000). Flow theory cannot help us in that respect: the challenges of the task should be matched with the individual's skill level, hence,

a need to focus on both task and person. And also the eudaimonistic theory leads us to focus on the person instead of focusing on task aspects. However, the cognitive evaluation theory / self-determination theory does lead to task oriented opportunities to enhance intrinsic motivation. The theory predicts that interpersonal events and structures (e.g. rewards, communications, feedback) that conduce toward feelings of competence and autonomy will enhance intrinsic motivation. Thus, positive performance feedback enhances intrinsic motivation, whereas negative performance feedback diminishes it. However, care must be taken with giving feedback: especially the role of rewards in shifting the locus of control from internal to external has been much debated. A recent meta-analysis confirms that virtually every type of expected tangible reward, but also threats, deadlines, directives and competition, undermine intrinsic motivation (Ryan, Koestner and Deci, 1999) because people experience them as controllers of their behaviour. On the other hand, choice and the opportunity for self-direction appear to enhance intrinsic motivation, as they afford a greater sense of autonomy.

Although intrinsic motivation is clearly an important type of motivation, most of the activities people do are motivated by (external) demands or rewards. This is what we call extrinsic motivation: an activity is done to attain some separable outcome. Ryan and Deci (2000) view extrinsic motivation as a continuum from external regulation to integration. Externally regulated behaviour depends on the demand and control of other people, the environment and other extrinsic factors. The other side of the continuum is the most autonomous form of extrinsic motivation: integration. This occurs when identified regulations have been fully assimilated to the self through self-examination and bringing external regulations and demands into congruence with one's own values and needs. This type of behaviour shares many of the qualities with intrinsic motivation, such that a person feels self-determined and engaged, however, the difference is that the behaviour is undertaken to reach an external goal.

Considering successful entertainment games we can reason why people feel motivated to play. These games pose a high challenge for skilled gamers (flow), they let the gamer control the course of actions (self-direction) and through web-based fora it is possible for gamers to compete and compare with others and build a social network (self-realization). However, when we choose to apply games for educational purposes, we may place external goals and demands on the players, thereby diminishing their intrinsic motivation. Not communicating these goals would be one way to avoid this, but from an instructional perspective, this may be inefficient. As Farmer et al., (1999) states: learners should be informed on the purpose and end terms of a training program.
It is then important to focus on minimizing the detrimental effects of external demands on the one hand, while still obtaining learning goals on the other hand. One way to accomplish this is to design a game where the goals of the game are similar to the learning goals. In that case, the rules of the game reflect the learning content and the external demands on the player can be minimal. This is the approach that is usually adopted in training trajectories in which training simulators are used. However, in training simulation, the "game" is not primarily based on (attractive) play, but on the (serious) training goals. It would therefore be better to turn the approach around and base serious games (or training simulations) primarily on game goals. Based on this approach learners may experience an intrinsic motivation to play. However, this approach makes it rather difficult to create a match

between learning goals and game goals. Most games, therefore, are often only a vehicle to transfer other knowledge or skills and the game rules and goals do not directly represent the learning content. Nevertheless, it is the major challenge for the serious game designer to build, within the constraints of the learning objectives, a virtual playground that complies to the characteristics of play and internal motivation. This means the creation of a sense of autonomy for the player, letting him choose his or her own player level. In addition, game specific features such as environment, the look, feel and behaviour of other entities, competition levels, playing with the rules, etc. should challenge to play, whereas the underlying rules (models) should match the training goals.
A feature that requires specific attention is the set of game rules: to have them being manipulated by the player may promote the player's understanding of these rules, value their worth, and provide a sense of autonomy. However, if these rules are the learning content and the trainee is inexperienced, by manipulating the rule set he or she may change the game in such a way that the game no longer serves any educational purposes. Thus, manipulating a rule set can only be permitted in certain cases.

3.2 Individual Differences

People can vary on a range of psychological attributes. These attributes are different in their content, their scope and their robustness. There exist many psychological tests that aim to measure for example behavioural attributes (e.g. risk taking behaviour, sensation seeking), cognitive styles (sensor modality, information processing and sensemaking strategies), and learning styles (preference for instruction method, content presentation, feedback) (Jonassen & Grabowski 1993). These tests may be used to predict which characteristics make a person succeed in what types of jobs, professional environments or social networks, or explain why some people are better at coping with misfortune. Similary, there may also exist differences in the learning value of a game for different types of individuals. However, lack of validation data leaves only few questionnaires to be used to investigate any relationships between characteristics of the individual (learning style) and the learning value of games. We have selected a questionnaire that may reliably and validly identify a person's learning style: Kolb's learning style inventory (Kolb, 1985; Willcoxson & Prosser, 1996) and we aim to investigate whether individual learning style may be a good predictor of gaming as preferred learning tool for individuals.

3.2.1 Kolb's Learning Theory

Kolb's learning theory sets out four distinct learning styles (or preferences), which are based on a four-stage learning cycle. In this learning cycle, immediate or concrete experiences (stage 1) provide a basis for observations and reflections (stage 2). These observations and reflections are assimilated and distilled into abstract concepts (stage 3) producing new implications for action which can be actively tested (stage 4) and in turn create new experiences.
The learning style preference is the product of two pairs of variables, or two separate 'choices' that we make: (1) we choose a way of grasping the experience, which defines our approach to it, and (2) we choose a way to transform the experience into something meaningful and usable, which defines our emotional response to the experience.

In other words we choose our approach to the task or experience by opting for 1(a) or 1(b):

- 1(a) - through watching others involved in the experience and reflecting on what happens ('reflective observation' - 'watching') or
- 1(b) - through 'jumping straight in' and just doing it ('active experimentation' - 'doing')

And at the same time we choose how to emotionally transform the experience into something meaningful and useful by opting for 2(a) or 2(b):

- 2(a) - through gaining new information by thinking, analyzing, or planning ('abstract conceptualization' - 'thinking') or
- 2(b) - through experiencing the 'concrete, tangible, felt qualities of the world' ('concrete experience' - 'feeling')

	Doing (Active Experimentation - AE)	**Watching (Reflective Observation - RO)**
Feeling (Concrete Experience - CE)	**accommodating (CE/AE)**	**diverging (CE/RO)**
Thinking (Abstract Conceptualization - AC)	**converging (AC/AE)**	**assimilating (AC/RO)**

- **Diverging (feeling and watching - CE/RO)** – People with a Diverging learning style prefer to watch rather than do, gather information and use their imagination to solve problems. They have broad cultural interests and like to work in groups. They are interested in people, tend to be imaginative and emotional, and be strong in the arts. Kolb called this style 'Diverging' because these people perform better in situations that require ideas-generation, for example, brainstorming.
- **Assimilating (watching and thinking - AC/RO)** – People with an Assimilating learning preference prefer a concise, logical approach. They excel at understanding wide-ranging information and organising it in a clear logical format. They are less focused on people and more interested in ideas and abstract concepts, furthermore, they are more attracted to logically sound theories than approaches based on practical value. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.
- **Converging (doing and thinking - AC/AE)** - People with a Converging learning style prefer technical tasks, and are less concerned with people and interpersonal aspects. Furthermore, they are best at finding practical uses for ideas and theories, and they tend to be technical specialists. People with a Converging style like to experiment with new ideas, to simulate, and to work with practical applications.

- **Accommodating (doing and feeling - CE/AE)** – People that have an Accommodating learning style prefer 'hands-on experience', and rely on practical intuition rather than on logical analysis. They use other people's analyses, and prefer to take a practical, experiential approach. Furthermore, they are attracted to new challenges and experiences. This learning style is prevalent and useful in roles requiring action and initiative. People with an Accommodating learning style prefer to work in teams to complete tasks in the field.

The aim of the next section was to investigate whether or not an individual learning characteristics may be a good predictor of gaming as preferred learning tool for individuals. We did so by investigating if a group of gamers, in this case Falcon IV gamers (a multiplayer flight simulation game) exhibit a similar learning style, which may be indicative of games being an appropriate tool for people preferring this learning style. The aim of the study of individual differences is to measure those attributes and to explain or predict behaviour. The *accommodating* learners will be most attracted by multiplayer role-playing games, hence, it is hypothesized that in our group of Falcon IV gamers this learning style will be most prevalent. Furthermore, we hypothesized that people that have an *assimilating* learning style preference will be least attracted by games, and thus we do not expect to find this learning style preference in our group of gamers.

Method

Participants
Eight men who frequently played the Falcon IV game, participated in this questionnaire study. Their age varied from 29 to 55 (M= 42.3, SD=7.3). They had 4 to 7 years (M=5.5, SD=1.4) experience playing the Falcon IV game and played 1 to 25 hours a week (M=7.4, SD=5.0). Their general experience with flight simulation ranged from 4 to 15 years (M=12.8, SD=5.3).

Procedure
The session with 8 participants lasted about half an hour. Before participants started with the Kolb learning styles questionnaire (Kolb, 1985), they were informed about the purpose of the study, and signed a consent form.

Results and Discussion

Learning type style	Number of participants
Accommodating	2
Diverging	2
Converging	2
Assimilating	2

Contrary to our expectations, the results show that all learning styles were evenly represented in the group. We had expected that in our group of participants the *accommodating* learning style would be most prevalent and the *assimilating* learning style would be absent. However, the group of gamers as a whole did not show a preference for a particular learning style. This may be due to the small group, and this small group containing very heterogeneous gamers in terms of age and specifically hours of gaming per week. Based on this exploratory result,

we cannot identify a specific learning style preference for which games may serve as adequate learning tools.

3.3 Conclusion

In this chapter we have identified competence, autonomy and self-realization as the three major influences in the internal motivation of people to undertake or like an activity. In addition, we have described external conditions that may affect a person's feeling of autonomy and competence such as rewards, feedback, meaningful goals and rules. This helps us understand why people like to play games and when we use games for educational purposes, it is important to consider these conditions. However, it is also important to establish whether games may serve as valuable learning tools for everyone, or whether there exist individual differences in the learning value of games. Therefore, in the second part of the Chapter we described a small exploratory study on learning style preference in gamers. Unfortunately, due to the limited number of subjects used, we were not able to link a specific learning style to a preference for (learning from) games. It is still conceivable that (serious) gamers, as active exploring and experiental individuals, will show a similar, more *accommodating*, learning style fitting with that preference.

4 Didactical aspect of serious gaming

The popularity of games for education and training can be ascribed to their immersive and motivating qualities, but is also the result of the opportunities that games present for providing different and better ways of training. This chapter discusses the benefits of games in terms of learning value and continues with presenting a new training approach that capitalizes on the possibilities games provide.

4.1 Introduction

In the traditional "instructor-centered" situation the instructor is dominant and the learner, more or less passively absorbs ("lean back") the abstract information presented by the instructor who stands in the centre of the attention. It is now conjectured that learners prefer to participate actively during classroom lessons in a more "lean-forward" style. This has led to *constructivistic* views on learning and teaching, which are based on more active participation of learners, such as *action learning*, *discovery learning*, *competence-based instruction*, *experiental learning*. The specific interactive characteristics of computer games seem to fit well within these educational conceptions and thus are supposed to be very useful for modern educational purposes. With regard to transfer of gaming a major question concerns how these computer games should be optimally used in order to benefit maximally from their educational potential.

A major aim of educational and training programs is to foster learning and transfer. Learning is understood as the observable and enduring change in knowledge or behaviour as a result of experience (Skinner, 1950; Thorndike, 1910).
This definition of learning incorporates both learning as a process of change and the outcome of that process: the durable change in knowledge or behaviour (Alexander, Schallert, & Reynolds, 2009). Transfer can be defined both in terms of the ability to flexibly apply (parts of) what has been learned to new tasks and/or new situations (see e.g., Detterman & Sternberg, 1993; Mayer, & Wittrock, 1996), as well as in terms of preparation for future learning (Bransford & Schwartz, 1999). To optimize learning and transfer, 1) learning tasks should reflect the relevant functional aspects of the to-be-performed real-world tasks (Korteling & Sluimer, 1999), 2) the learning environment should represent many relevant features that may help to encode the new information or may serve as retrieval cues for subsequent remembering of this information (Smith & Vela, 2001), 3) scheduling of learning tasks and feedback should create a level of 'desirable difficulty' for the learner (Bjork, 1994) or practice in the zone of proximal development (Vygotsky,1978) and 4) the learner should be facilitated to reflect on his/her learning and self-explain his/her strategies (Aleven & Koedinger, 2002; Chi, 2000; Schworm and Renkl, 2007). Apart from learning content related knowledge and skills, many training en educational programs also focus on teaching learners how to become self-directed or self-regulated learners (Knowles, 1975; Stubbé & Theunissen, 2008; Van Merriënboer & Kirschner, 2007; Zimmerman, 1990). When new technologies, innovative operational concepts, or other changes emerge, they should be able to take initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material

resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes (Corno, 1986, Ghatala, 1986).
This self-directed learning perspective has profound implications for the way instructors interact with learners, and the manner in which the learning environment should be organized (Zimmerman, 1990). The control over planning the learning trajectory, monitoring performance, assessing performance will shift from instructional agents (e.g., coach, mentor, computer system) to the learner (Van Merriënboer & Kirschner, 2007). And the learning environment should be flexible and adapt to the developing level of ability of the individual learner.

The conception of learning as described above is also consistent with what we know about the basics of neuronal development and the functioning of the brain (e.g., Hebb, 1949; Korteling, 1994). Also from a neurological standpoint the passive conception of learning will fail in certain ways. Knowledge and skills are embodied in the way neuron's in the brain are connected and interact with one another. Learning then, is the acquisition and development of memories, behaviour and skills by the constant refinement and expansion of these connections, i.e. the existing personal neuronal framework. Because the way the neurons connect is different for each individual the learning process should be tailored to fit each individuals framework. In a classroom full of learners, this is usually impossible. The quantity and quality of neuronal changes in the brain, and thus the learning results, will therefore be optimal when the learners are actively involved in the process of integrating new knowledge. In other words: when they are stimulated to actively link new information (i.e., new connections) in their personal neuronal framework.

Piaget (1950) called these processes assimilation and accommodation. Individuals construct new knowledge from their experiences. When individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. In contrast, when individuals' experiences contradict their internal representations, they may change their perceptions of the experiences to fit their internal representations. According to the theory, accommodation is the process of reframing one's mental representation of the external world to fit new experiences.

4.2 Job Oriented Training with serious games

Games may create dynamic, interactive and rich learning environment in which functionally relevant tasks need to be performed that offer the opportunity for memorization, practice and forming elaborate cognitive structures (Piaget, 1950) or schema's (Bartlett, 1932). They can be adapted to the individual learning needs and ability levels of learners, thus offering relevant tasks at a level of desirable difficulty to enhance (self-directed) learning and transfer.

However, not all instructional, or serious games seem to live up to their potential. Hays (2005) has reviewed 48 empirical research articles on the effectiveness of instructional games. This report also includes summaries of 26 other review articles and 31 theoretical articles on instructional gaming. For the present purposes, we suffice with presenting the major conclusions and recommendations of their report.

Conclusions: (1) The empirical research on the instructional effectiveness of games is fragmented, filled with ill-defined terms, and plagued with methodological flaws. (2) Some games provide effective instruction for some tasks some of the time, but these results may not be generalizable to other games or instructional programs. (3) No evidence exists that games are the preferred instructional method in all situations. (4) Instructional games are more effective if they are embedded in instructional programs that include debriefing and feedback. (5) Instructional support during play increases the effectiveness of instructional games. Recommendations: (1) The decision to use a game for instruction should be based on a detailed analysis of learning requirements and tradeoffs among alternative instructional approaches. (2) Games should be used as adjuncts and aids, not as stand-alone instruction, therefore instructor-less approaches (e.g., web-based applications) must include all "instructor functions."

These conclusions and recommendations of Hays (2005) emphasize the significance of the didactical context of a serious game. This is in line with research results of TNO Human Factors on the use of serious gaming for military training (Stehouwer et al., 2005, 2006, Hulst van der et al., 2008). Based on this experience and on the aforementioned theoretical conceptions of learning TNO Human Factors has developed a new training approach that specifically capitalizes on the possibilities and limitations of serious gaming. This new training method focussing on effective use of (computer) games is called Job Oriented Training (JOT).

Conventional training usually starts with theoretical sessions. Next, procedures and basic skills are practiced. Often, the first chance to practice the task is on the job. The instructor is in control. He knows the next step and the relevance of all parts. Learners apparently are supposed to learn mainly through the activity of the instructor. JOT focuses more on the *Job* itself, i.e., practice sessions guided under the supervision of one or more experts (Stehouwer et.al., 2005, 2006). Instead of a central role of the instructor, the learners are active in solving problems in authentic training scenario's.

Characteristics of a JOT approach are:

- Practice precedes theory. Given the discovery learning approach in JOT, no theory is provided in advance of the gaming sessions. The learner receives minimal instruction beforehand from the instructor. The basic idea is that the learners gradually develop the cognitive structures to understand and memorize the theory essential to the job.
- Active learning: the learner is challenged to actively contribute to the learning process. He or is put into a concrete, realistic scenario with authentic problems that have to be solved.
- Challenging and integrated task training. With progressing ability, training scenarios evolve from simple to more integrated and complex, presenting learners with an adequate level of difficulty in relevant job-related problems.
- Cooperative learning. Plans are made and problems are solved in collaboration with peers. By having learners work together with their peers they are forced to explain themselves and be clear about the motivations of their decisions.
- Reflective learning. To maximize the effectiveness of the training, learners have to reflect on their courses of action afterwards. Thus, learners are forced to share their experiences and, more importantly, get the opportunity to conceptualize the most relevant information or critical cues. After the reflection,

the instructor can comment on the courses of action taken and if necessary give his opinion on the conclusion drawn by the learners during their reflection. He can also point out if certain relevant cues are missed.

The characteristics of JOT are relatively easy to implement together with serious games. For example, the synthetic environments and scenario's that can be built with games enable instructors to provide realistic and authentic training scenario's in a classroom setting. Because the military is "the avant garde" in the use of serious games compared to other domains such as crisis management or medical training (Michael & Chen, 2006), JOT has been implemented and evaluated into several military courses. An example is the training of new platoon squad leaders of the Royal Netherlands Army; in this training program, the game Virtual Battle Space 1[1] is implemented and used according to JOT principles. Learners play several scenarios in multiple sessions over multiple days. Each individual scenario has a certain training goal and is developed specifically for this goal, with increasing complexity over sessions. Thus far, reactions of the learners and training staff are very positive and enthusiastic (Hulst, Muller, Besseling, Coetsier, 2008). At present, a more quantitative validation study is carried out in the training program of operators of submarine mine sweepers.

The pilot studies described above in which a game is embedded in a training program according to the JOT principles demonstrate the importance of completely reorganizing training programs and methodologies, utilizing all possibilities provided by the new technology. The JOT approach for developing a training program entails the following focus points:

Focus on the responsibility of the job
In JOT, high-level training objectives, i.e. competences, are defined in terms of meaningful tasks in a realistic context. The desire to feel competent is the motivator. People set a goal and try to achieve it. In this process they try to make sense of the world. This structuring and "sense making" process contributes to learning. In a JOT course, the learner starts practicing the job on day one. This first experience should give him a good overview of his new responsibilities. For example on the experience of performing a simplified version of the job, the learner can form a picture of what he was hired for. Good job performance is only possible with a clear idea of what is expected.

Challenge and practice in a relevant reality
The JOT methodology emphasizes that training should focus on practicing job related skills in a realistic and rich environment that provides learner with (realistic) information on the effects of his /her behaviour. Thus, learners form mental representations of the learning tasks that are elaborate and relevant for their job. Also, by providing learners with insight in what tasks their new job comprises, they will recognize the relevance of their practice and be motivated to put effort into it. Very often, however, reality itself is too complex and too probabilistic in nature to create a meaningful learning environment. A game may represent the dynamics and interactive nature of the real world, but use scaffolding techniques (augmented cues, AI) to provide support or feedback to the learner about the effects of her/his behaviour.

[1] Virtual Battle Space is published by Bohemia Interactive Studios.

The challenge of training cognitive complex tasks
In JOT the task is trained as a whole. This is termed integrated task training. Everything (knowledge, procedures, skills, problem solving) are trained in the context of performing the job in a realistic environment. The challenge is to set up a *curriculum of growing competence*, presenting high-level training objectives in terms of job performance, gradually making the task more complex, offering appropriate challenges all the time and providing clear feedback. The job is performed under circumstances of growing complexity and setting higher performance standards. The learner thus gets the opportunity to grow into his job (which, of course, is not really new in instructional design).

4.3 Conclusion

Games may provide meaningful and valuable learning environments if they are embedded in a training program that optimally exploits their opportunities and offers didactical environment that is congruent with the game features. JOT offers such a didactical approach: its focus on realistic, authentic practice can enhance learning value of games and increase learners' motivation to practice.

5 Transfer of Gaming

In the previous Chapter, we discussed why games may offer a valuable learning experience, and how they can be embedded in a training program so as to maximize its value. In the current Chapter, we will focus on training value and how transfer can be measured. We introduce the key concepts, describe methods for measurement, the metrics, and some limitations of such a quantitative methods.

5.1 Introduction

In the domain of simulation, synthetic- or virtual environments, the concepts of training effectiveness and efficiency are captured in the term transfer. Conform Paragraph 4.1, Transfer denotes the ability to flexibly apply (parts of) what has been learned to new tasks and/or new situations, i.e. real world tasks (see e.g., Detterman & Sternberg, 1993; Mayer, & Wittrock, 1996), as well as in terms of preparation for future learning (Bransford & Schwartz, 1999). In line with similar definitions provided by Baldwin & Ford (1988) and Gielen (1995) for Transfer of *Training*, we define Transfer of *Gaming* (ToG) as:

The degree to which knowledge, skills and attitudes that are acquired by playing a game can be used effectively in real (operational, professional) situations.

As such it is an important concept in determining training value. However, it can be difficult to determine what exactly is learned with respect to the (real) task or domain for which the training is intended. Transfer studies are complex and sometimes even impossible because the real-world situations do not permit the objective measurement of performance of former learners. And even when these real world measures can be collected, it remains questionable to what respect the training has contributed to that performance level, and to what respect performance and performance differences can be attributed to other factors. However, it is possible to get a reasonable insight in the Transfer of Gaming, or training value of games, by means of smart experimental designs.

5.2 Key concepts

It is generally conjectured that similarity between a synthetic world (simulation) and the real world results in transfer; that is: higher degrees of similarity lead to higher transfer (Korteling & Sluimer, 1999). The degree of similarity between a synthetic environment and reality is called *fidelity*. Fidelity denotes to what extent a simulation mimics the real equipment and environment in terms of physical measurable characteristics i.e. does a game steering set mimic the real world vehicle in such a way that the forces experienced during game play are the same as in the real vehicle. For most games the physical environment in which a person has to operate does not match that of the real world. It is therefore said that the fidelity of games is relatively low compared to for instance simulators on which normally mock-ups are used to mimic real world operator environments. However, it is not easily defined to what extent the fidelity of subsystems of a simulation contributes to the experience of realism (Roza, 2005). The graphics and animations of a game for example may be very realistic; however, if the behaviour of the entities is not realistic, the game will not ‘convince’ or attract the player. On the contrary, a simulation of an aircraft

made from plywood and photographs stuck on cardboard can be experienced as very realistic (Prophet & Boyd, 1970) depending on the goals that have been set.

Another important concept that needs to be clarified in this light is *validity*. It will be obvious that no game or simulation will copy all facets of the real world with high fidelity. Fidelity is not a strict necessary prerequisite for being valid. According to Garcia and Turner (2006) a product (simulation) is *valid* if it fulfils its intended use when placed in its intended training program. To clarify this - again using the example of flight simulation - some simulator applications might require an exact replica of the cockpit with realistic look and feel of all controls. Others might need only a generic cockpit, but require high fidelity aircraft behaviour. As long as transfer of training is obtained for those task aspects that are intended to be trained, a simulation is valid. Hence, in a training context, validity is always coupled to training goals. This even may sometimes require deliberate deviations from fidelity (Allessi, 1988; Van Emmerik, 2004).

5.3 Measurement

The differences between serious gaming and training simulation are easily named but it is hard to draw a clear-cut boundary to distinguish between them. Generally speaking, a game will usually be limited to a PC (like) environment whereas training simulations may comprise large mock ups, sophisticated visual-, auditory- and motion cueing facilities and complex, realistic interfaces. Furthermore, training simulations are designed to train people, while most games primarily are meant to entertain. Therefore, a training simulation will have dedicated tools for scenario generation and evaluation of human performance, whereas a game only provides rudimentary tools, e.g., for scenario management and performance measurement. Neither of these characteristics, however, is necessarily linked to gaming or to training simulation. Because they actually can be seen as two different positions on a continuum, much of the literature related to transfer of training with all kinds of synthetic environments could be applied to serious games as well. At least, the same approaches could be followed to determine Transfer of Training. Analogous to this we could then instead speak of Transfer of Gaming.

Morrison and Hammon (2000) describe three different main approaches for determining effectiveness of simulations: surveys; experiments and quasi-experiments; and training analysis.

- Surveys are often used for obtaining user reactions about efficacy. They are generally easy to administer and yield lots of (potentially) valuable data. On the dark side, however, this research strategy is prone to biases and subjectivity. Therefore, this topic will not receive further attention here.
- The experimental approach fits in the tradition of performance based research and as such combines empirical data from a realistic context with statistical techniques. Its advantages and challenges will be elaborated in the next paragraph.
- Training analysis is a way to estimate training efficiency by means of analytical models. Usually this involves forecasting or estimating (i.e., nonempirical data). Analytical methods are not widely accepted because they are highly complex, costly, and time consuming. Furthermore, they often require substantial (empirical) data input about efficiency and effectiveness to facilitate reliable predictions. Hence, for the current purpose we do not consider them further.

5.4 Experimental designs

In their now-classic book on experimental design, Campbell and Stanley (1963), extend the concept of validity to research design. In an overview of 16 research designs, they distinguish between the degree of experimental control (from fully controlled laboratory research to so-called 'quasi-experiments'. Generally, they contend that a strictly controlled experiment permits strong inferences about the effects (high internal validity). However, the degree to which these results can be generalized will be lower (low external validity). While quasi-experiments may be susceptible to threats of internal validity (because of less rigorous control), they allow the researcher to apply a more realistic context and thus have a higher external validity (i.e., better generalization to operational settings). A number of these designs are clarified below.

Experimental-versus-control-group method
The experimental-versus-control-group method uses a design in which the experimental group is trained with the game and the control group is trained on real-task equipment only. Afterwards task performance is measured on real task equipment on a predetermined criterion task. The experimental-versus-control-group method is generally thought to be the most appropriate study design to determine whether game training has improved subsequent real-life performance (Caro, 1977).

Pre-existing-control-transfer method
There are instances in which a concurrently trained control group might not be necessary. For instance: a game is introduced in an existing training program. Learner performance data from the older or on a predetermined criterion task can be compared to data of performance by the new experimental group who trained with the game. This method is called the pre-existing-control-transfer method.

Uncontrolled-transfer method
There are also circumstances where no control group exists. Such a condition can occur when safety plays a role e.g. forced landing by an airplane. When no control group can be formed, game training effectiveness can be established by determining whether subjects can perform the learned task on a real-life system the first time they perform this task. This is called first shot performance. Data collected from such studies will be suspect, since it cannot be conclusively shown that game training has had any effect on the real task operations performed by the subjects (Caro, 1977). This method is called the uncontrolled-transfer method.

Quasi-Transfer-of-Gaming method
Because of efficiency (or financial) reasons a method often applied in validation of game training is the Quasi-Transfer-of-Gaming method (QToG). The difference between the experimental-versus-control-group method and the QToG method is that in the former real-task training occurs while in the latter it does not.
The experimental group(s) get(s) game training. The control group exists of experts who daily work with the real task equipment. Eventually both groups are evaluated on a criterion task with the game. The difference in performance reveals the relative contribution of the game on the effectiveness of game training.

Backward transfer method
In a backward transfer study, an operator, who has already shown sufficient performance on the relevant task, has to play the game. If he can perform the task at hand backward transfer has occurred. The assumption here is that transfer of gaming in the other direction (forward transfer) for learners playing such a game will also occur.

Simulator-performance-improvement method
The simulator-performance-improvement method resembles an equivalent time samples design. Each training session, the performance of a learner is measured. An essential premise of an effective game training program is improvement in performance by the learners over several sessions of training. If this does not occur, there would be little expectation of improvement in executing the real task. However, the existence of learning does not necessarily mean that what is learned is relevant (and thus transfers) to the real task environment.

5.5 Quantitative transfer of training measures

Quantitative measures have been introduced to quantify transfer of training, mainly by Roscoe (Roscoe & Williges, 1980). These measures can be adopted for the use of transfer of gaming. In experiments using these measures an experimental group is trained with a game. After a certain period the group receives additional training on the real task until the real task performance of this group reaches a predetermined criterion level. The time needed for the experimental group to reach the real task performance on this criterion is then compared to the time needed by a control group, who has been trained on the real task only. The basic computation for **%T** (Percentage of transfer) is:

$$\%T = \frac{T_c - T_e}{T_c} \times 100\% \qquad \text{(Equation 1)}$$

where:

- T_c Time needed for on-the-job training by a control group to reach the criterion level
- T_e Time needed for on-the-job training by the experimental group after training with a game

From equation 1 it can be derived that when **%T** of a given game training program is 100% no additional field training is needed by the experimental group to reach the same criterion performance as the control group. When T_e increases, **%T** decreases, hence when **%T** is 0% training with the game does not produce any effect. **%T** can even become negative. This means that training with the game interferes with acquiring the necessary skills for executing the real task (Korteling, van den Bosch & van Emmerik, 1997).
For (expensive) training simulators, this percentage of transfer formula has a big flaw, as it fails to consider the previously provided amount of practice with the game by the experimental group. Because the percentage of transfer formula does not consider the amount of game training prior to on-the-job training it permits no conclusions about the effectiveness of the simulator as a training tool (Roscoe & Williges, 1980). However (and fortunately), this flaw is much less relevant for gaming since gaming is considered cheap, entertaining and (therefore) mostly done in spare time of during leisure.

An adequate measure, which reckons with the time spent in the simulator, is the Transfer Effectiveness Ratio (TER) or graphically the Cumulative Transfer Effectiveness Function (CTEF). The computation for TER is:

$$\mathbf{TER} = \frac{\mathbf{T_c - T_e}}{\mathbf{T_s}} \qquad \text{(Equation 2)}$$

where:

$\mathbf{T_c}$ Time needed for on-the-job training by a control group to reach the criterion level

$\mathbf{T_e}$ Time needed for on-the-job training by the experimental group after completing game training

$\mathbf{T_s}$ Game training time by the experimental group

A TER of 1.0 indicates that time savings for training the real task are equal to the amount of time spent playing the game. When TER is larger than 1.0 ($T_s + T_e$ is smaller than T_c) game training is more effective than training on the real task. When TER is lower than 1.0 the real task training is more effective. This does not necessarily mean that game play has little added value or that it is inefficient for training. Game training can still be very beneficial for a number of reasons:

- Game training may be less costly than training with real equipment.
- Game training may be less dangerous than training with real equipment.
- Game training may be preferred because of environmental issues.
- Game training gives the possibility of training under certain relevant conditions that rarely occur in real life such as emergency situations (Korteling, van den Bosch & van Emmerik, 1997).
- Game training allows the application of more effective instruction facilities such as performance measurement and feedback systems or record and replay systems.
- Gaming may result in an increased motivation that will boost efficiency of real life training or simulator training.
- Game playing me be done in leisure time, which makes it very cost-effective.

One should keep in mind that there is a maximum on the transfer of gaming. Mostly not all skills needed on the real task can be trained with the use of a game. Therefore TER is a negatively decelerated function of the game training time.

A measure for expressing the effectiveness of financial training cost has also been developed, because game training in general is less costly then real task training. It is expressed via the Cost Effectiveness Ratio (CER), which is a ratio of TER and the Training Cost Ratio (TCR). The computation for TCR is:

$$\mathbf{TCR} = \frac{\mathbf{C_s}}{\mathbf{C_c}} \qquad \text{(Equation 3)}$$

where:

$\mathbf{C_s}$financial cost of game training (per time unit)

$\mathbf{C_c}$financial cost of control group training (per time unit)

The formula for the CER is as follows:

$$\mathbf{CER} = \frac{\mathbf{TER}}{\mathbf{TCR}} = \frac{\mathbf{C_c\,(T_c - T_e)}}{\mathbf{T_s \times C_s}} \quad \text{(Equation 4)}$$

For different duration's of game training, CER, TER, as well as %T will change. A small fictional example will illustrate this:

A control group needs 20 hours of on-the-job training to reach the predetermined criterion level on a given task. After completing 8 hours of game training an experimental group only needs 16 hours of additional on-the-job training to reach the criterion level. In that case:
%T = 20%
TER = 0.50

Suppose that operating cost of game training has been figured out to be 15% of costs associated with the real-task equipment.
TCR = 0.15
CER = 0.50/ 0.15 = 3.33

If in another situation only 15 hours of additional on-the-job training are needed if the experimental group gets 11 hours of game training.
In that case:
%T = 25%
TER decreases to 0.45
CER = 0.45 / 0.15 = 3

Cost-effective training can be achieved with CER values above 1. For a CER smaller than 1, game training might still be effective for safety, or environmental reasons. To calculate safety or environmental ratios would require the availability of data and models estimate accident probabilities and / or damage to the environment. These could be quantified, in a similar vein as insurance companies translate risks into financial consequences.

5.6 Limitations of the quantitative measurements: Capturing indirect training value

Regardless of these attempts to capture efficiency of games in a metric, there is (anecdotic) evidence that playing a game might increase training efficiency through another mechanism: *motivation*, or rather, flow or engagement. As described in Chapter 3, flow is a state of deep concentration and involvement in an activity during which the player is motivated to continue his playful activities without any external values or real-world goals. In other words, the act of gaming in itself becomes rewarding for the player. This implies that a 'flow-generating' game with (some) educational value can boost training effectiveness.

Consider the following example: in a tank gunnery training, a Space Invaders[2] game is implemented as a bonus scenario. This requires the learners to perform their training tasks at ever increasing speed. As they like to play the Space Invaders game so much they are willing to spend their own time in the simulator and improve their skills beyond the training goals. It is also imaginable that players become so

[2] A TAITO Corporation publication.

involved in a game that they start to explore other information or task elements related to the domain the game is set in. Something like this seems to have happened within the Falcon 4.0 [3]community where some of the more fanatic players are known to actively search into literature about fighter pilot tactics, manoeuvring, avionics, or historical air battles. Thus, playing a game may have a large indirect learning value though motivating and stimulating game use during leisure time and thus enhance the transfer to a related real life task .

5.7 Taxonomy

Not all tasks, or types of tasks, can be adequately trained using games.
When designing game-based training, the context-, task- and training-analyses should identify the types of (sub)tasks and related skills that have to be trained. These task analyses specify the necessary input and task or environmental features (visual, auditory, conceptual) that are critical for task performance. These features need to be represented in the game environment to realize an adequate training environment for those tasks. The decision to use a game for a specific training program depends on whether or not those critical task features can be represented in the game environment and can thus be made after having executed a sound task analysis. However, on the basis of general knowledge on human performance (e.g. Fleishman, 1972; Proctor, et al., 2002, 2004) and learning processes, (Van Merriënboer, 1997; Van Merriënboer, Jelsma & Paas, 1992) it is possible to identify classes or types of tasks that are better suited to train using a typical game, and types of tasks that seem not suited for game-based training.
A typical game, in this respect, constitutes a PC game configuration such as a first person shooter or Rollercoaster Tycoon with a standard flat screen display and a simple manual control or a mouse. In a workshop with four training and simulation experts the degree of transfer was estimated for each type of task, expressed in +++, ++, +, -, --, --- meaning excellent, good, reasonable, little, very little and no transfer, respectively). Estimated degrees of transfer thus are very global and do not count for each game and/or for each task to be trained.
In addition, we did not take into consideration all kinds of environmental, psychological, and didactical factors that also may substantially affect the amount of transfer of gaming.

According to this taxonomy the amount of transfer is determined by the *similarity* between game and operational task with regard to the required human information processing involved. That is the degree to which task activities call upon the same (type of) attitude, skill, or knowledge. Next to the human-machine interface and the hardware environment, this similarity is determined largely by the underlying mathematical model (describing input-output relations, underlying rules, and relationships among task variables), task-goals, scenarios etcetera. Higher degrees of similarity in required human information processing generally lead to higher transfer (other factors being equal).

[3] A MicroProse publication.

Attitudes

• motivation	++
• initiative	+++
• integrity	+
• honesty	+
• courage etc..	-

Knowledge

• task-specific facts (background, context, goals, conditions)	++
• general facts	+/-
• rules and procedures (if…, then…, fixed sequences)	+++
• mental models, schemata (e.g. functionality of interfaces)	++

Social skills

• communication (primarily verbal)	+++
• cooperation, collaboration	+++
• leadership	++

Emotional skills

• nonverbal communication	+/-
• self efficacy	++
• empathy	++
• stress tolerance, hardiness	+++

Cognitive skills

• interpretation	++
• calculation, problem solving, (strategic) decision making	+++
• (contingency) planning	+++
• self-reflection	++

Perceptual-motor skills

• searching (different modalities)	-
• detection (different modalities)	-
• perception (different modalities)	+/-
• operation (controls, instruments, displays)	+/-
• motor performance	--
• physical fitness	++

On a superficial, or physical, level (i.e., “seen from the outside”) the game environment may differ substantially from operational environments in which people process information and operate. However, for most kinds of tasks (except primarily perceptual motor tasks) these differences do not necessarily concern the *underlying* social, emotional or cognitive processing operations. In other words: for the transfer of training of the non-perceptual-motor components of tasks, the amount of similarity between game and real task, such as exact forms or colours, often does not matter too much (e.g. Woodman, 2006 for a review). This means that, despite large superficial or physical differences between playing games and real tasks, serious gaming may allow people to learn many kinds of relevant skills. This is so because cognitive, social or emotional aspects aspects of games may highly resemble reality, despite the large physical differences.

As can be seen, we expect TOG to be limited with respect to perceptual-motor task components (Woodman, 2006), except when the game is specially designed to train a specific perceptual motor task. This is because perceptual-motor training requires that the specific characteristics of the physical task environment, (e.g., control devices, visual cues, and interfaces) are represented with high fidelity. Since most games are typically played on a PC or game console with a small flat screen, a keyboard and/or simplified game controls, such a high level of fidelity cannot be reached. These differences have large impact on sensory input and motor output and thus make perceptual-motor transfer impossible. Tasks that are mainly knowledge-based or in which social-, emotional-, and cognitive skills are prevalent are not limited by the specific physical characteristics of the game (PC, console, display). Here, the critical factor for transfer is whether the underlying rules and relationships are represented with sufficient fidelity.

5.8 Conclusions

In this chapter we have provided an overview of the different experimental methods and metrics to quantitatively measure transfer. Although true Transfer of Gaming is hard to assess, several estimates have been proposed that together provide a comprehensive insight in the training value of a game. By estimating and comparing the costs and effectiveness of the game-based training with an alternative training program, we can acquire cost-effectiveness ratios of the game based training. However, such a quantitative approach ignores some additional positive aspects of serious games . These aspects are related to the effects of gaming on motivation (flow), exploration behaviour and the fact that the cost of gaming may become very low when it is done in leisure time. To be complete, in discussing transfer one has to consider all factors that affect the utility of a synthetic training environment such as safety, cost, and when it concerns games, motivational aspects. The next Chapterwill also address those aspects of serious games.

6 Designing effective serious games

This chapter presents a stepwise methodology for designing, developing and evaluating serious games for educational purposes.

6.1 Introduction

Following the previous chapter, we start here again with the definition of ToG as the degree to which skills, knowledge, and attitudes acquired by playing a game can be effectively used in real (operational, professional) situations. It will be clear that the amount and quality of learning resulting from training in a serious game, is not only determined by the simulation or game itself. No matter how well designed a training system is, transfer will never be optimized without consideration of individual and contextual or external factors. Generally, ToG is determined by three overall factors: characteristics of the game, characteristics of the player and characteristics of the external conditions (context, didactics, organisation) under which the gaming takes place. The latter two global factors have already been discussed in previous sections and in other studies (e.g., Langelaan & Keeris, 2008; Maanen et al., 2008; Tannenbaum et al., 1993). Therefore, and for practical limitations, in the present study we only focus on the first factor, i.e., game characteristics. In the next section, a stepwise approach is presented for the design, specification, and development of serious games from a didactical and cost-effectiveness perspective. Didactical and cost-effective game specification.

The current section provides a reference framework entailing a stepwise approach for the design, specification and evaluation of serious games. This is done from a combined didactical and cost-effectiveness point of view aiming at optimal transfer of gaming at minimal cost. The framework is partly based on information from handbooks and research projects that have been carried out on the requirements analysis and specification of training simulators and synthetic training environments (i.e., Cohn, 2009, Farmer et al., 1999; Korteling et al., 2001; Milham et al., 2009; Stanney, 2009; Verstegen, 2004, Young, 2001, 2004) These documentations, however, mostly did not concern the specific aspects and requirements of *serious gaming*. For this paper, we have 1) selected the main findings and principles from these projects as far as these were relevant for serious gaming, 2) added (or translated) principles with regard to serious gaming and 3) finally put them into a stepwise approach to be used for developing the didactical aspects of serious games in a most cost-effective way.

Like other kinds of synthetic training environments, the requirements analysis and specification of a training game should always start with functional system analysis, i.e., the description of the elements, aims, boundary conditions and factors involved in the execution of a certain task to be trained. In subsequent stages, the outcome of this process has to be related to the cost and utility of serious gaming *versus* conventional training and/or simulation. Furthermore, a trade-off analysis is required to select those subtasks that can be trained effectively in a game at relatively minor expense. This analysis also has to take into account the cost and performance of the various the state-of-the-art game technologies, such as: interfaces, models, displays, mobile devices, bandwidth, augmented reality, alternate reality, etc. (Korteling et al., 2001).

This process cannot be carried out in a strict sequential order (“Waterfall”). Because new information comes up during development, insights may change and iterations among initial and final steps will have to be made (Verstegen, 2004). In order to help serious game developers in this complex and iterative process, the present reference framework will provide a clear overview of this complicate process.

6.1.1 A reference framework for instructional game development

Step 1: Assessment of the domain to be trained

This step involves the investigation of the feasibility and prospects of serious gaming for specific tasks to be trained.

Step 1.1 Context Analysis
The context analysis starts with a global description of the competences, or function to be trained within the context and surrounding conditions. This involves a description of the overall goals of the task and how these goals should be achieved, functions of systems involved, and the relevant scenarios, circumstances or environmental conditions (physical, mental and tactical aspects) that are encountered in task performance. An example of an overall goal is to take control over an area or to protect civilians of a city against revolting forces. The analysis of such goals should include the (complete) scope of the activities and goals.
The goals and context can be described and analysed at different aggregation levels.

At the highest level goal categories are for instance, crisis management, transport, reconnaissance, medical treatment, crowd and riot control, or human resource management. Finally, it should be noted that most tasks and games are goal-oriented: real tasks and the tasks of game players have to be brought to a conclusion, to an end. In order to develop a serious game, it is thus essential to identify the goals and subgoals of the relevant actors and the relevant critical factors that may prevent them from obtaining their goals.

Step 1.2 Task Analysis
A task is a (part of a) function allocated to a person. In other words: it is a goal-directed sequence of activities, which can be described at various levels. A task analysis decomposes a task into non-overlapping elements (subtasks), of which the most salient features are concisely described in terms of input, required operation(s), output, critical conditions and critical task-elements. In addition, a brief global description of the subtask may be given. The number of subtasks should be kept as low as possible.
The ordering of input → operations → output must not be taken as strictly sequential: It is a control loop in which perception (input) leads to a response (operations) with a certain effect on the system (output) which is perceived as feedback (input) that is translated into operations, and so on.
First and above all, it should be noted that the required level of detail of a task analysis varies substantially, depending of the purpose of the task analysis.
The exact specification of functional requirements and the specification of an optimal serious game configuration (on the basis of a cost-benefit trade-off analysis) requires a relatively high level of detail. The level of detail (and the amount of work)

involved in the task analysis is reflected in the number of sub-tasks and sub-task components.
Repetitions in task analyses lead to repetitions in the description of functional requirements and thus to repetitions in the cost benefit trade off analysis. Therefore, a non-redundant task analysis provides the most efficient representation of all task- and context variables that are involved in the task. Independence of subtasks allows for the construction of higher-order tasks just by combining subtasks. During training courses, more complex, higher-order, subtasks (e.g., planning, reconnaissance) are preferably trained as (complex) combinations of more elementary subtasks (e.g., map study) after these elementary subtasks are mastered. Conventional training programmes are structured according to these combinations of elementary subtasks. These higher-order concepts are not suitable to provide a concise, non-redundant description of tasks based on logical elements.
Specific game-related elements to take into account are:

- Number of relevant actors (players) in the task.
- To what degree does the learner have to get insight into other tasks allocated to other persons? In that case, role-playing may be an essential part of the game to be developed.
- After having analysed and described the task elements it is very useful to identify and describe possible gaming scenarios. These scenarios consist of goals to be obtained (environmental) conditions, actors, events, and systems (means, aids, tools) to be used. Scenarios may be combined into an overall story or story lines (narrative games). In narrative games, players are challenged to restore an equilibrium that is disrupted (e.g., finding the kidnapped princess).

Step 1.3 Training Analysis
The purpose of a training analysis is the specification of training requirements in terms of (a set of) related learning objectives. In a training analysis training objectives are determined on the basis of the discrepancy between the required knowledge, skills, and attitudes (i.e., competences to be deduced from the task analysis) and the current competencel-level of the learners. Training objectives have to be specified in terms off:

- Existing competence level of the learners.
- Required competence level of the learners.
- Type of competences (see taxonomy) that have to be trained.
- Required task performance (in terms of observable/measurable behaviour) showing if the training objectives have been met.
- Critical conditions (scenarios) for task performance.

These specifications are needed to construct training scenarios with events, assignments and instructions intended to learn the task. The task analysis (Step 1.2) includes a specification of operator activities required to perform the tasks, the required output and the critical (environmental) conditions under which the actor has to perform these activities. From these task descriptions *competences* can be identified; a competence is a learned capacity to perform a particular activity (requiring specific knowledge, skills and attitudes) at a specified level of proficiency. Specification of training objectives starts with identifying the required competences and competence levels, taking into account the current competence level of the learners. This results in a reduced list of task-specific competences. Then, the task-specific competences need to be clustered: the same competences can be

deployed in the context of different tasks. In this sense, competence-task relations are one-to-many relationships. For each identified competence the related tasks have to be specified and sorted according to complexity of the tasks.
Training objectives should be described in such a way that they can be used as final criteria for training and should preferably be defined in a testable form. Training objectives need to be specified such that gaming scenarios can be developed that cover all required competences and their relations.
The training objectives refer to real-task competences and performance. However, also specifications may be needed with regard to play *itself* in serious gaming.
One should therefore take into account the gaming experience and interests of the learners. For instance, many young males are already proficient in playing first-person shooter games, whereas (older) female players are not. Specifications in this regard include:

- Experience with gaming platforms (ranging from Magnavox and keyboard to Playstation 3 and Nintendo Wii).
- Experience with different types or genres of games, i.e.: shooter-, adventure-, sports-, driving-, simulation-, strategy-, role-playing-, fighting-games.
- Player categories (“killers”, “achievers”, “socializers”, and “explorers”).
- The reasons why the learners should like to engage in gaming, such as: self-development, being in control, having power, playing with rules, taking another identity, creativity, imagination, getting into flow, etc.

Step 2: Global cost-utility Analysis

A Global cost-utility analysis is needed when it is necessary or difficult to predict whether or not a serious game will be beneficial relative to other forms of training. It includes weighted measures of expected training value and foreseen training cost. When it is foreseen that the serious game is used by (potential) learners in their leisure time on their own PC, the cost will be mainly restricted to software development.

Step 2.1 Utility Analysis
The utility analysis considers the expected training value of alternatives in terms of general utility criteria. It helps to choose among alternatives. The following general prerequisites of a utility analysis can be respected:

- At least two alternative possibilities must be defined by using the same set of criteria.
- The criteria must be distinctive, non overlapping and exhaustive for the decision problem.
- The evaluation of the criteria must be done by subject matter experts.

The utility of training a certain task or function by serious gaming can be assessed by the following global criteria:

- Value of the training area for the organisation. That is: how important is this training for the tasks and continuity of the division, branch or system to obtain its typical goals.
- Importance of training difficulties to overcome and the possibilities to accomplish this by using gaming technology.
- Availability of training resources, taking into account environmental restrictions, training and exercise logistics, instructors, time constraints, etc.

- The attractiveness of a game is very relevant for retaining the attention and motivation of (potential) learners. Gaming provides opportunities to perform tasks in a realistic context, which is at the same time attractive, stimulating, and entertaining (“authentic training”).
- Flow describes the state where people meet tasks that are not too difficult (player stops) and not too easy (player gets bored). Flow is a state of mind which players can seek actively (and even may drive them into addiction).
- It seduces the player to play more often and to stay longer in the synthetic environment.
- Games can be played outside a professional context, outside working hours.
- If workers experience a game as attractive this can yield more training hours without additional organizational cost.

Step 2.2 Cost Analysis

The cost analysis considers the cost reduction potential of the application of training games, which is mainly determined by gaming technology and personnel (learners and instructors) involved.
For every alternative possibility a separate cost calculation should be performed. The following cost categories should be used, and for each, these rough subtask estimates should be made per year:

- Number of learners.
- Instructor cost and learner salaries.
- Hardware cost and software cost (only development cost).
- Updates, license of hardware and software e. g. after every five years, consider the maximum life cycle duration (e.g. 20 years).
- Game maintenance cost.
- Infrastructure cost (network, extra electricity facilities, building maintenance etc.).
- Infrastructure operating cost (electricity, heating).

Step 2.3 Decision on the Basis of the Cost-Utility Analysis

The cost categories as specified above can be treated in the following manner:

- Multiply the learner salary per year with the number of learners and multiply this number with the total training hours with the game.
- Add to the above the instructor cost per year per learner (i.e. divide the instructor cost on the number of learners per lesson: e.g. it may happen that the serious game has a different number of learners than a high-end training simulator.
- Add the hardware and software cost of the game alternatives (only development cost: consider the maximum life cycle duration and calculate depreciation).
- Add the hardware and software cost updates (including licensing) per year (supplier normally adds this to a maintenance contract).
- Add the game maintenance cost per year (e.g. in house operator).
- Add the infrastructure cost (consider the maximum life cycle duration and calculate depreciation).
- Add infrastructure operating cost.

Compare the grand total of every alternative with their utility values and decide on the basis of these figures which option has the highest utility to cost ratio. Note that a direct division of utility values by cost is for mathematical reasons (different scales) not possible.

Step 3 Detailed functional specification

This step involves the process of describing functional requirements and the instructional features of the serious game. The following sub steps describe how to proceed.

Step 3.1 Game element specification

Functional specifications are defined as game characteristics on an intermediate level, e.g., the display resolution that is required (in pixels/deg) and the display field of view without specifying *how* (by what technical means or components) these requirements should be attained, i.e., the type of display that is needed. Functional specifications may vary significantly in the level of detail. For each subtask a set of functional specifications has to be provided.

The training analysis has resulted in a list of required competences and competence levels (criteria for task behaviour and gaming competences and interests). This focus on competences and interests is essential because it would not be efficient (or even impossible) to train all identified tasks under all possible operational and environmental conditions. The analysis at competence level is aimed at focusing on the minimal set of tasks or task elements, and the task scenarios that encompass all relevant competences at the highest level required in the task repertoire under the most demanding conditions.

It is often not easy to specify which task elements (cues) have to be presented for efficient learning. Fundamental is the idea that some task elements are more relevant to task performance than others. The task elements that are most relevant to performance are called critical task elements.

In order to specify the game a number of factors have to be considered:

- Learner level: initial training usually requires less fidelity (realism) than the training of experienced learners.
- Type of task: it is usually more difficult (expensive) for perceptual motor tasks to achieve physical fidelity in games than for cognitive tasks.
- Repetitiveness / smartness of the task.
- Learner workload: subsequent scenarios with gradually increasing levels of difficulty and complexity may prevent too low or too high levels of learner workload.
- Part-task training: selectively focussing on those task variables that can be trained easy with a game and with high training effectiveness, may be crucial for successful serious gaming.
- Variance of task elements: if learning is conducted on the basis of a limited set of critical task elements, or limited variation in the complexity of those task elements, the training might not prepare for all aspects and all conditions of the operational tasks.
- Attractiveness: challenging training scenarios with competition, points and/or increasing game levels, and an interesting story line, are all aspects that can increase motivation to play and/or may induce so-called flow.
- Level of fidelity: in practice, the "desired" level of fidelity should be based on a cost-benefit trade off analysis. Achieving extra fidelity involves costs that should not exceed the benefit of higher transfer and/or efficiency of training.
- Full fidelity gaming is, in most cases, not required. It may even be the case that deviations from full fidelity are more fruitful, not only because of reducing soft- and hardware costs, but also because of the potential enhancement of fun and

engagement. Higher levels of fidelity can, however, in some cases contribute to the attractiveness of the game.
- Elaborate the most typical and potentially useful scenarios (see step 1.2).
- Scenarios may be combined into story lines that challenge gamers/learners to reach a certain goal.
- In developing scenarios and story lines, take into consideration the number of actors (players) and possibilities of role-playing.

Step 3.2 Instructional features

Implementation of the game or game network into an existing training program usually will require an adaptation of this program taking into consideration the possibilities and limitations of the new training system. Compared to traditional instruction, the game offers various additional training options that are not feasible in practical training situations. Possibilities include: quick change of training scenarios, automatic performance measurement, better feedback, using authentic learning environments, active discovery learning, collaboration, and after action reflection. It is, for example, relatively easy to measure and store all kinds of system parameters. However, some of these possibilities may require additional facilities for instructors. They may, for example, need extra scenario-management facilities, extra overview facilities, or performance measurement facilities. This allows for provision of automatic and objective measurement and detailed feedback concerning task performance.

In order to specify the requirements for the instructional features of the game, the following factors may have to be considered:
- Authoring, (de)briefing and reflection facilities.
- Monitoring, scenario control, guidance facilities.
- Feedback (content, form, timing).
- Degree of automation (instructions, performance measurement, feedback by a virtual coach or assistant.

This information can be gathered by interviewing instructors and/or domain experts, and by the results of the training analysis (step 1.3).

Step 4 Technological analysis and technical specifications

The functional specifications define the functional performance of the game component, not how this performance can be achieved. In the functional specifications the required resolution of the display system is specified, but not what type of display system or what specific product would be best. This step explains how to specify these specific technical requirements. This is done in three parts:
- First, identify game subsystems and related technologies.
- Second, investigate which technologies and products are on the market and investigate their (technical) performance characteristics.
- Third, identify cost of technologies and products and possibilities for cost-savings.

A technological inventory shows the major game platforms, engines and subsystems that are available, their performance characteristics, and their price.

Step 5 Detailed cost-benefit trade off Analysis and global game specification

A serious game is the result of a trade-off between the minimal necessary game components and reasonably high training benefits. In order to develop such a game, the following activities have to be undertaken:

- For using gaming to train this subtask (Step 3) estimate the costs of the technological requirements (Step 4).
- Select those subtasks which require game based training because they cannot be trained in a cost-effective way without games (high costs, danger, environmental restrictions).
- Select those subtasks that may benefit substantially of the potential advantages of gaming (e.g. attractiveness, flexible scenario generation, authentic training and guided discovery learning).
- And /or select those subtasks which require a considerable amount of conventional training (which should be known if the task domain is not completely new).
- Eliminate those subtasks that fulfil relatively minor training needs (Step 1.3) and require complex technological components (high costs).
- And/or eliminate those subtasks that lead to complex (expansive) technological requirements, whereas they can be trained effectively with other (e.g. conventional) means, such as exercises, classroom settings, books, video etc…

On the basis of the remaining subtasks a game can be globally specified. This can be done by aggregating the remaining selected subtasks and fitting them into a coherent game. This includes gaming scenarios with goals, boundary conditions, a physical and social environment with partners or opposing agents, (disturbing) events or disturbances, tools to be used, etc…. A narrative story line may include, or integrate, all these aspects in such way that by playing the game the learner is required to carry out the selected subtasks. In order to produce a complete game it may be necessary to include subtasks that were not selected initially.

Step 6 Prototyping and validation

Step 6.1 Prototyping

The benefits in terms of training efficiency, expected savings or technical operability of using games remain uncertain, as long as no prototyping and validation studies are performed. These testing platforms are not the complete serious game itself. Prototyping with testing platforms helps to determine the optimal trade-off between training value and costs for a set of training issues. These are the necessary steps in prototyping studies:

- Aggregation of technological entities.
- Description of possible soft-and hardware architectures.
- Identification of critical issues.
- Identification of possible platforms to investigate these issues.
- Implementation of necessary soft-and hardware to address the issue.
- Executing the tests.

In practice, this approach is conducted as an iterative process since the decomposition of the game into different entities is also affected by the choice of the hardware solutions. In addition, it has to be underlined that, when going into the detailed specifications, some major technical orientations have to be chosen.

Prototyping serious gaming is for a large part a matter of optimising development time. Depending on her/his specific tools and background knowledge, very different technical solutions may be adopted by a game developer.
Our approach leads to new solutions for training of which the validity has to be tested. If there are critical issues, tests should be conducted, in order to validate the effectiveness of the proposed solutions. The platform to be implemented for testing depends on the nature of the issue. The following questions determine the scope of the testing platform and its flexibility:

- Is it possible to test the functional result independently without having to build a complete game?
- What are the minimal subsystems required for the test?
- Do they have to be implemented completely?
- Which elements (or parameters) should be modified during the test?
- What will be measured and compared?
- In many cases, means for evaluation support will be needed. What kind of support is needed depends on the measures and criteria on the basis of which the effectiveness will be evaluated?

Step 6.2 Validation

The ultimate test concerning the quality of a game is its validation with respect to the training aims for which it was acquired. The validity of a game is the degree to which it fulfils its purpose within a specific training program, that is: the attainment of intended training objectives. The objective measurement of validity (i.e. the purpose of the training game) may be difficult, time intensive, and costly.
For example, the Generic Methodology for Verification and Validation (GM-VV) which is a standard under development for the Simulation Interoperability Standards Organization (SISO), regards validation as a systems engineering effort aimed at a justifiable, traceable, and evidence based qualification concerning synthetic environments. GM-VV includes mechanisms for transforming any collected (subjective or objective) evidence into acceptability claims concerning the various properties of synthetic environments and models. These acceptability claims for each Modelling & Simulation (M&S) property are then further aggregated into (a) claim(s) on whether the M&S system as a whole is acceptable for its intended use.
As validation efforts always are limited by time, money, and personnel, many organizations are hesitant to enter a formal validation trajectory. However, the approach presented here, like GM-VV, can be tailored to the needs and possibilities of both large and smaller projects. In this light it is very well possible to use subjective measurements. Even though the evidence they yield might reflect personal opinions, expectations or preferences and will therefore be less convincing than experimental data, each answer still contributes to the overall argumentation process and can support or deny a (part of a) validation claim. Ultimately the balance between the use of objective and subjective methods should reflect the acceptability of the risk associated with the use of the game under evaluation.
This approach includes the following activities:

- Determine the quality of the process of game specification that was used: are the specifications based on a structured approach including determination of training need, task- and training analysis, etc.
- Determine the scope of the validation: depending on the application of a particular game, some aspects might need detailed, objective validation whereas other aspects can be evaluated more globally or subjectively.

For example, serious games that are intended to train only procedural tasks can be validated subjectively, e.g., by collecting evaluations from training experts on the instructional quality of the game.

- Provide a structure to document the validation efforts such that all decisions can be traced back. Determine beforehand what sort of evidence is necessary to support the different (validity) claims about the game, and how this evidence should be collected ideally.
- Rating of the functional similarity between operational system and the serious game by domain experts.
- Ratings of the quality of the instruction-, feedback-, and scenario-generation facilities by experts of the area of training gaming.
- Ratings of the training trajectory design by training experts.
- Simple physical measurements with respect to the physical fidelity of the game, such as field of view, contrast ratios, level of detail.

In conducting the evaluation studies it is necessary to carefully prepare the evaluation sessions. Below, a brief overview is given of the basic conditions:

- The tasks to be performed in the game and the scenarios (events, conditions, sequence, etc.) in which these tasks are carried out must be described in every relevant detail.
- The game should only be equipped with the environmental and technical models that are needed for the evaluation.
- Both specific and general tasks that are concerned with either one or all of game elements to be evaluated should be included.
- Include at least 3 to 5 experts in the evaluation study. Balance the order of task, task conditions, and scenarios between the experts.
- The experts should be given only very general information about the scope of the experiments; they should not know the research questions they will be asked, until they have experienced the topics to be evaluated.
- The questions to be asked should be standardised throughout the evaluation.
- On the basis of the results of validation studies, the game system, possible instruction facilities, and curricula and the training trajectory must be adapted in order to optimise the training results.

6.2 Conclusions

The process of specification, design, development and validation of serious games is very similar to that of simulators and other advanced training systems. Globally, he same steps are undertaken: context-, task- and training-analyses, functional specifications are drawn up, then detailed cost-utility analysis is undertaken and technical specifications are recorded, followed by prototyping and validation. Specific for games, however, are certain features that need to be considered or require special attention during the process. These are, e.g., the narrative aspects, the challenge, the player-levels, the AI, and the other players.

7 Discussion

Gaming seems to get its appeal from its evolutionary utility. It has been argued that play provides a safe way to improve ones physical, social, and cognitive capacities. This makes play a 'natural' form of learning, which is triggered and supported by powerful endogenous and exogenous motivators, like fun, flow and competition. Motivation is mitigated by feelings of competence, autonomy and self-realization, and external conditions that act on those feelings such as rewards, feedback, meaningful goals and rules. The complex interplay of these variables is not yet understood. Until then, for play to be effective over a wide range of individuals, we recommend that educators use a variety of learning methods and encourage learners to be receptive to different learning approaches.

Numerous studies over the past ten years have documented that PC-based simulation training environments can offer effective training for certain types of tasks. The evidence in favour of desktop games, however, is less strong although positive results have been reported e.g., in academic achievement (Blunt, 2007), in aviation training (Proctor, et al., 2004) and education planning and evaluating small unit tactics (Proctor, et al., 2002). Much research on game effectiveness has also been done in the field of surgery. For instance, Rosser et al. (2007), showed that completion time was faster when surgeons had video game experience in a learning environment for laparoscopic surgery. These surgeons also made fewer errors. In the field of desensitizing patients with arachnophobia, Bouchard et al (2006) designed a therapy requiring patients to play *Half-Life.* In this environment the patients were increasingly exposed to spiders. Before the treatment, the majority stayed 2 meters from a bowl with spiders. After the treatment the majority was able to stand next to the bowl.

In the military domain, as mentioned in Chapter 3, the learning effects of game-based training on cognitive tasks has also been investigated. In a study of cockpit crew training, an experimental group trained on a PC-based simulator was compared to a control group. The results showed that the experimental group performed better on task management and situational awareness, but not on other cognitive skills, such as decision making and planning (Nullmeyer, Spiker, Golas, Logan & Clemons, 2006). In an overview of Hays (2005), in which he reviewed 274 documents and articles on instructional games, he concluded that empirical research thus far on the effectiveness of games is fragmented. Although the research showed that games can provide effective learning for a variety of tasks, this does not tell you whether or not to use a game for a specific task. Hence, there is no evidence that games are always the preferred method for learning in all situations.

Still, serious gaming is seen as a promising approach to training. This is because serious gaming combines elements from simulation, didactics, and entertainment. Ideally, these elements ensure that people are easily attracted to play a game, motivated to continue playing, and as a result, learn. Games could therefore be used when other methods of training are unattractive, expensive, or impose unacceptable risks for the learner or the environment.

The above implies that the use of games for training can be a solution for reaching groups of people who are not motivated by more traditional types of education. Gamers and gaming adepts, typically emphasize the fun, engagement and flow aspects of games (e.g. Prensky, 2001). However, we have to be careful not to conceive gaming as a cure-all for 'boring and uninspiring' educational problems. Instead, games should be added to the toolbox of educational strategies and be used sensibly. When we consider individual differences in peoples' motivation to play games, and individual differences in what they might learn from playing, we should also take into account for what types of tasks games or playful activities can be a powerful training tool. As could be seen in our taxonomy of Chapter 5, not all tasks may benefit from a game-based training approach. Schrier (2006) explored the potential of augmented reality games for teaching what she calls 21st century skills: e.g. information management, media fluency, communication, critical thinking, teamwork, etc. She found augmented reality games to provide motivating, fun and engaging environments to learn those skills. But how about teaching a learner engine maintenance and repair, a foreign language or playing music?
The taxonomy can be used for the set up of experiments aiming at measuring TOG or for the interpretation of experimental results. Moreover, both the stepwise reference framework presented in Chapter 6 and the taxonomy can be used to help game designers to develop games for specific kinds of training objectives or to analyse which kinds of tasks make up a specific game. For instance a first person shooter does not only consist of perceptual motor tasks such as finding and shooting the enemy, but also of communication, leadership, planning, situation awareness, and decision making. Hence, the taxonomy and reference framework presented in the present report can be used as an aid to globally predict TOG, to design games and to evaluate games.

At this point, the question whether or not play serves a role in learning does not need to be answered; play already does. Games however are a bit different, as they restrict and structure the envelope of playful behaviour. Here, there's an analogy between games and simulations. We know that not all simulators are effective trainers. They need for instance good curricula and carefully chosen performance measures and assessment criteria. We also know that in order to learn, the simulation should resemble the operational environment on key aspects of the specific task to be trained. This not only concerns the physical and synthetic environment, but also the (higher-level) information that is provided by the rules, scenarios, virtual characters, mathematic models, and story lines. It is not very effective to learn how to drive in a driving simulator using a keyboard interface, a mathematical flight model, or being allowed to violate the traffic rules. This is similar with games: some games have no transfer to reality and playing them will only improve your ability to play that game. On the other hand, when task activities call upon the same (type of) attitude, skill, or knowledge, a high degree of transfer is possible. This similarity is determined by the underlying mathematical model (describing input-output relations, and relationships among task variables) that calculates on task objectives, events, and scenarios etcetera. Higher degrees of similarity between gaming and real task performance processing generally lead to higher transfer (other factors being equal).

‘Serious games’ thus also seem to reflect the basic notion that certain realism criteria should be met in order to be valid instructional tools. This, and other considerations in the design and development of serious games are discussed in Chapter 6, in which we present a stepwise methodology for game development.

It should be noted, however, that the framework is in some cases rather redundant. For example, when a serious game is developed that is intended to get acquainted with a certain task or task domain in leisure time at home, the calculation of cost of (learner, instructor) salaries or infrastructure depreciation can be skipped. Likewise one may decide to start with an existing and available game and analyse what (sub)tasks can be effectively trained with the game, at which cost and in what training curriculum. In that case the context-task- and training analyses may be focussed only on those elements that are specifically involved in the available game(s). Therefore, it is always useful to look for possible shortcuts by skipping certain steps or execute them in a limited way. Finally, as Cohn (2009) states, there is no simple recipe for ensuring successful development of synthetic training systems, and there are no simple equations for calculating success. Games that produce high transfer of training for a task in a certain education may fail to yield similar results for other learners in another training setting. Or they may fail to be adopted by the training community for other reasons than cost or training effectiveness. Nevertheless, we have identified the main steps which, when followed, will reasonably increase the likelihood of a game that can be used to train knowledge, skills and attitudes that can be used effectively in real operational and professional situations.

We conclude that games and play can have a valuable role in training. Not to fully replace traditional training methods, but to substantially enrich existing training curricula, and to inspire and engage learners. A consequence of this, however, is that the traditional transfer of training framework does not apply completely to games. Therefore, existing notions have to take into consideration the minimal cost of training in leisure time, exploratory behaviour, motivation, inspiration, engagement and flow.

8 References

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9 Acknowledgments

This research has been supported by the GATE project, funded by the Netherlands Organization for Scientific Research (NWO).

10 Signature

Soesterberg, August 2011

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ONGERUBRICEERD

REPORT DOCUMENTATION PAGE
(MOD-NL)

1. DEFENCE REPORT NO (MOD-NL)	2. RECIPIENT'S ACCESSION NO	3. PERFORMING ORGANIZATION REPORT NO
-	-	TNO-DV 2011 B142
4. PROJECT/TASK/WORK UNIT NO	**5. CONTRACT**	**6. REPORT DATE**
032.13301	GATE Scientific Program	August 2011
7. NUMBER OF PAGES	**8. NUMBER OF REFERENCES**	**9. TYPE OF REPORT AND DATES COVERED**
52 (excl RDP & distribution list)	107	Final

10. TITLE AND SUBTITLE

Transfer of Gaming: transfer of training in serious gaming

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TNO, P.O. Box 23, 3769 ZG Soesterberg, The Netherlands
Kampweg 5, Soesterberg, The Netherlands

13. SPONSORING AGENCY NAME(S) AND ADDRESS(ES)

Netherlands Organization for Scientific Research, P.O. Box 93138, 2509 AC Den Haag

14. SUPPLEMENTARY NOTES

The classification designation Ongerubriceerd is equivalent to Unclassified, Stg. Confidentieel is equivalent to Confidential and Stg. Geheim is equivalent to Secret.

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

PC based games may have great learning value because they offer the opportunity to create dynamic an elaborate learning environments where learners can actively work on authentic problems. The present report covers the most crucial aspects serious gaming, i.e.: play, didactics and transfer. With regard to play, we conclude that play has a firm foundation in evolution and individual development. It not only drives the physical, social and cognitive development of animals and man, but also functions as a behaviour generator that stimulates the development of new types of behaviour and skills. We also describe the benefits of gaming from a didactical viewpoint and offer a new educational approach that is relevant for serious gaming. Next, the topics of effectiveness and efficiency of learning in games (Transfer of Gaming, ToG) are explored borrowing from knowledge built up in the areas of modeling and simulation and didactics. An overview is provided of the different transfer measures and some positive aspects of serious games that are not considered in these measures are discussed. Finally, a task-taxonomy and a stepwise reference framework is presented that can be used by game designers to develop serious games from an instructional and cost-effectiveness point of view.

16. DESCRIPTORS	IDENTIFIERS
Training, serious gaming, transfer of training.	Training, play, serious gaming, validity, transfer learning, simulation.

17a. SECURITY CLASSIFICATION (OF REPORT)	17b. SECURITY CLASSIFICATION (OF PAGE)	17c. SECURITY CLASSIFICATION (OF ABSTRACT)
Ongerubriceerd	Ongerubriceerd	Ongerubriceerd

18. DISTRIBUTION AVAILABILITY STATEMENT	17d. SECURITY CLASSIFICATION (OF TITLES)
Unlimited Distribution	Ongerubriceerd

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