Esther Kuindersma

Cleared

for take-off

Game-based learning to prepare airline pilots for critical situations

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Voor mijn jongens

Preface

The book that you are holding right now marks an era. An era of my life that I had not envisioned until September 2014. That was when I came across a vacancy, posted on Twitter. It read "serious gaming and didactics" and it was at the Netherlands Aerospace Centre NLR. When I read it, a fire inside me ingnited. Working on training methods for airline pilots. This was what I wanted to do!

It took a while, before I realised the vacancy was for a PhD position. I had never considered doing a PhD or even doing research. I hesitated: I was not sure that I could do this, and it would involve a pretty steep cutback in my paycheck.

At that time, there was a song on the radio that I liked very much. It was "Geronimo" by the Australian band "Sheppard". The title of the song is a reference to the famous Apache military leader Geronimo, and the custom of yelling his name before doing a courageous act. I took it as an inspiration and decided to take the leap.

Time flies by, and now it is 2019. Finishing my thesis took a bit longer than I hoped for, but I have made it. You are holding my book in your hands. It has been fun. It has been tough. It has been an adventure.

I would like to take this opportunity to express my gratitude to everyone who contributed to the completion of this work. I received the support and help of many people. Too many to thank everyone by name.

I would like to start by expressing my gratitude to my supervisors Jaap van den Herik and Aske Plaat from the Leiden Centre of Data Science (LCDS) at Leiden University, and my co-supervisor Jelke van der Pal at the Netherlands Aerospace Centre (NLR). I am grateful to all three of them for their guidance and support, but I owe Jaap a special thank you for his unfailing drive and enthusiasm to critique my writings in order to make me a real scientist. Thank you for working through all my puzzles.

Next, I wish to thank the participants in all my experiments, and every teacher and flight instructor that helped me find my participants. Without them, I would not have had anything to write about.

I thank NLR for giving me the opportunity to do this research, and I thank my colleagues at NLR for all they did for me. For helping me create the games for my research, contributing to my experiments and my data analysis, giving me feedback on my ideas and my writings, and for the great talks at the coffee machine and the fun during extracurricular activities.

Thank you to my family and family-in-law, for your continued interest in the progress of my research. Thank you to my friends for your encouragement and your patience when I needed to blow off some steam.

A special thank you to my paranymphs Armon and Alistair.

Armon, it was good to have you as a companion during my time at NLR. I enjoyed our discussions during our carpool rides about your research and mine, and the many days that we spent sequestered in our "cave".

Alistair, I am happy to have met you as one of my new colleagues at the HvA. Our coffee conversations have saved me from quite a few panic attacks during the final stages of my PhD.

Finally, thank you and lots of love to Sjoerd, who supported my decision to quit a good job and dive into this scientific adventure, and to Jasper and Thomas, who accepted many times that I did not have much time for them, because I had to write my book. Thank you for all your love and patience. My book is done now. Let's play.

Esther Kuindersma
Almere, 2019

Contents

List of Abbreviations

4C/ID	Four Components for Instructional Design (model)
AFPM-M	Aircraft Flight Path Management - Manual (ICAO core competency)
AFPM-A	Aircraft Flight Path Management - Automation (ICAO core competency)
AP	Application of Procedures (ICAO core competency)
AR	Augmented Reality
ATPL	Airline Transport Pilot Licence
BI	Behavioural Indicator
CBE	Competency-Based Education
CBT	Computer-Based Training
CBTA	Competency-Based Training and Assessment
CEGE	Core Elements of Gaming Experience
CEGEQ	Core Elements of Gaming Experience Questionnaire
COM	Communication (ICAO core competency)
CPL	Commercial Pilot Licence
EASA	European Aviation Safety Agency
EBT	Evidence-Based Training
FAA	Federal Aviation Administration
GBL	Game-Based Learning
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Airline Pilots Associations
IMI	Intrinsic Motivation Inventory

KNVvL	Royal Netherlands Aeronautical Association
KSA	Knowledge, Skills and Attitudes
L&T	Leadership & Teamwork (ICAO core competency)
MG	Mandatory Gameplay (experiment condition)
MP	Mandatory Participation (experiment condition)
MPL	Multicrew Pilot Licence
MPMG	Mandatory Participation, Mandatory Gameplay (experiment group)
MPVG	Mandatory Participation, Voluntary Gameplay (experiment group)
NG	No Gameplay (experiment condition)
NLR	Netherlands Aerospace Centre
PPL	Private Pilot Licence
PS&DM	Problem Solving & Decision Making (ICAO core competency)
SA	Situation Awareness (ICAO core competency)
SG4CD	Serious Games for Competency Development (model)
SOP	Standard Operating Procedure
StM	Shuttle to Mars (game)
UEQ	User Experience Questionnaire
VG	Voluntary Gameplay (experiment condition)
VP	Voluntary Participation (experiment condition)
VPMG	Voluntary Participation, Mandatory Gameplay (experiment group)
VPVG	Voluntary Participation, Voluntary Gameplay (experiment group)
VR	Virtual Reality
WM	Workload Management (ICAO core competency)

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Chapter 1

Introduction

On Thursday, January 15, 2009, US Airways Flight 1549 struck a flock of Canada geese, less than four minutes after take-off from La Guardia Airport, New York. With both engines out of order, the Airbus A320 first continued to climb but soon began a gliding descent. The captain took over control from the first officer, who then started working the engine restart checklist. Initially, the captain planned to return to La Guardia, but as he was directed towards a runway by Air Traffic Control, he responded that he was unable to do so. The captain requested landing at a different airport, which was immediately cleared, but again he was unable to do so. At that time, he announced that he would be landing the aircraft on the Hudson River.

This aviation incident became known as 'the miracle on the Hudson' [156]. Captain Sullenberger prevented a catastrophe that could have killed many, on board of the aircraft as well as in the city of New York, by safely landing the aircraft on the river [124, 187]. If we are ever in the situation to be aboard of such an unfortunate aircraft, we can only hope the pilots are able to perform a similar miracle. Here, we may ask the question, do all pilots have what it takes to perform such a feat?

Pilots of the older generation, like Captain Sullenberger, often have a background with diverse aviation experiences. Sullenberger learned how to fly at age sixteen. He was a fighter pilot in the US Air Force before he became an airline pilot, and he was a glider pilot. At the time of 'the miracle on the Hudson', he had over 40 years of aviation experience and almost 20,000 hours of flight time [187]. Many pilots of his generation have had similar careers with military backgrounds, or skills in leisure activities such as gliding or aerobatics before they started working on large, multicrew aircraft. These different experiences helped build their expertise and prepared them for a diverse set of emergencies [120]. Military pilots have been trained for the unexpected. They know how to anticipate and improvise. In leisure activities, such as gliding or aerobatics, pilots are trained to handle the aircraft manually without much automation in various circumstances.

In contrast, younger pilots have often taken a different, more direct route to becoming an airline pilot. They have started their careers in high-tech, modern aircraft with advanced automation, thus putting less emphasis on developing their experience with all kinds of situations and with manual control over the aircraft. Although the younger pilots have received extensive training, they have logged fewer hours of flight time when they start their airline careers, and as a result, they have less experience flying in different situations.

Research shows that, in critical situations, pilots fall back on prior experience [163, 185]. If pilots have little prior experience, what do they have to resort to? They may not have the necessary experience to fall back on. An important question is: how can the limited experiences of the younger pilots be compensated? This question is currently being investigated in different areas [185].

In general, experience leads to competencies. When pilots fall back on their experience, they rely on their competencies. Thus, competency development may be a way to make up for the lack of experience. We may ask how these competencies can be developed if not by experience. The answer is: competencies may also be developed by training [152].

In our research, we will study the viability of game-based learning as a training method to develop the competencies that are essential in critical situations. For this purpose, we define a suitable training method (see Definition 1.1).

Definition 1.1 - Suitable training method

A training method is considered suitable if the method has the quality of being appropriate for a particular purpose or situation.

Based on this definition we are able to define a viable training method (see Definition 1.2).

Definition 1.2 - Viable training method

A training method is considered viable if the method is suitable for reaching the learning objective, and is accepted as such by the target group.

In this chapter, we will start by exploring the lack of experience (Section 1.1). Next, we will discuss two perspectives on game-based learning as a possible way to reduce the experience deficit (Section 1.2). From there, we will formulate the problem statement that will guide our research, along with three research questions (Section 1.3). Then, we will describe the methodology along which we will perform our research (Section 1.4). In Section 1.5, we will provide the structure of this thesis. In Section 1.6, we will state the contributions of our research to the field of game-based learning (GBL). Finally, in Section 1.7, we will describe the environment in which we will perform our research.

1.1 Exploring the experience deficit

In difficult situations, experience may be what a pilot needs to bring the situation to a good end. Obviously, young airline pilots have not had the chance to gain the experience that their older colleagues have. Hence, they may lack the diverse experiences that older pilots possess and can rely on.

In this section, we will look at the cause of this difference in experience and the problem it may pose (Subsection 1.1.1). Subsequently, we will look at a possible solution to this problem by providing experience through training (Subsection 1.1.2).

1.1.1 The lack of experience

At the start of their airline pilot career, most younger pilots have less experience than their predecessors had when they started their careers. This is a result of at least five factors, viz. (1) a different career development, (2) more automation in modern aircraft, (3) increased overall safety in aviation, (4) new training curricula, and (5) more simulation-based training. Below, we briefly describe these five influencing factors. The order in which we describe the factors is not related to the power of their influence.

1. **Career development.** For older generation pilots, becoming an airline pilot was usually not an initial career choice. Often they started out flying for the military or flying on air freighters or smaller aircraft. Hence, they already had a substantial number of flight hours before being trained as an airline pilot. Nowadays, youngsters make their choice to become an airline pilot while still in secondary school [120].
2. **Automation in modern aircraft.** In modern aircraft, many tasks from take-off to landing can be performed by the autopilot. As a result, the pilots can focus on navigating, communicating, and maintaining situation awareness. They monitor the system and only need to take over control manually in case of a deviation. The advanced automation, in combination with highly reliable systems, has many safety benefits. However, as an adverse effect, it leaves the pilots with little exposure to unexpected situations [163]. Furthermore, in unexpected situations, the high-level automation may surprise the pilots by doing something other than they expect [185].
3. **Increased safety in aviation.** Since the rise of air travel, the safety of air travel has increased immensely. Although the media attention for every aviation incident that occurs, may give an opposite impression, air travel is the safest means of transportation [178]. Paradoxically, this increased safety poses a new threat. As pilots are hardly ever exposed to dangerous situations nowadays, they do not get to experience how it feels and how they should handle themselves under such pressure.
4. **New training curricula.** Aspiring pilots enrol in flight schools that are often connected to an airline. Since 2006, they can be trained for a specific type of multicrew aircraft to obtain their MPL. With this MPL, they become a first officer on a passenger aircraft while they have only a relatively small number of flight hours. Under the supervision of an experienced captain, they continue training and build their flight hours on that specific type of aircraft. Although the MPL has been implemented in

37 programmes [75], it has not delivered many pilots yet. Furthermore, the Federal Aviation Administration (FAA) of the US Department of Transportation does not recognise the MPL. The MPL will be discussed in more detail in Subsection 2.2.4.

5. **Simulation-based training.** Airline pilot training is an extensive programme with many hours of classroom and computer-based instruction, in addition to practical training. There has been a shift from hands-on flying in a variety of aircraft to training in flight simulators. These simulators are high fidelity copies of actual cockpits, and a simulator flight resembles an actual flight. However, flying a simulator is not the same as flying the actual aircraft. First, the experience is influenced by the pilot's awareness that nothing bad can actually happen [139]. Second, simulation-based training is focused on a relatively small set of scenarios and the pilots more or less know what is coming. Hence, the simulation-based training does not prepare the pilot for a wide range of unexpected situations. And third, in handling the scenarios in the simulator, pilots remain inside the normal flight envelope. The flight envelope refers to the defined limits of conditions such as speed, altitude, and acceleration that the aircraft is permitted to operate within [62]. Flight simulators do not have the aerodynamic modelling for beyond-the-normal-envelope flight [8, 191]. Outside the normal flight envelope, the simulator behaviour is inaccurate.

Together, these five factors have diminished the amount of experience that the younger pilots have when starting their airline pilot careers. Experience in itself is only one of the factors that make a pilot a well-qualified, competent pilot. However, through experience, a person will build up competencies. Section 2.4 will provide the necessary background on competencies, competency-based training, and its application in aviation.

Having little experience is not a problem in itself. For most normal situations, the pilots are adequately prepared by their training. The lack of experience may cause problems in the rare event that a serious, non-normal situation surprises or startles the pilot. It may be a situation that the pilot is not familiar with or a situation that is unprecedented. This thesis uses the term *critical situation* (see also Definition 2.5 on p. 21) for such situations as well as for full emergencies.

The technical knowledge and skills of a pilot are the basis of his[1] job performance, but in critical situations, it may come down to his non-technical competencies. For instance, being able to remain calm, and overseeing the situation are crucial to solving the problem at hand. The competencies needed in critical situations will be described in Section 5.1.

1.1.2 Providing experience through training

The lack of experience may result in pilots not developing the competencies they need in critical situations. The obvious solution for a problem caused by a lack of experience is ensuring that the pilots gain more experience. However, the current developments in airline pilot training do not support an increase in hands-on experience in the actual aircraft. Alternatively, if the competencies cannot be gained from actual flight experience, they

[1] For brevity, we use 'he' and 'his' wherever 'he or she' and 'his or her' are meant.

need to be gained otherwise. According to Parry [152], competencies can be developed through training. Hence, training may provide an alternative for experience to develop competencies.

Nowadays, an essential part of the current pilot training curriculum is done in flight simulators. Simulator training is suitable for aviator skills and procedures [150]. Additional simulator scenarios can be developed to practice for critical situations with a focus on the essential non-technical competencies rather than the technical skills. However, there are two drawbacks: (1) flight simulators are relatively scarce, limiting their availability and increasing the cost of use, and (2) the use of simulators is a formal way of training as it is highly standardised and regulated. Therefore, we should look for alternative training concepts that can complement simulation-based training in a less expensive, and more flexible way.

In our research, we will focus on GBL, which is a relatively cheap, easily accessible, and motivating training method. We define game-based learning as follows [206].

Definition 1.3 - Game-based learning

Game-based learning is a training concept that uses games with specific learning objectives that have been designed to balance gameplay with subject matter, and with the player's ability to apply the subject matter to the real world.

GBL is also known as *serious gaming*. It is a training concept that may provide a meaningful alternative to actual flight experience or simulation-based training to strengthen the competencies needed in critical situations [111].

Training benefits of GBL have been acknowledged in relation to widely accepted instructional concepts, such as situated learning [24], increased intrinsic motivation [128], and experiential learning [109]. Additionally, GBL brings practical advantages such as making mobile learning [41, 116] and on-demand training [83] possible in a broader context. Other technologies, such as simulations, and augmented and virtual reality can be incorporated into games to enhance the gameplay and the learning effects. Moreover, learning from games is a good match with the skills, attitudes, and expectations of the new generation of airline pilots [111].

In Chapter 2, we will provide background on GBL and airline pilots. Chapter 3 will elaborate on the design of games for competency development.

1.2 Two perspectives on game-based learning

When looking to apply GBL for the development of competencies by airline pilots, two perspectives need to be considered: (1) whether games are a suitable training method to develop competencies, and (2) whether airline pilots will accept to be trained through games.

1.2.1 The suitability of games to train competencies

Although most games for learning are being designed and applied for knowledge acquisition [22, 38], other learning outcomes can be achieved. In our research, we aim to investigate the suitability of using games to train competencies. If games are not suitable to train competencies, i.e., if competencies cannot be developed by playing a game, they will not be effective to help airline pilots to handle critical situations.

1.2.2 The acceptance of game-based learning by airline pilots

Game-based learning is still a relatively new training concept. Nevertheless, it has been successfully used in the military [20, 135, 158, 182] and health care [46, 77, 205].

So far, in aviation, and specifically in the training of airline pilots, game-based learning has not been applied widely. In part, this is due to legislation. As yet, GBL is not an accredited training method for aviation. Therefore, students cannot log the hours they spent on GBL as training hours. Once legislation allows the hours to be credited, game-based learning may be a viable training method for airline pilots.

To make GBL a successful training tool for airline pilots, (1) the training needs to be accredited, and (2) the intended target group (i.e., the airline pilots) should accept the technology as a training method. If airline pilots do not play the games, they will be unable to reach the learning objectives for which these games were designed.

1.3 Problem statement and three research questions

In Section 1.1, we described five factors that contribute to the younger airline pilots having little experience at the start of their careers. The lack of experience may cause the pilots not having fully developed all competencies they need in critical situations (see Definition 2.5 on p. 21). Hence, the younger pilots may be unable to act adequately in critical situations. In those situations, the outcomes can be catastrophic. Therefore, finding a different way of developing these competencies is crucial.

In Section 1.2, we then briefly introduced game-based learning: an innovative and promising training concept using games for learning. Games may be able to provide the younger pilots with an alternative form of experience. This leads to our problem statement, which reads as follows.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

To help answer the problem statement, we formulate three research questions.

Young airline pilots may lack certain competencies that are essential in critical situations. Developing these competencies will be the primary goal of the serious game. The game should be designed specifically for that.

In Section 1.2, we discussed two perspectives on the issue of game-based learning. The first perspective is related to the suitability of a serious game to train competencies. This leads directly to our first research question.

RQ 1: *How should a serious game be designed to support competency development effectively?*

The second perspective is related to the acceptance of game-based learning by airline pilots; i.e., whether airline pilots are open to game-based learning and are willing to play a serious game. This raises the question to what extent it matters whether the target group is willing to play a serious game. Playing and gameplay are commonly considered to be voluntary activities [26, 89]. Game designers believe that voluntary gameplay is fundamentally different from mandatory gameplay [69, 133, 135, 160]. Gaming is generally assumed to occur in a voluntary setting: a person has a choice to play or not to play. This will most likely be different in the case of serious games, as they will often be implemented as part of a curriculum. Hence, the gameplay of a serious game will generally be mandatory in nature instead of voluntary. This may have an effect on the outcomes of the serious game. Therefore, our second research question reads as follows.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

A common expectation for a successful training is that the learning leads to a change in behaviour that subsequently can be transferred from the training environment to the work environment. This issue is commonly referred to as 'transfer of training'. It was first brought up by Woodworth and Thorndike [212] at the beginning of the twentieth century and remains current. However, the first step towards a successful training is determining the reaction of the participants [105]. A positive reaction from the target group is almost a prerequisite. Without it, there may not be any learning, behaviour change or organisational effect. This applies to all types of courses, including courses based on game-based learning.

Consequently, we formulate our third research question as follows.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

Together, the answers to the three research questions will allow us to answer the problem statement.

1.4 Research methodology

Within our research, we will apply three research methods. To address the research questions, we will use (1) literature research, and (2) experiments. To identify which competencies are essential in critical situations, (3) a job analysis is used.

We will discuss the adopted methodology per research question (summarised in Table 1.1).

To answer RQ 1, we will identify and discuss the main requirements that a serious game should meet to support competency development, based on insights obtained from the literature.

To answer RQ 2, we will conduct three experiments to determine what the effect of voluntary play is on the outcomes of a serious game.

Table 1.1: Research methods for answering the research questions

	RQ 1	RQ 2	RQ 3
Literature research	×	×	×
Experiment		×	×
Job analysis			×

To answer RQ 3, we will perform a qualitative study to determine how airline pilots react to a serious game that is designed as a training method for competencies which are essential in critical situations. For the qualitative study, we will first design and develop the serious game. This game will be designed in accordance with the main requirements identified in answering RQ 1.

1.5 Thesis structure

The structure of this thesis is as follows.

Chapter 1: Introduction. In this chapter, the problem statement and three research questions are introduced, along with the research methodology and thesis structure.

Chapter 2: Background. In Chapter 2, we will provide background information on the five elements of the problem statement: (1) serious game, (2) train, (3) airline pilots, (4) to act adequately, and (5) critical situations.

Chapter 3: Towards a design model. In Chapter 3, we will identify and discuss the three main requirements that a serious game should meet for competency development (in accordance with RQ 1). Moreover, we will present the SG4CD model.

Chapter 4: The CloudAtlas game: Voluntary play in serious games. In Chapter 4, we will investigate (1) the effect of voluntary play on the learning effect of a serious game, and (2) the gameplay experience of the players (in accordance with RQ 2).

Chapter 5: Creating Shuttle to Mars: a game to provide experience. In Chapter 5, we will start by identifying the competencies that are essential in critical situations. Then, we will report on the design and development of the serious game *Shuttle to Mars*, which is aimed at developing the competencies that airline pilots need in critical situations. The preparations lead to the experiment described in Chapter 6.

Chapter 6: Measuring the Shuttle to Mars experience. In Chapter 6, we will investigate how airline pilots react to the *Shuttle to Mars* game and what their attitude is towards training competencies through GBL(in accordance with RQ 3).

Chapter 7: Conclusions and discussion. Finally, in Chapter 7, we will summarise the answers to the research questions and provide an answer to the problem statement. Moreover, we will formulate three conclusions and give an outlook on future work.

Table 1.2 gives an overview of the relations between the chapters and the PS and RQs.

Table 1.2: Overview of relations between chapters and the PS and RQs

	RQ 1	RQ 2	RQ 3	PS
Chapter 1	×	×	×	×
Chapter 2				×
Chapter 3	×			
Chapter 4		×		
Chapter 5	×		×	
Chapter 6			×	
Chapter 7	×	×	×	×

1.6 Contributions

This research makes the following four contributions to the field of game-based learning.

1. Competency development for airline pilots through game-based learning is explored for the first time. To our knowledge, the *Shuttle to Mars* game is the first game designed to develop the competencies that airline pilots need in critical situations.
2. Our Serious Games for Competency Development (SG4CD) model contributes to a dedicated competency development model for game-based learning. It provides guidelines on what elements need to be present in a serious game designed for competency development.
3. With our *CloudAtlas* experiments, the assumption of voluntariness in serious games is tested for the first time.
4. The reactions of the participants in our experiments show that game-based learning will be well-received by airline pilots.
5. This thesis emphasises that designing effective serious games for experience and highly professionalised users is a great challenge.

Together, the contributions listed above indicate that the competency development of airline pilots may benefit from the introduction of game-based learning into the airline pilot curriculum.

1.7 Working environment for the research

The research reported in this thesis was commissioned by the Training, Simulation & Operator Performance department of the Netherlands Aerospace Centre (NLR). NLR is the main organisation in the Netherlands for identifying, developing, and applying advanced technological knowledge in the area of aerospace.

NLR performs research aimed at making air traffic safer, more environmentally friendly, and more efficient. The Education & Training team of the Training, Simulation & Operator Performance department focuses on innovations in the training of aerospace personnel, such as pilots, air traffic controllers, and astronauts.

Chapter 2

Background

This chapter provides background information in support of the present research. The problem statement reads as follows.

Problem statement: To what extent can a *serious game* be used to *train airline pilots* to *act adequately* in *critical situations*?

The problem statement contains five main elements: (1) serious game, (2) train, (3) airline pilots, (4) to act adequately, and (5) critical situations. We will discuss these elements to show the relations between them.

For clarity, we will discuss them in a different order than they occur in the problem statement.

First, we look at airline pilots (Section 2.1), followed by how they are trained for their jobs (Section 2.2). Then we will define the critical situations airline pilots may have to deal with (Section 2.3). Acting adequately in such situations requires competencies. Hence, we will look at competencies and competency development next (Section 2.4). Subsequently, we will define game-based learning and discuss serious game design (Section 2.5). Finally, we will tie the elements together in Section 2.6.

The contents of this chapter are based on the following four publications.

1. Kuindersma, E. C., Field, J. & van der Pal, J. (2015). Game-based training for airline pilots. Paper presented at the Simulation-Based Training for the Digital Generation conference at the Royal Aeronautical Society. London, UK.
2. Kuindersma, E. C., van der Pal, J., van den Herik, H. J. & Plaat, A. (2015). Voluntary play in serious games. In A. De Gloria & R. C. Veltkamp (Eds.), *Games and Learning Alliance, 4th international conference* (pp. 131–140). Heidelberg, Germany: Springer.
3. Kuindersma, E. C., van der Pal, J., van den Herik, H.J., & Plaat, A. (2016a). Comparing voluntary and mandatory gameplay. *International Journal of Serious Games*, 3, 17.
4. Kuindersma, E. C., van der Pal, J., van den Herik, H. J., & Plaat, A. (2017). Building a game to build competencies. In J. Dias, P. A. Santos & R. C. Veltkamp (Eds.), *Games and Learning Alliance, 6th international conference* (pp. 14-24). Heidelberg, Germany: Springer.

2.1 Airline pilots

A little over a century ago, on January 1st, 1914, the first scheduled commercial passenger aircraft flew with one passenger [6]. The flight from St. Petersburg, FL to Tampa, FL is considered to have been the first airline flight, and that makes its pilot, Tony Jannus, the first airline pilot in history. It was ten years after the first controlled, sustained flight of a powered, heavier-than-air aircraft, by the Wright brothers [45].

Definition 2.1 - Airline pilot

An airline pilot is a professional pilot operating a passenger aircraft for a commercial airline.

In this section, we will look at airline pilots. First, we will describe the history of the airline pilot profession (Subsection 2.1.1). Then, we will take a look at the airline pilots of the future (Subsection 2.1.2).

2.1.1 A short history of the airline pilot profession

In the early days of aviation, pilots were pioneers. In the years between the First and Second World War, most pilots flew for the military. When commercial air travel became popular after the Second World War, many pilots joined the airlines after their military careers had ended [120]. For a long time, becoming an airline pilot was a career switch for pilots who had learned to fly elsewhere. The military was the main supplier of the airlines [120].

In 1961, the first integrated, *ab initio* (literally, 'from the beginning') education for airline pilots was established, and students without any prior flying experience could register to become an airline pilot [149]. Still, it was not until the 1980s, that becoming an airline pilot shifted from a career switch to a career choice. The *ab initio* training courses delivered increasingly more airline pilots. These pilots were well trained but did not have the experience that the prior generations had gained in the military or other types of aviation jobs [120].

2.1.2 Airline pilots of the future

Currently, there are 290,000 airline pilots in the world, and an increase up to 440,000 is expected in 2027. A total of 255,000 new pilots are needed to accommodate growth and to offset retirement [7].

The pilots of the future, who will be trained over the coming years, are considered to be part of the *Millennial Generation* [136] and the *iGen* [195]. These generations have spent their entire lives surrounded by and using digital technology, making it an integral part of their lives. Prensky [159] called the members of the Millennial generation the 'digital natives', contrasting them to older generations of 'digital immigrants' who had to learn to adopt digital technologies at a later age.

Members of the younger generations may have specific preferences for learning, work, and communication. They are believed to have different thinking patterns as they are used to receiving information quickly, to multitasking and to parallel processing. They prefer graphics to text, wish non-linear access to information and thrive on immediate satisfaction. This group of learners may benefit from a move away from traditional teaching methods which generally use lectures to transfer information [40].

Using digital technology would be an appropriate method to educate them. Prensky [159] believes that serious games are better suited for the current generations of 'digital natives' than traditional methods, leading to better learning outcomes.

It all implies that other, more appropriate and modern training methods should be used in addition to the traditional methods to utilise the full potential of students from these generations.

2.2 Airline pilot training

In this section, we will look at the development of airline pilot training over time. First, we will describe the early days of aviation, before airline pilot training was standardised (Subsection 2.2.1). Then, we will look at the introduction of standardised licensing and training (Subsection 2.2.2). In Subsection 2.2.3, we will discuss the traditional training approach for the ATPL. In Subsection 2.2.4, we will discuss the modern training approach of the MPL, introduced in 2006. Finally, we will take a brief look at innovations in training delivery in Subsection 2.2.5.

2.2.1 Before standardised airline pilot training

In the early days of aviation, learning to fly carried a certain amount of danger, as it was mostly done by completing exercises in the actual aircraft [150]. The very first pilots learned by discovery, or by observing and imitating experienced pilots. Later on, airline pilot training was formalised and subjected to regulations. The first training devices, or early simulators, were invented around 1910. They allowed a safer way of training [150].

In the early twentieth century, aircraft were mainly used in the military. The First World War required a large number of pilots to be trained. This led to selection criteria and standardised training for military pilots. Although several airlines were established in the period between 1914 and 1922, commercial aviation did not yet catch on with the general public. At that time, air travel could not compete with railroad travel. Since the operating costs of air travel were high and the capacity for passengers was limited, air travel was quite expensive. Moreover, at that time, air travel was not as safe as railroad travel.

In 1918, the US Postal Service started delivering mail by aeroplane as an attempt of the US government to establish an air transportation system. The 1930s and 1940s brought several developments that improved the safety and comfort of air travel, such as the use of radio, and the invention of jet engines, better instruments and the pressurised cabin. Larger and faster aircraft were built, allowing the transport of more passengers [45].

After the Second World War, commercial aviation started to grow, and more airline pilots were needed. They came (again) from the military, bringing along their military training and the experience they had gained [120].

2.2.2 Standardised licensing and training

As air travel was growing, the ICAO was established in 1947, to promote the safe and efficient development of civil aviation. Part of the task of International Civil Aviation Organization (ICAO) was the adoption of standards and recommended practices for international aviation. Among them were the standards for pilot training and licensing, recorded in ICAO Annexes 1 and 6 [39, 207].

The issuance of licences

Since 1947 until today, the requirements for each licence are determined by ICAO in the International Standards on Personnel Licensing [154], but the implementation varies from country to country. Pilot licences are issued by aviation authorities, such as the European Aviation Safety Agency (EASA) in Europe and the FAA in the United States.

The licence requirements are time-based. For each licence a prescribed number of flight hours is mandatory, as well as a number of theoretical study hours. Different types of flight hours are distinguished, such as Pilot in Command or Instrument Flying hours. Once the required number of hours is logged, the licence will be issued.

In standardised training courses, pilots are trained to meet the requirements of the licence they wish to obtain. Hence, the training of pilots is strongly related to the licensing.

In the traditional training approach, a pilot needs to earn successive licences to obtain an Airline Transport Pilot Licence (ATPL). This is referred to as *stacking*. The pilot first learns how to fly a single-engine aircraft and obtains a Private Pilot Licence (PPL). Then, he learns to fly larger, commercial aircraft and obtains a Commercial Pilot Licence (CPL). Finally, the pilot will earn the ATPL.

The modern approach allows a pilot to obtain the MPL without stacking.

2.2.3 The traditional approach: Airline Transport Pilot Licence

From the introduction in 1947 until now, most airline pilots have been trained in the traditional way. At the end of their training, they have earned the ATPL, which is required to work for most airlines.

Requirements for the ATPL

An ATPL permits the holder to operate as a captain or co-pilot on a multicrew multiengine aircraft, in addition to the single-pilot operation of a single- or multiengine aircraft.

The ATPL requires a total of 750 hours of theoretical study. The pilots need to pass a total of fourteen theoretical exams, on topics such as principles of flight, navigation, and meteorology.

With a CPL and a completed ATPL theory course, a pilot has a *frozen ATPL*. A frozen ATPL allows the pilot to be employed as a co-pilot on a multicrew multiengine aircraft. After meeting the flight time requirements (i.e., 1500 flight hours), the licence will be unfrozen, and a full ATPL will be issued. See Table 2.1 on p. 18 for ATPL requirements.

The general structure of ATPL training

The initial training of airline pilots is generally split into *Ground School* and *Flight School*. After graduation, a pilot will receive additional training from an airline before he may start to work as an airline pilot. Throughout his career, a pilot will need to partake in *recurrent* training to keep his knowledge and skills up to date.

Ground School. In *Ground School*, the extensive theoretical part of the ATPL training is taught, with a focus on knowledge transfer. Ground School usually takes approximately nine months. During this period students do not get to fly. Traditional training delivery methods such as print media, lectures, discussions, and drill & practice are commonly applied.

Flight School. After successful completion of all theoretical exams, the aspiring pilot will start *Flight School*. This is the practical, flight training part of the ATPL training. A major part of the training is hands-on. It may take place in the actual aircraft or a simulator. Instructors apply observations, step-by-step demonstrations, briefing & debriefing, and in-seat instruction to teach skills and procedural knowledge.

Appendix A describes the training delivery methods commonly used by instructors to teach their students, both in Ground School and Flight School.

After graduation. Once a pilot graduates and finds employment with an airline, he will receive Base Training and Initial Operating Experience training. In Base Training, the pilot will fly the actual aircraft without passengers and with minimal crew, to perform a variety of procedures. For the Initial Operating Experience training, the pilot will be under the supervision of a *line check airman* who is also the captain of the aircraft during his first 40 actual flight hours.

Recurrent training. After obtaining the ATPL, the pilot will need to participate in recurrent training and annual checks. Every airline pilot will take one or more courses each year to keep up his knowledge and skills. These recurrent courses cover a variety of topics including Instrument Rating, Crew Resource Management and Operator Proficiency. Recurrent courses may take place in the actual aircraft or a simulator. The period after which knowledge and skills will need to be updated through recurrent training varies with the subject. It can range from six months to three years.

Adaptations in airline pilot training

Over time, aviation has seen developments that have had an effect on the ATPL training. Aircraft became faster, safer, and highly automated. Incidents involving airliners created new insights into the optimal operation of aircraft. Adaptations were made to the curriculum and the delivery methods to keep the training up to date. However, overall, the training of airline pilots has seen only a few changes since the first adoption of Annex 1 [78, 207].

Simulators. A major innovation in aviation training was the standardisation of simulators as training devices in the 1970s. This allowed part of the training to be moved from the actual aircraft to the simulator, improving safety and lowering costs [150].

Computer-based training. With the advent of the personal computer in education, computer-based training (CBT) also became part of the ATPL courses. In the 1980s, CBT was standardised by ICAO, allowing it as a formal training method for airline pilots to fulfil the requirements in theoretical study hours.

To incorporate these developments, over time the regulations regarding training delivery methods have been modified to allow the use of simulators and CBT.

Multicrew aircraft. Modern airliners are multicrew aircraft. A flight crew generally consists of a *captain* and a *first officer* (also called a *co-pilot*). During a flight one of the two holds direct responsibility for flying the aircraft as the Pilot Flying (PF). The other is referred to as Pilot Monitoring (PM). He carries out support duties and monitors the PF's actions [157]. The PM should be sufficiently aware of the aircraft state in order to assume aircraft control in case of an emergency. A number of fatal aviation incidents have led to new insights into the importance of crew interaction in the cockpit [85].

Automation. The increasing use of highly automated aircraft affects the pilot tasks, roles, and responsibilities in the cockpit and thus changes the competence requirements for future pilots. By the year 2030, necessary pilot competencies are expected to include operational monitoring, visualisation, vigilance, and originality [58]. They need to be able to fully take over from the automated systems at any time, having a clear total picture of relevant elements of air traffic and being able to come up with unusual or clever ideas [58].

New insights and lessons learned from the outcomes of aviation incidents have led to the introduction of new modules into the ATPL curriculum, such as the Advanced Quality Training Program and Upset Prevention and Recovery Training. Multi Crew Cooperation and Crew Resource Management training [85] training have been introduced in order to pay more attention to communication and collaboration.

2.2.4 A modern approach: Multicrew Pilot Licence

In 2006, ICAO introduced the MPL licence, along with the modern educational approach of competency-based training [101, 140, 207, 208]. It was the first major change since the standardisation of CBT in the 1980s.

The objective of the MPL is to provide an alternative pathway for student pilots to become first officers on modern airliners [56, 140, 207]. Right from the start, the MPL training course allows the student pilots to operate as part of a crew in a specific aircraft type for a specific airline [56].

The MPL approach to airline pilot training makes more use of simulators, allowing a reduction in flying hours [56]. There is more focus on multicrew operation and less focus on single-pilot operation.

Competency-based training in aviation

In aviation, competency-based training (see Definition 2.8) is commonly referred to as competency-based education (CBE) and also as evidence-based training (EBT) [61, 101]. We will use CBE to indicate competency-based training throughout this thesis. More recently, the term CBTA has been introduced as the aviation wide approach to competency-based training.

CBE is implemented in aviation for the training of airline pilots, as well as for maintenance engineers, air traffic controllers, and cabin crew. ICAO defines competency as 'the combination of knowledge, skills, and attitudes required to perform a task to a prescribed standard under a certain condition' [129, 207]. This corresponds with our definition of competency (see Definition 2.6).

The focus of CBE training programs is on the quality of training rather than on the number of hours. focusing on pre-specified competencies allows the application of the most efficient means of skill development rather than being obliged to follow a curriculum of prescribed numbers and types of training hours [81, 101]. In general, this makes CBE programs shorter and less expensive than traditional programs. CBE is also considered to be more student-centred, as faster learners are not slowed down by the curriculum, and slower learners can take their time to master a subject without being forced to move on prematurely.

Requirements for the MPL

The MPL permits the holder to operate as co-pilot on a multicrew, multiengine aircraft in commercial air transport with a specific airline. In contrast to the ATPL, the requirements for the MPL are not based on hours but on competency. Still, minimum requirements for flying hours and theoretical study apply. Table 2.1 shows the requirements for both ATPL and MPL. The main differences can be found in the required minimum age and the required minimum total flight hours.

We will discuss competency-based training in more detail in Section 2.4.

The general structure of MPL training

Any MPL training course consists of four phases [78], which are followed by Base Training and Line Training within the airline environment. Currently, the MPL training courses apply the same theoretical examinations as the traditional ATPL training courses. The four MPL phases and their contents are as follows [78].

Table 2.1: ICAO licence requirements for ATPL and MPL

	ATPL	MPL
Purpose	Commercial, professional	Commercial, professional
Minimum age *	21*	18*
Minimum total flight hours*	1500 hours*	250 hours*
Theoretical instruction	750 hours 14 exams	750 hours 14 exams
Flight test	ATPL Skills test	MPL Skills test
Additional ratings	Class/Type Rating	Class/Type Rating
Renewal period	90 days IR: 1 year	90 days IR: 1 year

Differences between ATPL and MPL requirements are marked with *.

1. **Core.** Ground School and basic single-engine single-pilot training
2. **Basic.** Introduction of multicrew operations & instrument flight
3. **Intermediate.** Multicrew operations applied to multiengine turbine aircraft
4. **Advanced.** Type Rating within airline environment

ICAO, the International Air Transport Association (IATA), and the International Federation of Airline Pilots' Associations (IFALPA) have identified eight competencies to be the ICAO Core competencies [129, 207]. They describe the technical and non-technical knowledge, skills and attitudes that are needed to operate safely, effectively and efficiently in a commercial air transport environment (see Table 2.2). The ICAO core competencies form the basis of the MPL curriculum. Each competency is divided into a minimum of six and a maximum of thirteen behavioural indicators. The behavioural indicators can be found in Appendix C.1 on p. 211. The behavioural indicators are used to assess the demonstration of competencies by the student pilots. Once the required level of performance is met, the competency is considered achieved [129].

Table 2.2: ICAO core competencies

ICAO Core competencies
1. Application of Procedures (AP)
2. Communication (COM)
3. Aircraft Flight Path Management - Automation (AFPM-A)
4. Aircraft Flight Path Management - Manual (AFPM-M)
5. Leadership & Teamwork (L&T)
6. Problem Solving & Decision Making (PS&DM)
7. Situation Awareness (SA)
8. Workload Management (WM)

Acceptance of the MPL approach

In 2006, the introduction of MPL and MPL training courses was received with scepticism [56]. Advocates of MPL praised the innovative way of training fully capable pilots in less time using technological advancements. In contrast, critics stated that cadets could not gain sufficient practical flying experience due to the reduction in flight time. MPL has advantages as well as disadvantages (see Table 2.3).

Table 2.3: Advantages and disadvantages of MPL [141]

Advantages
▪ Direct training for co-pilot duties. ▪ Training starts in a multicrew environment. ▪ Crew Resource Management and Threat Error Management are core foundations of the MPL syllabus. ▪ Does not dictate high number of solo flight hours on small aircraft like the current CPL. ▪ Flight academies and airlines must be well-linked and cooperative to develop this new licence. ▪ Airline and aircraft-specific training, therefore, training is more relevant. ▪ Greater levels of standardisation for pilot training worldwide. ▪ Trainees have their early experiences, and make their initial errors, in a safe and controlled environment.
Disadvantages
▪ Trainees cannot fly solo until sufficient hours are met on single-engine aircraft. ▪ Could be a real threat to safety as it is radically different from the current standard of training. ▪ Actual flying hours are reduced by 50% under the MPL licence compared to CPL. ▪ There are accusations that the MPL licence was driven mainly for economic interests. ▪ Uncertain whether trainees can learn to fly in an environment without real danger to life, e.g., simulators. ▪ Simulators may not be able to replace real-life Air Traffic Control environment.

The discord on the value of MPL reflects on the acceptance. Out of the 91 ICAO member states, 53 had adopted MPL regulations in 2015 [78, 208]. In September 2016, ICAO had registered a total of 1,822 MPL graduates and 3,613 MPL students in 37 MPL programs [75].

2.2.5 Innovations in training delivery

In addition to CBE, there are several innovations in training and education that are promising for aviation training, but that are not yet being used on a large scale. Such methods may offer advantages over the traditional training methods, such as (1) flexibility in time and space, and (2) their appeal to the next generation of airline pilots. This thesis focuses on serious games and game-based learning. In Section 2.5, we will elaborate on serious games and GBL.

Below, we define serious games (Definition 2.2), and recall[1] our definition of game-based learning (Definition 1.3).

[1] Please note that we recall a definition that has been defined previously. For this reason it maintains its original number.

Definition 2.2 - Serious games

Serious games are games - digital and non-digital - with specific learning objectives, that have been designed to balance gameplay (fun) with subject matter (learning) [108].

Definition 1.3 - Game-based learning

Game-based learning is a training concept that uses games with specific learning objectives that have been designed to balance gameplay with subject matter, and with the player's ability to apply the subject matter to the real world.

Other technological innovations that may become valuable to supplement the theoretical and simulation-based training of airline pilots are augmented reality (AR) and virtual reality (VR). At this time, AR and VR are not considered as fully independent training methods, but they can be integrated into a serious game. Below, we define and briefly describe AR (Definition 2.3) and VR (Definition 2.4).

Definition 2.3 - Augmented reality

Augmented reality is a live view of the physical, real-world environment of which elements are augmented in real-time by computer-generated sensory input.

AR is the technology of adding digital information to the physical world. The technology can enhance a user's current perception of reality. Advanced AR technology can help to make the information about the real world surroundings of the user interactive and can digitally manipulate them [167].

Augmented reality is currently being used on a limited scale in training, predominantly for explanation purposes. When AR reaches maturity, it can function for a broader range of applications. In potential, AR is suitable for electronic on-the-job support and can, therefore, be used for just-in-time, just-enough, just-in-place training and might replace parts of initial training for aviation professionals [142].

Definition 2.4 - Virtual reality

Virtual reality is the computer simulation of physical presence in places in the real world, as well as in imaginary worlds.

VR environments are mostly visual experiences, displayed on a computer screen or through special head-mounted displays. Some simulations include sensory information, such as sound and even tactile information. The technology of creating a virtual world immerses the user.

While wearing a VR headset, the user is mostly unaware of the actual environment. The immersion effect gives the user the feeling they are present in the virtual environment. As a result of this effect, VR may be used in pilot training to replace or complement certain training in flight simulators [202]. This would decrease costs and it may allow for more personalised and even unsupervised training. The high level of immersion of VR technology can also support specific individual training needs [142].

2.3 Critical situations

In this section, we will first look at the classification of situations into normal and non-normal situations, which is commonly used in aviation (Subsection 2.3.1). Then, we will define critical situations as a specific category of non-normal situations (Subsection 2.3.2).

2.3.1 Normal and non-normal situations

In aviation, situations are commonly categorised as *normal* or *non-normal* situations. *Normal* situations are those in which everything goes according to the plans and procedures. The plans and procedures are recorded in Standard Operating Procedures (SOPs). The SOPs contain standard checklists that should be accurately followed for a wide range of tasks in normal situations. Airline pilots working for any airline will receive the SOPs from their company.

A situation in which it is not possible to operate the aircraft using the normal procedures is considered a *non-normal* situation. SOPs also include many checklists that must be followed in non-normal situations. A non-normal situation is not necessarily an emergency. It may become an emergency when the safety of the aircraft or persons on board or on the ground is endangered [59]. The SOPs also include checklists for many different emergencies. Non-normal situations or emergencies occur every day but rarely result in accidents [25].

In this thesis, we do not focus on all non-normal situations or even on all emergencies. We focus on *critical situations* (see Definition 2.5).

2.3.2 Defining critical situations

During a flight, there may be a moment that something unexpected happens, i.e., what happens does not match with what the pilots anticipated [185]. Most of these unexpected events do not pose a problem, as pilots are trained to handle them by using the checklists and procedures. When an event is unexpected and potentially dangerous, and, on top of that, unknown to the pilot involved, we define it as a *critical situation*.

Definition 2.5 - Critical situation

A critical situation is an event during any stage of flight, that is unexpected and unknown to the pilot involved, and potentially dangerous.

Hence, a critical situation is an unexpected non-normal situation, for which the pilot does not have a checklist or procedure, either because they do not exist or the pilot is unaware of them. A critical situation may (momentarily) surprise the pilot, causing him to lose his grip on the situation, and the situation may become an emergency. In critical situations, the pilot's abilities to stay calm, think, and act are essential. In Chapter 5, we will investigate the competencies needed to act adequately in these situations.

2.4 Competencies

In this section, we will look at competencies and competency development. First, we will define competencies and competency development (Subsection 2.4.1). Then, we will take a look at competency-based training (Subsection 2.4.3) and training design for competency development (Subsection 2.4.2).

2.4.1 Defining competencies and competency development

The word *competency* is closely connected to *competent*. When an aircraft is boarded, one expects the crew to be competent. In everyday usage, this means that they are expected to do their job correctly. According to the Oxford Living Dictionaries [37], we count on them "having the necessary ability, knowledge or skill" to fly that aircraft safely. One may also assume that they will be efficient and capable.

Competencies are more than just skills. Skills indicate *what* an individual needs to be able to do, to perform his job, whereas competencies indicate *how* an individual needs to behave or act in order to be successful in his job. In competencies, the whole is greater than the sum of its parts. The skills are interrelated with knowledge and attitude.

Definition 2.6 - Competency

A competency is an integrated set of knowledge, skills, and attitudes that allows an individual to perform a task or activity within a specific job and under a variety of job circumstances.

Competencies are commonly described in terms of knowledge, skills and attitudes (KSA) and assessed by observing behavioural indicators [177]. The same terms are used in Bloom's taxonomy of educational objectives [10, 21] which is a classification of behaviours that are important in learning. The taxonomy was originally published in 1956 [21] and has been updated since [10, 31]. Bloom's taxonomy distinguishes between three types of learning objectives, viz. (1) cognitive (knowledge), (2) psychomotor (skills), and (3) affective (attitudes). It provides hierarchical models for each of the three learning domains.

Within the domains, learning objectives are classified based on increasing levels of complexity. These levels go from simple to complex, from concrete knowledge to abstract evaluation. Learners should go through all levels to develop knowledge and skills that are internalised and can be used in new situations.

The process of competency development is a series of doing and reflecting, in which a person moves through five levels of competency [53]: (1) novice, (2) advanced beginner, (3) competence, (4) proficiency, and (5) expertise. The objective of professional training is to help the novice student to become proficient at his job, and to become an expert eventually.

In competencies, knowledge, skills and attitudes are integrated. This makes the development of competencies more complex than acquiring knowledge or learning a skill [201]. This complex learning involves the coordination of constituent skills and transfer of what is learned from the learning environment to the work setting [201].

We define competency development as follows.

Definition 2.7 - Competency development

Competency development is the acquisition and enhancement of competencies, either through experience or through training [152].

2.4.2 Training design for competency development

Instruction within a competency-based curriculum is not necessarily designed to support competency development. CBE and its underlying theories are curriculum theories, and not so much an instructional design theory [132]. CBE gives guidelines on how to build a competency-based curriculum, but it does not provide guidelines for the design of the instruction or the form of the training.

Van Merriënboer and Kirschner [201] list nine examples of theoretical design models that can be applied for complex learning. These models converge on one central point: the need for authentic learning tasks as the driving force for complex learning. Authentic learning tasks help learners to integrate all parts of a competency (knowledge, skills and attitudes). They stimulate the coordination of constituent skills, and they facilitate the transfer of what has been learned to new situations and tasks [107].

Among the nine theories mentioned by Van Merriënboer and Kirschner [201] are the well-known cognitive apprenticeship theory [36], the constructivist learning environments [96], and the 4C/ID model [198]. Of these theories, we find in particular the Four Components for Instructional Design (4C/ID) model interesting for our research. Van Merriënboer [198] introduced the 4C/ID model in 1997, providing guidelines for instructional design for competency development. The theoretical model of 4C/ID has later been adapted by Van Merriënboer and Kirschner [201] to provide more concrete guidance in the prescriptive "Ten Steps to Complex Learning" approach.

In Chapter 3, we will use the 4C/ID model as the basis for answering RQ 1. Whereas the other models are mostly focused on curriculum design in general, the 4C/ID model is more specific and provides guidelines to design learning activities. On the design research map Sanders [176], the 4C/ID model can be positioned as a research-led model with an expert mindset. In Section 3.2, we will translate the components of the 4C/ID into game elements.

The 4C/ID model

The 4C/ID model [199] describes training environments for complex learning in four interrelated components: (1) learning tasks, (2) supportive information, (3) procedural information, and (4) part-task practice (see Figure 2.1). We follow the order of the components as given by Van Merriënboer and Kirschner [201]. They describe the four components as follows [201, p. 12-13].

1. ***Learning tasks.*** *Authentic whole-task experiences based on real-life tasks that aim at the integration of knowledge, skills, and attitudes. The whole set of learning tasks exhibits high variability, is organised in simple-to-complex 'task-classes', and exhibits diminishing learner support within each task class.*
2. ***Supportive information.*** *Information helpful for learning and performing the problem-solving, reasoning, and decision-making aspects of learning tasks, explaining how a domain is organised, and how problems in that domain are (or should be) approached. Supportive information is specified per task class and is always available to learners. This information provides a bridge between what learners already know and what they need to know to successfully work on the learning tasks.*
3. ***Procedural information.*** *Information prerequisite for learning and performing routine aspects of learning tasks. Procedural information specifies exactly how to perform the routine aspects of the task and is best presented just in time; precisely when learners need it. It is quickly faded as learners gain more expertise.*

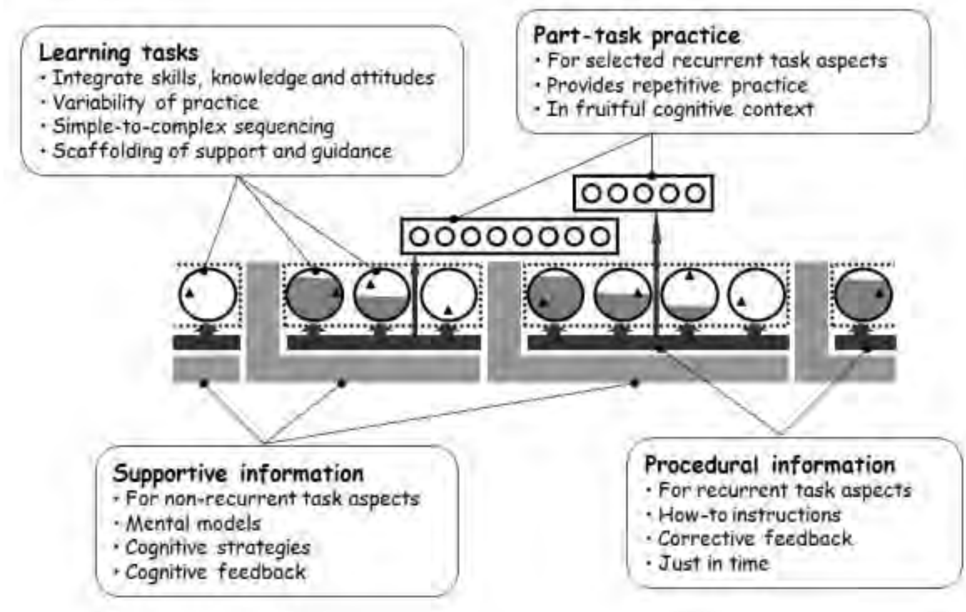


Figure 2.1: Four Components for Instructional Design (4C/ID) [201]

The 4C/ID model offers a holistic approach to designing training environments for the development of competencies. It aims to design training environments that let students acquire and transfer professional competencies to an increasingly varied set of real-world

Van Merriënboer, J. J., & Kirschner, P. A. (2018). *Ten steps to complex learning: A systematic approach to four-component instructional design (3rd edition)*. New York, NY: Routledge.

contexts and settings [199, 201]. The model revolves around whole-task practice to integrate knowledge, skills and attitudes, i.e., competencies. A task is not divided into steps that are practised separately and then combined, but it is practised as a whole. This allows the student to perform the task in a way that resembles the task performance in a job setting.

Any learning task should be authentic. The idea of authentic learning tasks is the core of the 4C/ID model. Authentic learning tasks are realistic and meaningful. They challenge the student to apply knowledge and skills within a context similar to the working environment. Learning tasks consist of multiple assignments, in which both repetition and variation are important.

The learning tasks are combined into task classes, based on complexity. Within the task class, learning tasks are varied to improve transfer of the acquired competencies. Learning tasks and task classes are sequenced to allow a gradual increase of complexity. Guidance and support should gradually decrease during a training program.

The 4C/ID model links to multimedia principles [200] allowing the model to be used in digital environments, such as serious games. Several studies have applied the 4C/ID model to game design [60, 88, 126, 196]. Although these studies have linked game characteristics to the elements of the 4C/ID model, none of the studies is conclusive about what elements should be present in a serious game to support competency development.

With our research, we aim to provide guidelines about what elements to include in the design of a serious game for competency development. In Section 3.2, we will translate the 4C/ID model into characteristics that should be represented by elements of a serious game for competency development.

2.4.3 Competency-based training

In Subsection 2.2.4, we have briefly discussed competency-based training, which in aviation is commonly referred to as CBE.

Although CBE originated in the 1960s, it has been getting more attention since the turn of the century. CBE is a popular model for curriculum development, flowing from a behavioural foundation. CBE can be a highly effective training approach, particularly when the curriculum is specified and sequenced [132].

We define competency-based training as follows.

Definition 2.8 - Competency-based training

Competency-based training is a student-centred training approach that measures learning outcomes rather than time. Assessment is based on students demonstrating specific behaviour associated with competencies.

The theoretical origins of CBE are not well established. According to McCowan [132], CBE originates from two learning theories, viz. (1) Thorndike's behaviourism and (2) Taylor's scientific management. McCowan [132] also connects CBE to Dewey's progressive education. Hodge [87] speaks of "theoretical resources grounded in behaviourism and systems theory" and of "humanist contributions in the form of mastery learning". Magnusson and Osborne [127] state that CBE includes "elements of programmed instruction, specified behavioural objectives, hierarchical beliefs of knowledge acquisition and social behaviourist assumptions about learning techniques".

CBE begins with a clear specification of the competencies that are to be developed and at what level the students should master them [16]. These specifications are made available in competency texts, which are commonly developed by educators in cooperation with the work field [101]. If a student can show evidence that he already has mastery of a particular competency, he should be allowed to move to the next level. This evidence can be provided through a prior learning assessment, such as a test or a completed project. A student's rate of progress through a programme is based on the mastery of the competencies, instead of time or the number of courses completed [101].

Competency-based training in aviation

In aviation, CBE is also gaining popularity (see also Subsection 2.2.4). Although the adoption of CBE is increasing, the training approach is not free from criticism [101]. After implementing the MPL training in 2006 (see Subsection 2.2.4), ICAO is now (2019) proposing to extend CBE to the training of all commercial pilots as well as other groups of aviation personnel, such as aircraft maintenance personnel, air traffic controllers, and cabin crew [2]. For this purpose, ICAO has installed a CBTA task force and updated the "Procedures for Air Navigation Services - Training" documents (PANS-TRG) [162]. Specifically, Amendment 5 will introduce (1) revised definitions for terms related to competencies; (2) a description of how competency-related concepts are interlinked; and (3) a generic methodology to design competency-based training and assessment. This amendment will become applicable in November 2020.

2.5 Game-based learning

This section will provide a background to the topic of game-based learning. First, in Subsection 2.5.1, we will define game-based learning and the related concepts of gamification and simulation. Then, in Subsection 2.5.2 we will look at serious games research. In Subsection 2.5.3 we will discuss the voluntariness of gaming. Finally, in Subsection 2.5.4 we will look at game-based learning for aviation.

2.5.1 Defining game-based learning and serious games

GBL is also commonly referred to as *serious gaming*, although this term is slowly being replaced. Abt was the first to introduce *serious games* in relation to instruction in 1970 [1]. However, the term was popularised by Sawyer and Rejeski in 2002 [179]. Even before Abt introduced the term, it had already been used in different contexts [51]. The actual use of games for learning is not a recent practice [188, 209]. The essence of serious games is play, which has a vital role in human development. Children acquire many essential competencies and develop important social structures by means of play [89, 155, 204]. This has long been acknowledged in the development of young children, but also applies to adult learning. Games have been used in training for centuries [135, 188, 209]. The use of war games as military exercises has been traced back as far as 4000 years ago [135], and role-playing has been long integrated into training such as for sales and communication skills.

Although the first use of the term *serious gaming* [1] focused on non-digital educational games, nowadays it includes both digital and non-digital games. The current perception places emphasis on digital, online games, but analogue games, such as board games, are still widely used.

In education and training, games are increasingly accepted as a way to inform and instruct. Several terms are applied to indicate this use, such as game-based learning, educational games, instructional games, applied games, edutainment, and serious gaming. In our research, we will use the term *game-based learning* and *GBL*.

In Chapter 1, we defined GBL and serious games. For readability, we recall[2] our definitions of game-based learning (see Definition 1.3) and serious games (see Definition 2.2) here.

Definition 1.3 - Game-based learning

Game-based learning is a training concept that uses games with specific learning objectives that have been designed to balance gameplay with subject matter, and with the player's ability to apply the subject matter to the real world.

Definition 2.2 - Serious games

Serious games are games - digital and non-digital - with specific learning objectives, that have been designed to balance gameplay (fun) with subject matter (learning) [108].

There is not one single definition of serious games, but there are many [1, 23, 108, 135, 216]. Serious games share many characteristics with other types of games, but in addition, they have a *serious* component. They do not have entertainment as their primary purpose.

At the basis of most definitions of serious games lies the definition of games in general [1, 89, 97, 133, 174]. Although there is not a particular definition of games that is universally accepted, game designers have reached considerable consensus about the main principles of games [112]. However, a game does not necessarily need to satisfy all principles. Games often have rules, goals, a story-line, and outcomes. They offer interaction, feedback, and competition. Furthermore, and critically important: they are fun, or - as they can be frustrating at times – at least they are *immersive* or *engaging* [112].

We will use the following definition of games.

Definition 2.9 - Games

A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome [174].

[2] Please note that we recall two definitions that have been defined previously. For this reason they maintain their original numbers.

Please note that we use the terms *purpose*, *goal*, and (learning) *objective* within the context of GBL. Although these words have a similar meaning, we use them with a specific intent.

The *purpose* of a game is not the same as the *goal* of the game. The *goal* of a game can be to solve a puzzle, rescue a princess or get the highest score, while the *purpose* may be to learn about fractions, a foreign culture or just entertainment. For serious games, the *purpose* is to reach a learning *objective*. In some serious games, the *goal* of the game and the *purpose* of the game (i.e., reaching the learning *objective*) may coincide.

Below, we define these terms.

Definition 2.10 - Purpose

The purpose is the reason for which a game is played or for which it exists.

Definition 2.11 - Goal

The goal is the object of a player's ambition or effort with regard to the game; it is an aim or desired result.

Definition 2.12 - Objective

The (learning) objective is a specific result with regard to learning that a person aims to achieve with available resources and within a time frame. Objectives are specific and easy to measure.

A growing market

Interest in serious games has seen significant growth. A steep increase has been in the number of serious games developed [9, 51] and the value of the global market for products and services related to serious games and GBL [5]. In 2014, worldwide revenues for GBL were $ 1.8 billion [3]. Since then, interest in GBL has further increased, and the worldwide GBL market is now in a boom phase [5]. In 2017, the market for GBL had reached a value of $ 3.2 billion [4] and is projected to reach over $ 17 billion by 2023 [5].

Currently, we see that some economic sectors make more use of serious games than others. The military still has a tradition of using games for training [188, 210] and is a front-runner in the application of GBL. Gaming technology allows the creation of engaging simulations at a lower cost than traditional simulations that are still commonly used in the military [188]. In the past, simulations and games focused mostly on combat training, but more recently military games are covering soft skills as well.

Besides the military, government, education, health care, and corporations are the primary markets for GBL [135]. Government games are mostly aimed at the training of first responders; e.g., police and firefighters. In education, especially online games are finding their way to the classrooms. These games cover a great range of topics and are mostly aimed at increasing student motivation. Health care uses games for the treatment, recovery, and rehabilitation of patients, but also increasingly for the training of medical professionals. Corporate training is adopting the use of games in the workplace in addition to e-learning courses.

2.5.2 Serious games research

In addition to the growing number of serious games being developed, there has been an exponential increase in the number of serious games publications [22, 33, 38, 90, 117, 214].

In this section, we will look at meta-analyses of serious games studies, learning in games, and serious games design.

Meta-analyses

Serious games studies are strongly heterogeneous in design, making meta-analysis a difficult task [38].

According to Boyle et al. [22] and Connolly et al. [38], the most reported learning outcome for GBL was knowledge acquisition. Serious games were applied less for skill and social skill acquisition and behaviour change.

Studies show that GBL is beneficial for the development of 21st-century skills and other cognitive skills [137, 166, 183, 194]. Especially strategy games and virtual worlds are found to have the characteristics that support the development of 21st-century skills [166].

Ke [100] reviewed a total of 89 publications on the design, use, and evaluation of computer-based games. The majority of the studies, 65 out of 89, evaluated the effects of a specific game on learning. In many of these studies, the effects of games were compared to the effects of traditional instruction. The second largest group, 17 out of 89 studies, explored the effective instructional design of games for learning [100]. A common finding in these studies was that learning games need to have features aimed at instructional support.

Research to date has mostly focused on the effectiveness of GBL, and the comparison between serious gaming and traditional training methods (e.g., [146, 153]). Several serious games studies have found evidence of a positive effect of the use of a game on learning. In a meta-analysis, Wouters et al. [213] found a medium effect that confirms that learning may be improved by the use of instructional support in GBL. They observe that instructional support in GBL is desirable when the objective of the game is to help players acquire knowledge and skills. In contrast, Girard et al. [73] claim that there are not sufficient empirical studies investigating the effectiveness of games in learning to conclude that GBL is effective. Although Connolly et al. [38] did find empirical evidence for the positive effects of GBL, they also conclude that more qualitative research is needed to provide more rigorous evidence.

A meta-analysis by Wu et al. [214] has shown that the majority of serious games studies fail to use a foundation in learning theory. The authors also concluded that researchers who do apply a theoretical foundation tend to adopt a more modern learning theory such as constructivism, or modern principles of learning theory, such as experiential learning and situated learning [214].

Learning in games

Learning is inherent to playing games [89, 110, 133, 160, 204]. In a game, a player will start playing and learn in, and from, the process. No player will start by reading the theoretical background of the game. According to this 'performance before competence' concept [30], they will experience first, and then relate new information to what is already known. This is an inductive way of learning. Traditional education usually applies a deductive approach.

Players can learn from a game, even if the game is not explicitly designed for learning. Many learning principles can be found in games [70, 71, 72]. Using games for specific learning purposes requires instructional elements and design based on learning theories. Integration of the game design and the instructional design is essential. However, this integration is difficult [108, 171]. Studies show that many serious games are unrelated combinations of subject matter and game elements [171]. An insufficient integration will result in games that are not much fun and not very effective for learning. Learning in games is mostly implicit [165]. The player is not consciously engaged in a learning activity. He is playing the game to reach desired goals, which may lead to a behavioural change [32] or the accomplishment of another learning objective. However, implicit knowledge and skills cannot be consciously manipulated and are not likely to transfer to new situations [165]. Therefore, in serious games learning will have to be made more explicit in order to allow transfer of skills and knowledge.

Playing a game provides players with a concrete experience of a system [171]. It can be a platform for experiential learning, allowing the player to learn from doing and reflecting [109]. A game is a complete system with complex interactions and relationships, in which skills, ideas, and experiences have a meaning. Learning in such an environment is considered more meaningful than learning without context [70].

A game environment is usually multimodal, using multiple forms to represent information. This supports players in creating more useful mental models [130]. The use of multisensory cues can engage players, direct their attention and provide feedback [52].

Serious game design

Many serious games studies have focused on determining the effectiveness of a game, but there have also been studies that have focused on the design of serious games. Such studies have tried to identify the elements that need to be present in serious games in order for the game to be effective. To illustrate this, we will discuss three studies that can help to design a successful serious game, viz. (1) the RETAIN study by Gunter et al. [80]

to design and evaluate serious games with embedded academic content, (2) the LM-GM study by Arnab et al. [11] to map learning and game mechanics, and (3) a study by Paras and Bizzocchi [151] on game, motivation and effective learning.

1. **The RETAIN study.** Gunter et al. [80] proposed a model to support the design of game-based learning, based on specific (educational) needs that are not covered in entertainment games. The principles in the RETAIN are based on three instructional theories, viz. Keller's ARCS model [102], Gagné's learning events [68], and Bloom's taxonomy of learning outcomes [10, 21]. RETAIN is an acronym for the components that a serious game should provide: Relevance, Embedding, Transfer, Adaptation, Immersion, and Naturalisation. Gunter et al. [80] have found that endogenously embedding the content makes sure that the gameplay is relevant as well as immersive.

2. **The LM-GM study.** The Learning Mechanics Game Mechanics mapping model (LM-GM) was introduced by Lim et al. [123] and evaluated by Arnab et al. [11]. The model aims to support the design and analysis of serious games by reflecting on pedagogical and game elements present in a serious game. The authors have extracted learning mechanics and game mechanics from literature. The model links the pre-defined learning elements to the pre-defined game elements. LM-GM-based analysis of a serious game will lead to a game map connecting the learning mechanics to game mechanics. Such a map, based on the LM-GM model, can also be used to design a serious game.

3. **A study on game, motivation and effective learning.** Paras and Bizzocchi [151] recognise the vital role of motivation in game-based learning. They state that "games foster play, which produces a state of flow, which increases motivation, which supports the learning process". In addition, they state that reflection is also essential. However, they find that in a state of flow, players rarely reflect on their learning. The state of flow is interrupted when players have purposeful and critical thoughts. Paras and Bizzocchi [151] suggest that the best way to implement reflection phases in serious games is by making it endogenous to the gameplay.

To the extent of our knowledge, there have not been any studies resulting in clear guidelines on serious games design guidelines for specific learning objectives, such as competency development.

In Chapter 3 we will attempt to provide such guidelines based on the above models.

2.5.3 The voluntariness of gaming

Many game definitions claim that games should be played voluntarily [26, 69, 89, 133, 135]. In Chapter 4, we will study the effect of voluntary gameplay in GBL, to answer RQ 1. The essence of voluntariness of gaming is that a person has the freedom to choose whether or not to play. Below, we define voluntariness.

Definition 2.13 - Voluntariness

Voluntariness is a choice being made out of a person's free will to play a game, as opposed to being made as a result of coercion or duress.

Once a person decides to play, he is bound by the rules of the game. However, the player is free to continue or stop playing. Once the playing of a game is forced, it ceases to be play [26]. The voluntary character of gaming contrasts with traditional training methods, which are usually mandatory in nature. A student may have voluntarily started a particular training or course, but usually, he will not have a choice in the training methods used.

What does this mean for GBL? GBL is sometimes referred to as *serious gaming*. The term *serious gaming* was meant to be an oxymoron, to emphasise the opposition between the playfulness of the game and the seriousness of the message [51]. If games are fun by definition, they cannot be serious at the same time [23, 133]. Also, games are non-productive and separate from the real world [89], whereas serious games have specific learning objectives related to life or work skills [69]. In contrast, Huizinga [89] stated that play is a serious activity and that 'fun' and 'serious' do not necessarily exclude one another.

Thus we have the following paradox: games should be played voluntarily, but serious games are meant to be instructional, and instruction is typically non-voluntary [69]. This paradox may have an effect on player attitude and, with that, the learning outcome of the serious game. Players may have a more positive attitude when they are allowed a form of voluntariness, i.e., the freedom to choose to play a serious game, which may result in a more positive attitude, higher engagement and more time spent in the game [27].

In most serious games studies (e.g., [84, 138]), participants volunteer to play the serious game, whereas participation is mandatory in an average training setting. Here we face the paradox again. When serious games are to be deployed in a training setting, they will be mandatory as well. However, this conflicts with the assumption that games are played voluntarily.

GBL may be expected to have a more voluntary character by offering a student freedom of choice. The student has the freedom to choose whether to play or not to play the game. Psychological studies have shown positive effects of freedom of choice on motivation and participation [26, 27]. Hence, it is plausible that freedom of choice may also have a positive effect on the learning outcomes of a serious game.

Research [15, 18, 44, 67] has shown that offering learners a choice in their assignments empowers them to take control. It is the start of a nice line of reasoning. Being in control provides the learners with ownership of the learning process and motivates them to be engaged. This increases interest and, with that, it increases time spent on the chosen assignment. The freedom to choose what, when, and how to contribute to the learning process can motivate learners to participate actively and accomplish more. Motivation and active participation have also been identified as having a positive influence on the effectiveness of serious games.

Heeter, Lee, Magerko and Medler [84] conducted a study of mandatory play, which they refer to as *forced*. They found that non-gamers, with little or no experience with digital games, are likely to be at a disadvantage in GBL because obtaining the intended effect of a serious game depends on how well the game is played. The negative affect that non-gamers experience in a game may interfere with learning or with the cognitive benefits. Their study also included *resistant* players who would not play the game if they did not have to. They have less attention for the game they have to play, and they experience less positive and more negative feelings about that game. Heeter et al. [84] concluded that serious games are least effective for players who dislike a game, and most effective for those who like it.

If they do not play a game by choice, players may still consent to playing the game. As such, consent is related to freedom of choice. Mollick and Rothbard [138] examined the role of consent as a psychological response to *mandatory fun* in gamification in the work environment. They found that games which employees consented to, significantly increased their positive affect, while resistance resulted in a decrease in positive affect and a marginal decrease in performance. Mollick and Rothbard [138] concluded that employees who play games outside of work are more likely to consent to games in other settings and that individuals who are allowed to choose which game to play, show higher levels of consent and *perceived control*, i.e., a sense of control over their own experience. Perceived control is similar to our concept of voluntariness (see Definition 2.13), leading us to expect that playing a serious game voluntarily will increase positive affect and possibly performance.

Based on the motivating aspect of choice (see Subsection 2.5.3) and the original definition of games (see Definition 2.9), we expect that voluntary play, or freedom of choice, will have a positive effect on the outcomes of serious games.

2.5.4 Game-based learning for aviation

Airline pilots receive many hours of training in flight simulators. This allows technical skills to be trained that are needed in situations that rarely occur in real life, or would be too dangerous to train during an actual flight. Serious games could complement pilot training by providing a less complex and less expensive setting for training non-technical skills that do not require a lifelike, or high-fidelity environment.

Despite the general acceptance of simulators for aviation training, the aviation sector has not yet embraced GBL. Partly, this is due to the lack of regulation. GBL is not yet allowed as a formal training method for airline pilots. Time spent on serious games cannot be logged as theoretical study hours. New regulations are expected to be installed in 2019.

The other part, we believe, is due to unfamiliarity. Positive effects will need to be proven and supported with scientific evidence to persuade decision makers. This thesis is part of the research on the viability of GBL for airline pilot training.

In Chapter 4, we will report on a series of experiments measuring the effect of voluntariness on the outcomes of GBL, to answer RQ 2. In Chapter 6, we will report on an experiment measuring airline pilots' acceptance of using a serious game to develop essential competencies for critical situations, to answer RQ 3.

2.6 Chapter conclusion

In this chapter we have discussed (1) airline pilots, (2) competencies, (3) airline pilot training, (4) critical situations, and (5) game-based learning. Combining the diverse information from the previous sections, we may draw three conclusions about competency development and game-based for airline pilot training that support the problem statement.

Conclusion 1

The first conclusion is based on the following three findings.

1. Critical situations require cognitive skills and competencies that pilots generally develop with experience (see Section 2.3).
2. Most young airline pilots come from an *ab initio* training and do not have the rich experience in aviation that prior generations of pilots had (see Section 2.2).
3. The MPL training course is designed directly around the modern multicrew airline practice, but it provides fewer opportunities to build experience (see Subsection 2.2.4).

Conclusion 1: Since young airline pilots do not have the opportunity to develop through normal experience their competencies that are essential in critical situations, they need to find ways to develop these competencies through training.

Conclusion 2

The second conclusion is based on the following three related findings.

1. The next generation of airline pilots will be *digital natives* [159]. These youngsters have experienced technology around them all their lives, and are believed to prefer the use of innovative, digital technology in learning (see Subsection 2.1.2).
2. The MPL training course is based on modern views of education and will apply modern technology. It allows the training to be tailored to the individual needs of students (see Subsection 2.2.4).
3. Game-based learning is a modern concept in training and education (see Section 2.5).

Conclusion 2: Since game-based learning is an innovative training concept that may appeal to the next generation of airline pilots, that will fit seamlessly within the MPL curriculum, it will be a fitting choice for looking at game-based learning for training the competencies.

Conclusion 3

The third conclusion is based on the following set of three findings, that are again related but different.

1. Part of the airline pilot curriculum (both in ATPL and MPL courses) relates to non-technical skills (see Section 1.1.2).
2. Game-based learning may enable non-technical skills to be trained outside the flight simulators, increasing the time that the flight simulators are available for technical training (see Subsection 2.5.4).

3. Game-based learning has been shown to be beneficial for the development of 21st-century skills. There is an overlap between 21st-century skills and non-technical skills in aviation (see Subsection 2.5.2).

Conclusion 3: Since game-based learning can support the development of skills and competencies outside the flight simulators, it may prove to be a beneficial addition to the airline pilot training curriculum.

Chapter 3

Towards a design model

In our research, we focus on serious games for learning. They can be applied to achieve a variety of learning objectives, such as knowledge acquisition, skill acquisition, and behaviour change [22, 38]. Our claim is that serious games are also suitable for the development of competencies (see also Subsection 1.2).

In addition to being developed through experience, competencies can be developed by training [152]. For our research, we take as point of departure that this training can be performed through game-based learning (see Chapter 1).

For this purpose, the serious games will have to be designed in such a way that they support the intended competencies. As far as we know, no models or frameworks have been presented to aid the design of serious games for competency development. In this chapter, we will work towards a design model for serious games for competency development.

It leads to RQ 1, which we will address in this chapter and which reads as follows.

RQ 1: *How should a serious game be designed to support competency development effectively?*

In Section 3.1, we will look at three requirements to develop competencies through game-based learning. In Section 3.2, we will translate the 4C/ID model (see also Subsection 2.4.2) as a starting point for the design of serious games for competency development. In Section 3.3, we will discuss authentic learning tasks as the core of competency development. Subsequently, in Section 3.4, we will identify sixteen essential elements of successful and effective serious games. Then, in Section 3.5, we will introduce the SG4CD model to provide guidelines for the design of serious games for competency development. Finally, in Section 3.6 we will address RQ 1 and give an outlook on further research.

3.1 Three requirements for competency development

The starting point of serious game design should be the learning objective in order to optimise the learning experience. However, to achieve the learning objective, it is pertinent that the game is played. Therefore, the player should be motivated to play the game. Moreover, the learner should be motivated to play the game by its gaming merits, not solely because of its learning objectives. In order to achieve a considerable level of immersion, the player should enjoy playing the game. It means that designing a serious game should mimic the design process of an entertainment game, aiming to make it a successful and enjoyable game. To create a serious game that gets played, it must be designed as an effective entertainment game.

To set the stage for the design of serious games for competency development, we formulate three main requirements.

Requirement 1: The game is playable and attractive.
The learning objective of a serious game is achieved by playing the game. Without any gameplay, the learning objective cannot be reached. Thus, the first requirement for any serious game is that the game is playable (see Definition 3.1) and attractive (see Definition 3.2).

Requirement 2: The game supports learning.
Our research focuses on serious games with a learning objective. Therefore, the gameplay should support the learning intended by the learning objective. The learning objective should be embedded in the core of the gameplay.

Requirement 3: The learning elements address competency development.
Theory on the development of competencies [199, 201] shows that a well-defined set of instructional elements should be present in training materials for competency development. In a serious game for competency development, equivalents of such elements should be implemented.

Definition 3.1 - Playable

A game is considered playable when it is easy to operate, pleasurable to play and it gives the player a positive experience, despite its challenges.

Definition 3.2 - Attractive

A game is considered attractive when its gameplay and visuals are appealing to the player and invite the player back to play again.

To create an effective and successful serious game for competency development, requirement 3 should be the starting point of the design process. In the following sections, we will first identify what is needed for competency development by looking at the 4C/ID model [201]. After that, we will look at what is needed to make the serious game effective and successful.

3.2 Translating 4C/ID into game characteristics

The four defining components of the 4C/ID model are (1) learning tasks, (2) supportive information, (3) procedural information, and (4) part-task practice. These components have been discussed in Subsection 2.4.2. In this section, we will look at what the use of the 4C/ID model [201] means for game design.

When designing a serious game for competency development based on the 4C/ID model, the four components should be taken into consideration in the design. However, from the description of the four components by [201, p. 12-13] (see also Subsection 2.4.2) we infer that the components should be represented in a game by more than four characteristics of the serious game. We have translated the 4C/ID model [199, 201] into six characteristics that should be incorporated in a serious game for competency development (Figure 3.1).

Figure 3.1: Six characteristics that support competency development

Below, we will describe the six characteristics and connect them to the four components of the 4C/ID model (Table 3.1).

1. **Sequencing.** Learning tasks should typically be sequenced from simple to complex. Learning tasks can be divided into task classes. The learning tasks in a class are similar in complexity, but show high variability (e.g., because of varying conditions) and have a gradual decrease in support and guidance. The gradual increase of complexity helps to optimise the learner's cognitive load.
2. **Strengthening routine aspects.** Certain aspects of a learning task should be performed routinely and automated by a learner. Part-task practice helps learners to automate these aspects. It provides ample repetition and immediate corrective feedback to strengthen automaticity.
3. **Authentic learning tasks.** Learning tasks should be based on complete, real-life tasks that make an appeal on the competency as a unit of knowledge, skills and attitudes. To promote inductive learning and to facilitate transfer, learning tasks should differ from each other in all dimensions on which real-life or professional tasks differ from each other (e.g., different conditions).
4. **Conditions.** All conditions under which a task may be performed should be identified, partitioned into those that affect the complexity of the task and those that do not affect the complexity. The first task class should use the most straight forward conditions, gradually increasing to the most complex in the final task class. The conditions provide variability within a task class.

5. **Support and feedback.** Complete, real-life tasks, even under the easiest conditions, are usually too hard to perform for learners. Support and feedback allows a learner to perform authentic tasks of a particular complexity level (task class) that would otherwise be out of their reach. Support that is given for the learning tasks should decrease during the task class. This is called *scaffolding* [211].
6. **Integrated knowledge.** Any information offered, bot supportive and procedural, should be integrated into the learning task. It should be relevant and offered at the right time during the course. Supportive information can be presented before the learning task through books, lectures or multimedia. It helps with the non-routine parts of learning tasks. New information should be connected to already present knowledge. Procedural information is often presented just-in-time by an instructor, quick-reference guide or mobile app. It is connected with the routine aspects of individual learning tasks. The learner should be able to transform the new information into cognitive rules.

Table 3.1: Connecting the 4C/ID components to the characteristics for competency development

4C/ID Component	Characteristic
1.Learning task	1. Sequencing
	2. Authentic learning task
	3. Conditions
2. Supportive information	4. Support and feedback
	6. Integrated knowledge
3. Procedural information	4. Support and feedback
	6. Integrated knowledge
4. Part-task practice	5. Strengthening routine aspects

For a serious game to stimulate the development of competencies, the player should use those competencies to reach the game goal (see Definition 2.11). By offering relevant learning tasks with increasing complexity, the serious game allows the player to apply his competency (see Definition 2.6) under varying conditions. Thus, the game provides the player with useful experiences and allows him to develop the competency. When a player can use an acquired competency in a different situation, this is referred to as *transfer* [212] (Definition 3.3). Transfer is commonly divided into *near transfer* (Definition 3.4) and *far transfer* (Definition 3.5).

For example: learning to tie a shoelace and then tying all kinds of shoelaces is considered near transfer. The situations in which the skill is applied are similar to the situation in which it was learned. Learning about project management in a classroom setting and afterwards successfully managing different projects is far transfer. Projects are different from the classroom, and may also strongly differ from each other.

The intended outcome of the serious game is that the player can apply his developed competency in his work settings. The work situation may resemble the game situations, but in general the work setting will be different from the serious game environment, hence this is considered far transfer. The development and transfer of competency are visualised in Figure 3.2.

Definition 3.3 - Transfer

Transfer is the application of what is learned in one task to another task.

Definition 3.4 - Near transfer

Near transfer is the application of what is learned in one task and within one context, to another task that is similar to that of the learning environment within a similar context.

Definition 3.5 - Far transfer

Far transfer is the application of what is learned in one task and within one context, to a different task in a context that is different from the learning environment, e.g., in a real-life environment.

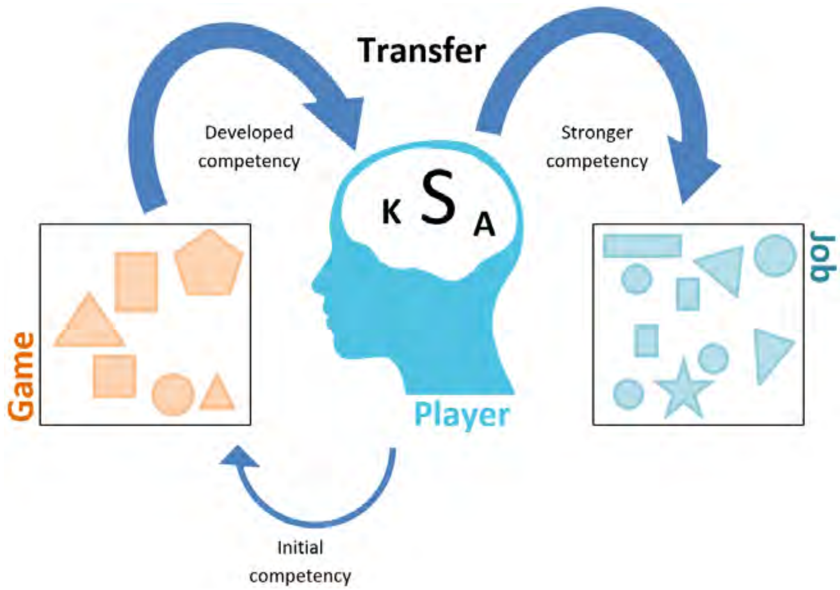


Figure 3.2: Competency development and (far) transfer through a game

The player's initial competency, consisting of KSA, forms the input into the game (left in Figure 3.2). The game provides the player with tasks that are similar to tasks within a job setting (right in Figure 3.2). However, in the game the tasks are more structured in type and sequence. By playing a series of different types of tasks within the game, the player's competency is developed and strengthened. The player then has a stronger competency that can be transferred to his job setting. Although the tasks within the job setting are usually more varied (i.e., real-time world), the player has been prepared for a wider range of tasks by playing the game.

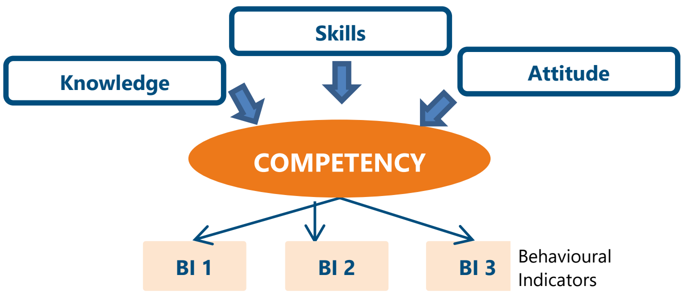


Figure 3.3: Competency and behavioural indicators

Definition 3.6 - Behavioural indicator

A behavioural indicator is a specific description of behaviour that is expected and desired from a person who has acquired a specific competency and is correctly using it [54].

A set of BI's will provide evidence of the extent to which a person has mastered the corresponding competency. The behaviour described in BI's applies to specific job tasks. A task does not necessarily address all behavioural indicators of a competency. In addition to the BI's, there are working conditions (Definition 3.7) and task characteristics (Definition 3.8) that apply to the job task. Figure 3.4 shows the match between the game and the job task, based on working conditions (WCo) and task characteristics (TCh). The match between the game and the job is elaborated upon at the end of the section.

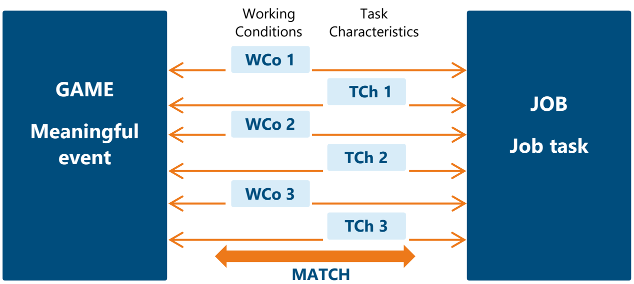


Figure 3.4: Working conditions and task characteristics to match game and job

Definition 3.7 - Working condition

A working conditions is a circumstance under which a task has to be performed. Working conditions can be different each time the task is performed. They may affect the complexity of the task, and they may add stress to the situation.

Definition 3.8 - Task characteristic

A task characteristic is an attribute that identifies a particular task.

Not all working conditions will always apply to a job task, and a job task does not need to be described with all task characteristics at the same time. In normal situations, time pressure may be low, but in a bad weather situation, time pressure may be extremely high. Both *time pressure* and *weather* are working conditions. A task can be a simple, yet important task that needs to be performed accurately. *Complexity* (simple), *importance* and *accuracy* are task characteristics.

Table 3.2 lists eight examples of working conditions and nine examples of task characteristics.

Table 3.2: Examples of working conditions and task characteristics

Working conditions	Task characteristics
Danger/hazards	Complexity
Environmental conditions	Difficulty
Multitasking	Need for interaction
Visibility	Solution multiplicity
Distractions	Accuracy
Information availability	Information flow
Time pressure	Need for multitasking
Weather	Importance
	Task type

To develop the competency, the player needs to perform learning tasks of associated authenticity in the game environment, i.e., they must be associated with the professional's task and its context. This requires the game to contain meaningful events (see also Section 5.3.2), that resemble actual job tasks and that provide challenge.

To create authentic learning tasks, the meaningful game events should match actual job tasks. This match should be based on (1) the competency, (2) the behavioural indicators of the competency, (3) task characteristics, and (4) working conditions. See Figure 3.5 for a visualisation of the relations between competency, job task and game event.

Figure 3.5: Matching meaningful game events with job tasks

3.4 Identifying the elements of serious games

In Section 3.1, we have formulated three requirements. Requirements 1 and 2 are related to two outcomes of a serious game, i.e., to the gameplay and to learning.

In this section, we will identify the elements that serve to make a serious game both a successful game and an effective learning method. We will first present our selection of eleven elements for gameplay (Subsection 3.4.1). Then, we will list our selection of ten elements for learning (Subsection 3.4.2). Please note that both lists of elements are overlapping, resulting in a selection of sixteen elements of serious games.

In total, we have arrived at a selection of sixteen elements of which we claim that they are the basis of creating a successful serious game. Please note that there is no consensus on what constitutes a successful game and there is no fail-safe recipe to create one. Therefore, our selections are not exhaustive lists and not all elements need to be present at the same time. In Table 3.3, we will describe all sixteen elements from the perspective of gameplay and learning.

3.4.1 Eleven elements for gameplay

As stated above, there is no standard recipe for a successful game. Even commercial games do not always succeed, despite all the money and effort that is put into the design and development of the game [55, 118]. However, there is some consensus on what constitutes a successful game and the elements that contribute to success [66, 93, 94, 110, 135, 151, 169, 174, 180].

Based on the literature, we have come to a selection of eleven game elements that are commonly present in successful games: (1) Non-linearity, (2) Players, (3) Theme, (4) Levels*, (5) Genre*, (6) Reality*, (7) Narrative*, (8) Rules*, (9) Goals*, (10) Rewards*, and (11) Feedback* (Figure 3.6). The * marks the elements that have a dual purpose (see Subsection 3.4.2). See Table 3.3 for a description of the game elements.

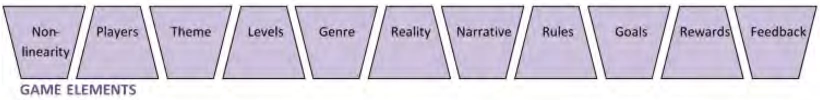


Figure 3.6: Game elements - elements that make the game playable and attractive

3.4.2 Ten elements for learning

Based on literature on serious game design [11, 128, 131, 135], we have selected ten elements that support learning from inside the game: (1) Levels*, (2) Genre*, (3) Reality*, (4) Narrative*, (5) Rules*, (6) Goals*, (7) Rewards*, (8) Feedback*, (9) Assessment, and (10) Learning content (Figure 3.7). In eight of these elements (marked with *), game design overlaps with serious game design, i.e., these elements have a dual purpose. They serve to make the game playable and attractive, and they also support learning. To create a more specific learning experience, instructional elements can be added to the game that assess the players performance or that explicitly provide learning content. These added elements do not contribute to the game experience per se [80].

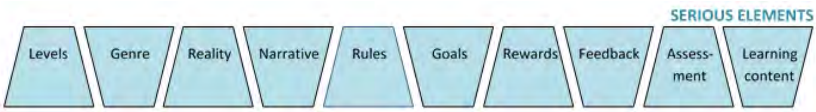


Figure 3.7: Elements *inside* the game that support learning

However, the learning effect does not have to come from the gameplay all by itself. The combination of the game with other training delivery methods in an educational or training setting, so-called blended training, can provide instructional support that will contribute to the learning effect [46]. Serious games can be used in combination with other, more traditional, training methods. Using supportive elements can also make an entertainment game educational. We have selected three elements that support learning from outside the game: (1) Collaboration, (2) Briefing, and (3) Reflection (Figure 3.8). See Table 3.3 for a description of the learning elements.

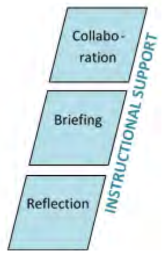


Figure 3.8: Elements *outside* the game that provide instruction support

Table 3.3: Description of serious games elements for gameplay and learning

Elements	Gameplay	Learning
Non-linearity	A linear game is entirely predetermined. The player has no way of influencing the outcomes. Non-linearity provides the player with meaningful choices leading to unique solutions [169]. New possibilities emerge from the player's actions.	
Players	A game has one or more players who are active participants. They interact with each other or with the game environment to collaborate or compete [144]. The actions of the player(s) make the gameplay.	
Theme	The theme is the setting in which the game is placed, e.g., an ancient civilisation, outer space, or a war zone. Abstract games such as Go and Chess, do not have a theme at all.	

Table 3.3 continued from previous page

Elements	Gameplay	Learning
Levels*	Most games are divided into levels. Each level has a specific goal or task for the player. Very often, a level must be completed before the player can move on. Subsequent levels have an increasing complexity, and with that, keep offering a new challenge.	Designing different game levels allows for the good design of challenge. For learning, challenge is essential. The level of difficulty of a game should match the capacities of the player. Too difficult causes frustration, too easy causes boredom. For optimal motivation, the level of difficulty should be just above the player's capacities. This is related to the zone of proximal development [204] and Flow theory [42, 43]. For the best gaming experience, the level of challenge should not be constant [180].
Genre*	Games can be categorised into different genres, but there is no consensus on the definition of the genres. Bakkes [14] suggests five genres into which the majority of (video) games can be classified: action games, adventure games, role-playing games, simulation games, and strategy games. Games may combine elements from more than one game genre.	Entertainment games are categorised based on features of gameplay. Serious games use the same genres, but can also be categorised on the cognitive skills and functions they engage [147]. Not every game genre is suitable for every learning objective.
Reality*	Games are commonly described as "separated from real life" [89]. This can be achieved by using fantasy elements, which are also considered to be motivating [69]. However, a game is often an abstraction of reality, and it simulates parts of that reality. The degree of realism of the simulation is referred to as *fidelity*. Different kinds of fidelity can be distinguished: structural and functional fidelity. Structural fidelity refers to the realism of the physical environment and functional fidelity to the realism of the tasks within the environment. It is possible to maintain a high (functional) fidelity within a fantasy environment.	The amount of realism is not critical. The game can be an abstraction of reality as long as the game has a high functional fidelity. Reality and fantasy go hand in hand. Fantasy is a motivating factor. It can also offer analogies and metaphors for real-world processes, and it may provide a safe environment without real-life consequences [69, 128].
Narrative*	The narrative is the storytelling in a game. It fits in with the theme of the game, and it includes a plot, the characters, and the setting. It also has a specific point of view. The narrative does not interact with the gameplay [110].	The narrative provides a motivating context. For effective learning, the learning content must align with the narrative and the gameplay [52]. There needs to be a meaningful connection.
Rules*	Rules and mechanics go together to let the player experience the gameplay. The rules are directives on how the players should behave. They set boundaries on how the player can interact with the game. Examples: One needs brick and lumber to build a road in *The Settlers of Catan* game [190]. The dice can be rolled three times in *Yahtzee* [215].	Rules form the boundaries of the game and set the consequences of violating these boundaries [131]. These consequences affect the player's behaviour and as such the learning outcome.

Table 3.3 continued from previous page

Elements	Gameplay	Learning
Goals*	A game is won, when the game's goals are reached. The goals are an important motivator. They should be consistent and clear to the players. The goal of the game is generally related to the genre, e.g., it can be to clear the field, beat the opponent, or to reach a destination.	A serious game will have game goals and learning goals (also: learning objectives). They do not need to be the same, but they should both be clear and specific [50]. The level of specificity of the goal in a game can affect the learning outcome [131].
Rewards*	Players can earn rewards via gameplay. A game may give rewards to players, with which they improve their capabilities, capacity or for example, expand their options to customise the game [50]. Rewards motivate players, both intrinsically and extrinsically. Having fun playing the game is an intrinsic reward, whereas receiving a bonus for reaching one's destination is an extrinsic reward.	In behaviourist learning, rewards play an essential role to reinforce learning. A learner will show the intended behaviour to receive the reward.
Feedback*	A game may provide feedback in many ways. Usually, it does so frequently and with intensity [99]. The game will respond to the player's actions. It lets the player know whether these actions are correct, how far he has progressed in the game, or which way he should go.	Feedback is often seen as a motivating element. It informs the player of the progress towards game goals [131]. It is also a reinforcing element in learning, allowing the learner to learn from his mistakes and to prevent him from making the same mistakes again.
Assessment		In-game assessment can provide valuable information about the learning outcomes. Assessment can be done with or without the player knowing it. Game scores may be used to assess the player, but the assessment can also be separate from the core gameplay.
Learning content		The subject matter involved in a serious game can be integrated into the gameplay (endogenous), or it can be added as a separate layer (exogenous) [80, 184]. It is important that offering the learning content does not interrupt the gameplay [95].
Elements outside the game that support learning		
Collaboration		Working with fellow students adds social interaction, shared views, discussion and support. Students can learn from watching each other play. They can deliberate to find the best approach. Playing with or against each other may be a strong motivator.
Briefing		Before the game is played, relevant knowledge and skills can be addressed in other training methods, e.g., in a lecture or a book. The teacher can use the briefing as an advance organiser [68] to inform the players about the knowledge and skills they will need in the game and to activate prior knowledge.

Table 3.3 continued from previous page

Elements	Gameplay	Learning
Reflection		In between or after gameplay sessions, reflecting on the gameplay experience with a teacher or fellow students can make the implicit learning in the game explicit and transferable to new situations [109].

Elements with a purpose for both gameplay and learning are marked with *.

3.5 SG4CD model: Serious Games for Competency Development

We have translated the 4C/ID model [201] into six characteristics for competency development, and we have identified sixteen elements for serious games. To show the relations between the characteristics and the elements, we introduce the SG4CD model.

The SG4CD model (Figure 3.9) identifies the (serious) game elements and supporting elements needed to accommodate the development of competencies through playing a game. The SG4CD model is a research-led model with an expert mindset [176].

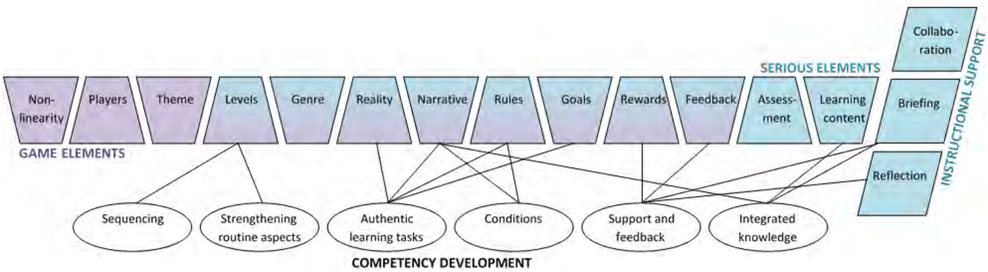


Figure 3.9: The Serious Games for Competency Development model (SG4CD model)

The coloured part of the model represents the serious game itself and the environment in which the serious game is used. The elements derived from game design (see Subsection 3.4.1) are represented in purple. These *game elements* contribute to the game experience. The elements derived from serious game design (see Subsection 3.4.2) are represented in blue. These *learning elements* inside and outside the game, are responsible for learning. The overlap between game elements and learning elements is visualised by way of the colour gradient.

The characteristics derived from instructional design for competency development (see Section 3.2) are represented in white ovals in the bottom part of the model. These *characteristics for competency development* need to be supported by the serious game and the environment in which it is used. The lines in the model indicate which elements of the serious game can support the characteristics of competency development.

1. **Sequencing.** The game should offer the learning tasks in a sequence from simple to complex. This can be done by organising the game into *levels*.
2. **Strengthening routine aspects.** Routine aspects are automated by repetition. This can be achieved by using a *level* system with recurring tasks.
3. **Authentic learning tasks**. To create authentic learning tasks in a game environment, the game designer must create situations in the game that resemble actual job tasks and that trigger specific competencies. The *narrative* is most important for this, together with the *reality* (or fantasy), *rules* and *goals* of the game.
4. **Conditions.** Varying the conditions to provide a variety of authentic tasks throughout the game can be supported by the *narrative* and *rules* of the game.
5. **Support and feedback.** Learning support and feedback can be given through game *feedback* and game *rewards*. *Briefing* and debriefing activities outside the game, such as *reflection*, can also provide feedback.
6. **Integrated knowledge.** The knowledge that the learner needs should be provided just-in-time. This is part of the *learning content*. It can be integrated with the *narrative* or offered explicitly inside or outside the game.

3.6 Chapter conclusion

We seriously believe that serious games can be used for the development of competencies. As far as we know, earlier research did not focus on this application of serious games. Therefore, there is, in our opinion, a need for guidelines on the design of serious games for competency development.

In this section, we will answer RQ 1 (Subsection 3.6.1) and look at further research (Subsection 3.6.2).

3.6.1 Answering research question 1 (RQ 1)

We are now able to answer

RQ 1: *How should a serious game be designed to support competency development effectively?*

First, we looked at what is needed for a successful serious game for competency development. We have formulated three requirements in Subsection 3.1.

1. **The game is playable and attractive.**
2. **The game supports learning.**
3. **The learning elements address competency development.**

From the 4C/ID model [201], we have derived that the development of competencies needs (1) sequencing of tasks, (2) strengthening of routine (part-)tasks, (3) authentic learning tasks, (4) varying conditions, (5) support and feedback, and (6) integrated knowledge. We have shown that these characteristics (see Figure 3.1) can be supported by sixteen elements that are commonly present in (serious) games or that can be added in or around the games.

Based on literature of game and instructional design, we have identified the elements that are needed for successful serious games for competency development. We have introduced our SG4CD model, which is pictured in Figure 3.9. The SG4CD model identifies the thirteen (serious) game elements and three supporting elements needed (see Table 3.3). With our SG4CD model, we show what game and learning elements should be applied to accommodate the development of competencies through playing a game. Based on our model, serious games for competency development can be designed in a more structured way.

3.6.2 Outlook

Our SG4CD-model is a model that is based on literature about game design, serious game design and instructional design for competency development. The model will need to be verified in practice. The design of a selection of games for competency development should be compared to the model to test its validity.

Future research may focus on applying the SG4CD model to other learning objectives. The characteristics for competency development are added in a separate layer in the SG4CD model. Therefore, similar models may be developed for other learning objectives, such as knowledge acquisition or attitude change, by identifying what elements are needed to fulfil the instructional requirements with regard to other learning objectives. The learning elements needed in a serious game to achieve the learning objective can then be identified by combining instructional design for the learning objective with the game and learning elements of our SG4CD model.

Chapter 4

The CloudAtlas game: Voluntary play in serious games

In this chapter, we will address RQ 2, which reads as follows.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

Voluntariness is an important feature of games. Several scholars in the field of games list voluntariness as one of the main characteristics [26, 69, 89, 133, 135] (see also Section 2.5.3).

To the best of our knowledge, no studies have taken into account the possible effect of voluntariness on learning and gameplay within game-based learning (i.e., voluntary versus mandatory gameplay). To fill this hiatus, we performed a series of three experiments. We aim to determine to what extent the learning effect and the gameplay experience of a serious game are affected by the student's freedom to choose to play the game.

This chapter is organised in seven sections. In Section 4.1, we will give an overview of how we set about to measure the effect of voluntariness by conducting three experiments. The three experiments are then discussed one after the other in three subsequent sections: Sections 4.2, 4.3, and 4.4. Then, in Section 4.5, we will discuss the three experiments as a whole. Section 4.6 describes the limitations we faced. Finally, in Section 4.7 we will answer the research question.

This chapter is based on two previous publications:

1. Kuindersma, E., van der Pal, J., van den Herik, H.J., & Plaat, A. (2015). Voluntary Play in Serious Games. In International Conference on Games and Learning Alliance (pp. 131-140). Springer International Publishing.
2. Kuindersma, E., van der Pal, J., van den Herik, H.J., & Plaat, A. (2016). Comparing Voluntary and Mandatory Gameplay. International Journal of Serious Games, 3(3), pp. 67-83.

4.1 Measuring the effect of voluntariness

With our series of three experiments, we aim to measure the effect of voluntariness on the outcomes of playing serious games. In Subsection 4.1.1, we will first identify the outcomes of playing serious games. Then, in Subsection 4.1.2, we will describe our expectations about the effect of voluntariness. In Subsection 4.1.3, we will discuss the general set-up of the experiments. A comparison of the three experiments will be provided in Subsection 4.1.4.

4.1.1 The outcomes of serious games

In this study, we examine the effect of voluntariness on the outcomes of a serious game. We distinguish two types of outcomes, viz. (A) the learning effect of the game, and (B) the gameplay experienced by the player. Below, we discuss and define both types of outcomes.

A. Learning effect

The learning effect is the main type of outcome in an investigation of serious games. The primary goal of a serious game is to make the player learn something (see Definition 2.2). Each game has specific *learning objectives* (Definition 4.1) that describe what the player will learn from the game. After playing the serious game, the player will demonstrate to have achieved a *learning outcome* (see Definition 4.2), e.g., by demonstrating specific behaviour or successfully taking a test. In an ideal situation, the learning outcome will match the learning objective.

This study focuses on the *learning effect* (Definition 4.3) of a serious game. The learning effect is not necessarily identical to the learning outcome. Part of the learning outcome may be a result of something other than playing the serious game, e.g., prior knowledge, the use of other learning materials, or the interaction with other players. It may even be a result of an unrelated activity. An *effective training method* (Definition 4.4 is successful in producing the desired result [57], i.e., in achieving the learning objective.

Definition 4.1 - Learning objective

A learning objective is a statement that defines the intended goals of a learning activity in terms of the knowledge and skills that the learner will acquire as a result of the learning activity. It describes an intended *state.*

Definition 4.2 - Learning outcome

A learning outcome is a statement that describes the knowledge and skills a learner has achieved and demonstrated upon completing the learning activity. It describes an observed *state.*

Definition 4.3 - Learning effect

The learning effect is the part of the learning outcome that can be attributed to the learning activity.

Definition 4.4 - Effective training method

A training method is effective when it produces the desired result, i.e., the intended learning effect.

B. Gameplay experience

The second type of outcome of playing a serious game is how playing the game is experienced by the player. In our studies, we look at the gameplay experience as a combination of the player's motivation, his enjoyment, and engagement. Below, we will define motivation, enjoyment and engagement.

In a setting of mandatory play, players will be obliged to play. They are not free to choose whether to play or not (i.e., play is an imposition). This may have a negative effect on the game experience [84, 138]. Therefore, we also take into account a player's feeling of being subject to an obligation.

Definition 4.5 - Motivation

Motivation is the willingness to participate, and the enthusiasm and determination with which a player participates.

Definition 4.6 - Enjoyment

Enjoyment is the extent to which the player is taking pleasure or satisfaction in participating.

Definition 4.7 - Engagement

Engagement is the extent to which the player is involved or committed to his participation.

The meanings of motivation, enjoyment, and engagement are overlapping, but the concepts are certainly not equal. A player can be motivated to play, yet not enjoy the game or never become engaged in the game. Similarly, a player may become engaged in a game he was not motivated to play. He may even be engaged in a game he believes he does not enjoy.

Based on the two types of outcomes of serious games, we split RQ 2 into two subquestions.

RQ 2a: *To what extent does the voluntary play of a serious game affect the learning effect?*

RQ 2b: *To what extent does the voluntary play of a serious game affect the gameplay experience of the player?*

To answer RQ 2 and its subquestions, we conducted an exploratory study to determine whether using a serious game as a learning tool voluntarily as opposed to mandatorily, has an effect on the outcomes.

The exploratory nature of the study guided us in our structuring of the study. We decided to have a series of experiments, in which the next experiment took into account the results of the previous experiments in its structure and design. We decided in advance to limit the number of experiments to three.

After each experiment, we will try to answer RQ 2a and RQ 2b with respect to the experimental conditions. Using the outcomes of all three experiments, we will answer RQ 2.

4.1.2 Expectations

In conducting the series of experiments, we have six expectations. The expectations are based on literature about the effectiveness of serious games (see Subsection 2.5.2) and voluntariness (see Subsection 2.5.3). References are provided in the respective subsections.

1. **The game.** First of all, the CloudAtlas game that was designed for these studies, is expected to be an effective learning game. We expect that players gain knowledge about clouds by playing the game, and that they are able to recognise the clouds and decide the best way to act around these clouds.
2. **Test score.** Furthermore, we expect a positive effect of voluntary play on the learning effect. We expect voluntary players to achieve a greater improvement of their knowledge of and insight into clouds than mandatory players. Voluntary players should achieve higher test scores.
3. **Game score.** As the knowledge of and insight into clouds is part of the gameplay, we expect voluntary players to do better in the game than mandatory players and achieve higher game scores.
4. **Enjoyment.** Also, we expect a positive effect of voluntary play on the gameplay experience. We expect voluntary players to enjoy the game more than mandatory players.
5. **Time spent playing the game.** As a result of the greater enjoyment, we expect that voluntary players will play the game for a longer time than mandatory players.
6. **Obligation.** Volunteers participate out of their own choice. Hence, it is to be expected that voluntary participants are motivated to participate, more so than mandatory participants. We even expect a negative effect of mandatory participation. Mandatory participants will have a negative feeling about being obliged to play.

4.1.3 General set-up of the experiments

All three experiments have a similar set-up and look for the same measurements. The research design of the three experiments is a combination of exploratory and experimental research. The participants study written materials on cloud identification, play a game (voluntarily or mandatorily), and then take a test. All participants are free to choose how much time they spend on studying the written materials.

Participants who play the game voluntarily are free to choose how long they play, including not playing at all. Participants who play the game mandatorily have to play for at least ten minutes. The procedure is described in more detail in Subsection 4.2.3, and the materials are described in Subsection 4.2.4.

The second and third experiment build on the previous experiments, using the same procedure and materials but with some adaptations. The adaptations made for the experiments are described in Sections 4.3 and 4.4.

In all three experiments we differentiate between the participants based on two independent variables, viz. (1) participation, and (2) gameplay[1].

1. **Participation.** Participants who have volunteered to participate in the experiment are voluntary participants (VP). In contrast, the participants who partake in the experiments as part of a school assignment are mandatory participants (MP).
2. **Gameplay.** Participants who are free to choose whether they play the game and how long they play the game, are voluntary players (VG). In contrast, the participants for whom a minimum of ten minutes of gameplay is enforced, are mandatory players (MG).

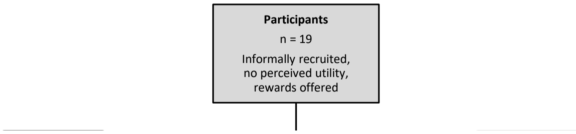
Experiment 1

The first experiment (Figure 4.1) had an informal, non-educational setting. It took place in July and August, 2015. A total of 19 voluntary participants (VP), with no link to aviation, were randomly assigned to either voluntary gameplay (VG) or mandatory gameplay (MG). Moreover, a reward was offered to the participants. The experiment yielded interesting outcomes that led to a second experiment. Experiment participation, even when assigned to the mandatory gameplay (MG) condition, has a much stronger voluntary character that GBL normally will have. Therefore, the second experiment was set up as part of a course to create some level of mandatory participation (MP). We will discuss the results of Experiment 1 in Section 4.2.

Experiment 2

The second experiment (Figure 4.2) was carried out from March to May, 2016, with a total of 74 participants. A total of 71 participants had no link to aviation. The experimental design and materials were adapted to include mandatory participants (MP) in addition to the voluntary participants (VP), and to introduce a no-gameplay (NG) condition in addition to voluntary (VG) and mandatory (MG) gameplay. Some of the participants

[1] Please note that in order to avoid confusion between participants and players, we use the abbreviation *P* for participation/participants and *G* for gameplay/players.



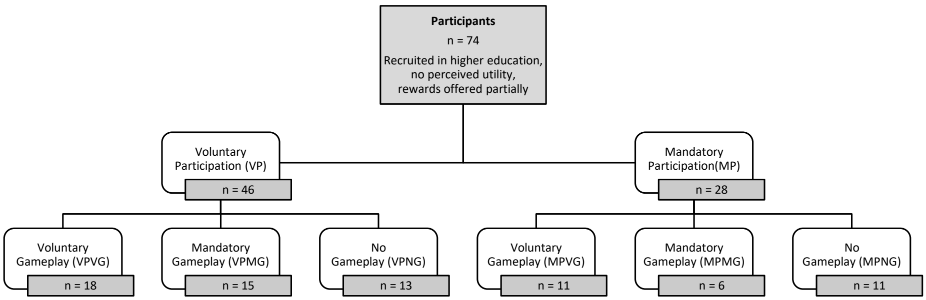


Figure 4.2: Structure and number of participants of Experiment 2

Experiment 3

The third experiment (Figure 4.3) took place between February and August, 2017, with a total of 83 participants. This experiment had a formal setting with a stronger distinction between voluntary (VP) and mandatory (MP) participation. No incentives or rewards were offered to eliminate possible confounding variables. All participants were (aspiring) pilots. Therefore, the topic of the experiment had a stronger relevance and utility for them.

The third experiment confirmed, to some extent, the interesting outcomes of the previous experiments. We will discuss the results of Experiment 3 in Section 4.4.

Overall discussion of the three experiments

In Section 4.5, we will give an extended overview of the results of all three experiments.

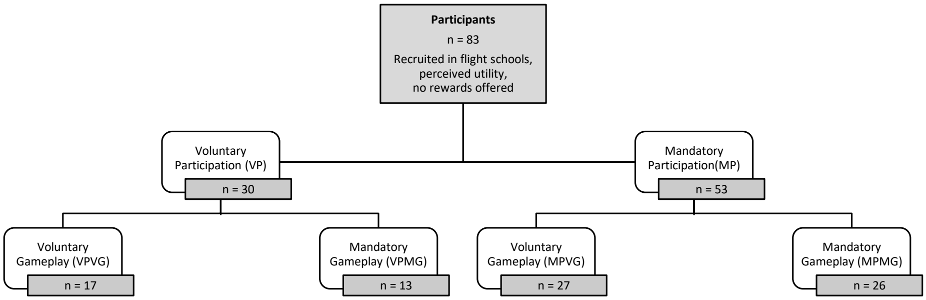


Figure 4.3: Structure and number of participants of Experiment 3

4.1.4 Comparing the experiments

Although the experiments have a similar set-up, there are differences between them in the areas of (A) independent variables, (B) setting, (C) incentives and rewards, (D) utility, and (E) the measurements for which we look. Below, we discuss these differences. An overview is given in Table 4.1.

A. Independent variables

In all three experiments, we compared playing a serious game voluntarily (VG) with playing the game mandatorily (MG).

In addition, in the second and third experiment, we looked at the effects of participating in the experiment voluntarily (VP) versus mandatorily (MP).

All participants in Experiment 1 participated voluntarily (VP). Hence, in Experiment 1, all participants are in the group of voluntary participation (VP). In Experiments 2 and 3, teachers assigned participation to their students, resulting in a group of mandatory participants (MP) in addition to the voluntary participants (VP).

The independent variables for all three experiments are (1) Participation and (2) Gameplay.

B. Setting

All participants in Experiment 1 were recruited through social media. They volunteered to participate. In Experiment 2, recruitment was done through institutions for Higher Education, and in Experiment 3 through Flight Academies. Some participants volunteered; for others it was part of a school assignment. This resulted in an informal setting for Experiment 1 and more formal settings for Experiments 2 and 3.

C. Incentives and rewards

In Experiment 1, all participants who completed the experiment had a chance of winning a gift card. This can be considered to be an incentive to participate. In Experiment 2, some of the VP participants had a chance to win a gift card, while other VP participants received school credits. Receiving credits can also be considered to be a reward. The MP participants were neither offered an incentive, nor did they receive a reward. In Experiment 3, we did not offer any incentive or reward to the participants.

D. Utility

When utility is lacking, motivation to learn is unlikely [203]. Based on the work by Vroom [203] and Clark, Dobbins and Ladd [34], we define utility as follows.

Definition 4.8 - Utility

Utility is the perceived usefulness of a training to reach a particular goal, for example in a job or career.

Participants have a higher motivation to learn and report a greater amount of learning when they identify the utility of the training for their job or career [34, 168]. Furthermore, a higher sense of utility has been linked to a higher motivation to transfer the knowledge and skills to the workplace [121, 170].

For Experiments 1 and 2, we did not focus on recruiting participants for whom the topic of the experiment was relevant. A small number of participants may have perceived utility in the topic, but in general, the topic was not a motivating factor. Experiment 3 was aimed at pilots and pilots-in-training. Therefore, the topic was more relevant to them; i.e., they had a higher perceived utility.

E. Measurements

All three experiments in the study serve to determine the effect of voluntary (VG) and mandatory (MG) gameplay on the game's learning effect and the player's game experience. In total, we look at seven measurements (see below and Table 4.1) to determine the learning effect and game experience. Two measurements are objectively measured, viz. Game score and Test score, the other measurements are more subjective as the participants give their personal opinion about them. The participant's opinion about being obliged to play is used to measure the effect of mandatory play. After Experiment 1, we add a focus on the motivation to participate and the engagement in the game.

With regard to the learning effect (RQ 2a), we look specifically for Measurement 1: Game score; Measurement 2: Test score; and Measurement 3: Time spent playing the game.

With regard to the gameplay experience (RQ 2b), we look for Measurement 4: Enjoyment; and Measurement 5: Obligation. If present in the experiment, we will also look for Measurement 6: Motivation; and Measurement 7: Engagement.

Table 4.1: Comparing the experiments

	Experiment 1	**Experiment 2**	**Experiment 3**
Independent variables	Gameplay	Participation, Gameplay	Participation, Gameplay
Setting	Informal	Formal	Formal
Incentives and rewards	For all participants	For some participants	None
Utility	None	None	High
Measurements			
1. Game score	+	+	+
2. Test score	+	+	+
3. Time spent	+	+	+
4. Enjoyment	+	+	+
5. Obligation	+	+	+
6. Motivation	-	+	+
7. Engagement	-	-	+

4.2 Experiment 1: Informal Setting

The first experiment was set up to determine whether voluntarily using a game as a learning tool will result in a better performance on a test. It took place in an informal setting. The design of Experiment 1 is based on one independent variable, being Gameplay.

The design will be described first (Subsection 4.2.1), followed by the participants (Subsection 4.2.2), the procedure (Subsection 4.2.3), and the materials used (Subsection 4.2.4). Then, the results are presented (Subsection 4.2.5) and discussed (Subsection 4.2.6). Finally, conclusions on Experiment 1 are drawn (Subsection 4.2.7).

4.2.1 Design

The study employed a balanced mixture of quantitative and qualitative methods, using two groups for the independent variable of gameplay. Participants were randomly assigned to one of the two Gameplay[2] groups.

1. **The voluntary gameplay group (VG)** in which players were free to choose how long to play the game or not to play the game at all.
2. **The mandatory gameplay group (MG)** in which players had to actively play the serious game for a minimum of 10 minutes.

Remarks

1. In the first experiment, all participants volunteered. To allow a comparison with the second and third experiment, we will categorise all participants as voluntary participation (VP).
2. The independent variable was the type of Gameplay.
3. We focused on five measurements: (1) game score, (2) test score, (3) time spent playing the game, (4) enjoyment, and (5) obligation.

[2]Please note that in order to avoid confusion between participants and players, we use the abbreviation *P* for participation/participants and *G* for gameplay/players.

4. We did not take into account motivation and engagement.

4.2.2 Participants

Participants were recruited through social media (Facebook, LinkedIn, and Twitter) and by personal invitation. They were told that the experiment was related to aviation, but the focus on gaming was not disclosed. Only persons over the age of 18 were selected to participate. They were asked to give their informed consent before being registered. As an incentive, participants were offered a chance to win a €100 gift certificate. Chances of winning were related to completing all stages of the experiment, not to personal results.

A total of 64 persons registered for the experiment and completed the online pre-experiment questionnaire (Q1). The 64 participants were randomly assigned to one of two groups, resulting in a VG group of 29 participants and an MG group of 35 participants. Out of the 64 registered participants, 19 completed the experiment in a valid way, i.e., by studying the materials and taking the test. The other 45 participants failed to complete the experiment by a variety of failures. Inquiries after the experiment showed that many participants discontinued their participation due to other priorities; such as work or social obligations. The experiment was completed by 10 men and 9 women with a mean age of 39 ($SD = 15.0$). There were 10 completed responses from VG participants and 9 from MG participants. The VG and MG groups did not differ significantly regarding sex, age and interest in gaming.

In the pre-experiment questionnaire (Q1), participants indicated their prior knowledge on a scale of 1 to 10. This resulted in a mean score of 4.2 ($SD = 2.4$) with no significant difference between groups.

4.2.3 Procedure

Participants had to register for the experiment by submitting an online consent form. After registration, each participant was automatically and randomly assigned to one of the Gameplay conditions.

The participants answered the online pre-experiment questionnaire, before starting on the training. They were then asked to study the written materials and play the game, if applicable for their respective Gameplay condition. Voluntary players were free to decide if and how long they played, while mandatory players were told to spend a minimum of ten minutes playing. Participants could complete all parts of the training, at their convenience, through a web page with the experiment instructions and materials. They were free to study as long as they wished and proceed to the test when ready.

Figure 4.4 shows the experiment's procedure in relation to the materials.

4.2.4 Materials

The materials, developed for Experiment 1, were used in all three experiments. For Experiment 2 and Experiment 3 some adaptations were made. The complete set consisted of three parts.

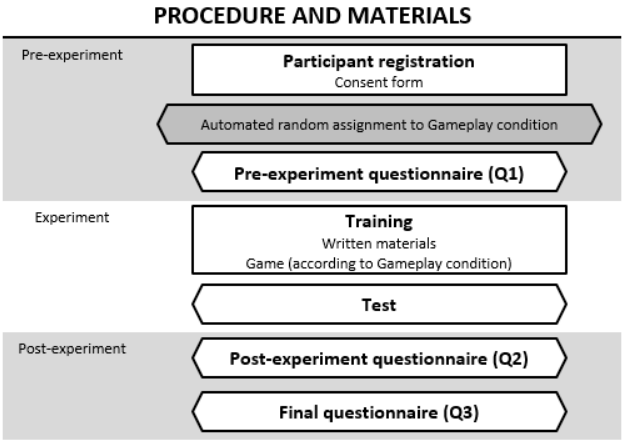


Figure 4.4: Schematic representation of the procedure and corresponding materials

- **A. Questionnaires.** A pre-experiment questionnaire (Q1), a post-experiment questionnaire (Q2), and a final questionnaire (Q3).
- **B. Training materials.** Written materials and a serious game.
- **C. Test.** A test with questions regarding cloud identification and risk assessment.

All materials (see Appendix B) were available online. The experiment's materials are shown in relation to the procedure in Figure 4.4. We will first discuss (A) the three questionnaires, followed by (B) the training materials, and (C) the test.

A. Questionnaires

The participants were presented three questionnaires, which are briefly discussed below: a pre-experiment questionnaire (Q1) with a short assessment of prior knowledge at the time of registration; a post-experiment questionnaire (Q2) with questions about motivation directly after the experiment; and a final questionnaire (Q3) a few weeks after the experiment. All questionnaires are included in Appendix B.

Since no validated questions about voluntariness or enjoyment have been found in the literature, the questionnaires have been constructed specifically for the study.

In addition to multiple choice questions and 5- and 7-point Likert scale items [122], the questionnaire contains items with a 10-point scale. Such a scale is easily understood across age groups and education levels [86] and provides appropriate data for analysis [35]. The use of an even scale avoids the neutral midpoint, forcing the participants to make a distinct choice for each item. Furthermore, the use of a 10-point scale is common in both customer satisfaction questionnaires and game reviews.

Pre-experiment questionnaire (Q1). After registration, participants were presented the pre-experiment questionnaire with questions about (1) demographic information, (2) level of motivation, and (3) level of prior knowledge of aviation and meteorology.

Post-experiment questionnaire (Q2). After the test, participants were presented the post-experiment questionnaire. This questionnaire solicited information about gaming preferences and personal motivation. The voluntary players were asked about the extent of the freedom of choice they experienced in choosing to play or not to play the game. The mandatory players were asked whether they would have played the game when given a choice. Upon completion of the test and the post-experiment questionnaire, participants were informed about the follow-up and about their chance of winning the gift certificate.

Final questionnaire (Q3). A few weeks after completion of the experiment, all participants were asked to answer a short, final questionnaire. The final questionnaire (Q3) for Experiment 1 (see p. 188 in Appendix B.3) contained 5 questions. The participants were asked about how they had heard about the experiment and their reason to participate. They were also asked to express their opinion about the experiment.

B. Training materials

Through a website, the participants were presented two types of training materials: (1) written materials, and (2) a serious game. Depending on their assignment to a Gameplay condition, the participants received access to a specific version of the game. In both versions of the CloudAtlas game, the game was played in the exact same way (see the description of the game below). In the VG version of the game, voluntary players had access to the test and questionnaire (Q2) at any time. In contrast, the mandatory players had to play the MG version of the game for at least 10 minutes before they could continue to the test and questionnaire (Q2).

Written materials. The written materials consist of approximately 2000 words (see Appendix B.4). The written materials offer information about (1) cloud classification, (2) characteristics of the ten cloud types, (3) three possible hazards, and (4) the effect of clouds on aviation. The materials show drawings and photographs of different types of clouds. Both VG and MG players had unlimited access to the same set of text-based materials.

The CloudAtlas Game. The *CloudAtlas* game was designed to be played in an internet browser using the keyboard as the input device. Each individual game was relatively short. The game was designed to challenge the players to improve their high score, thus providing repeated exposure to the cloud types and their consequences.

Game environment. The game environment showed a side view of a simple landscape with a runway and the sky above it (Figure 4.5). On the left side was a small aircraft. From the right side clouds and objects entered the screen. At the bottom of the screen a dashboard provided information about the amount of fuel and oxygen available, the current game score, hazards and the weather conditions.

Gameplay. The goal of the game was to fly an aircraft as far as possible. The player had to adjust the altitude of the aircraft to avoid clouds and obstacles, or to land the aircraft if needed. The game ended when the player ran out of fuel or oxygen. The distance travelled translated into a game score.

Rules. The *CloudAtlas* game had eight main rules.

1. The aircraft had to take-off. It was not allowed to leave the aircraft on the runway.
2. Flying used up fuel. Flying at low altitude consumed more fuel than flying at high altitude.
3. Flying at high altitude consumed oxygen.
4. Flying through or under clouds exposed the aircraft to the hazards.
5. The chances of the hazards occurring and the intensity with which they occur, depend on the type of cloud, the weather conditions and a small random factor.
6. After an initial warning, increasingly more points were deducted from the score for unnecessary landings.
7. Collisions with objects immediately ended the game.
8. Running out of fuel or oxygen ended the game.

Resources. The player started each game with a limited supply of fuel and oxygen. During the game, the player could fly through boosters to receive extra fuel and oxygen.

Clouds. During flight, the player encountered ten types of clouds that were addressed in the written materials. Applying their knowledge about clouds and possible hazards, the players had to take decisions on how to respond. They could (1) fly through a cloud, (2) go over or under it, or (3) land the aircraft to wait for the danger to pass.

Hazards. Clouds could lead to three hazards to the aircraft: icing, turbulence and lightning. These hazards were visualised on the screen and had an effect on the game by increasing the aircraft's fuel consumption. Hazards could be avoided by flying at high altitude, but this required oxygen.

Objects. The player also encountered balloons and flocks of birds. Collisions had to be avoided because they ended the game.

Score. At the end of the game, the distance travelled with the aircraft translated into a game score. Picking up boosters during flight added to the score, while points were deducted for making unnecessary landings.

C. Test

After playing the game, the participants could proceed to the test. The test consisted of eleven knowledge questions and seven application questions. The knowledge questions asked participants to reproduce cloud characteristics and recognise clouds from drawings and photographs.

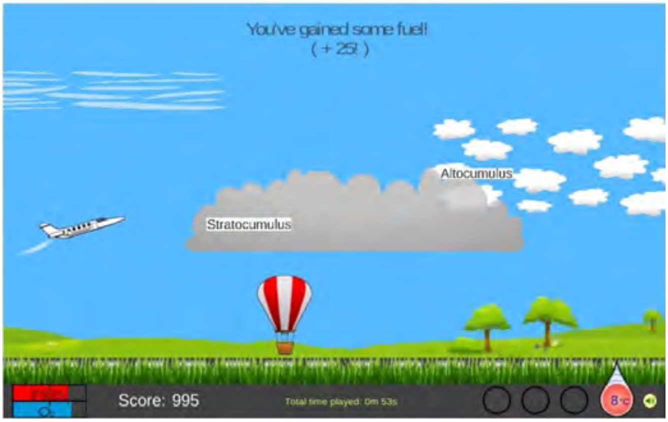


Figure 4.5: CloudAtlas screenshot

In the application questions, participants applied their knowledge to a given situation. A picture of a game situation with an aircraft and a particular type of cloud was presented with four possible routes. Participants are asked to choose the best route, taking into consideration safety, comfort and efficiency, and to identify their reason or reasons for choosing the specific answer. An example of an application question is provided in Figure 4.6. In the example, Route A would be the best option. It would be unnecessary and inefficient to choose route D and land the aircraft. It would be unsafe to take route B or C, because of the risk of a collision with the birds. Route B may also cause some discomfort due to turbulence, and there is a risk of icing on the wings of the aircraft. Moreover, it is also necessary to look at the cloud further ahead. It would be better to pass over this cloud than to go under it, because of the risk of lightning.

All questions in the test had weights assigned to them. In general, application questions were considered to be more important. Therefore, they were assigned higher weights than knowledge questions. Test scores were calculated as the percentage of points earned out of the maximum.

The test makes up the first part of the post-experiment questionnaire (Q2), which can be found can be found in B.2 on p. 176.

4.2.5 Results

In the first experiment, 19 participants (10 VG and 9 MG) completed the experiment by taking the test. The game was played by 16 of them, 3 VG participants chose not to play the game. Below, we discuss the results with regard to (A) the learning effect, and (B) the gameplay experience.

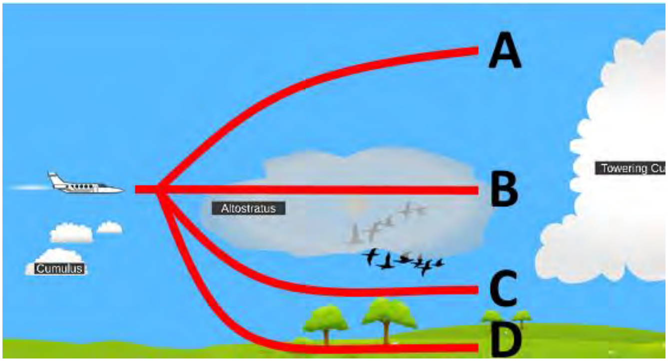


Figure 4.6: Screenshot of CloudAtlas test item: application question

A. Learning effect

For the learning effect in Experiment 1, we will look at the results for Measurement 1: Game score, Measurement 2: Test score, and Measurement 3: Time spent playing the game.

Measurement 1: Game score. Game scores ranged from 721 to 4770. This has resulted in a large standard deviation for game score among the 10 voluntary players (VG) and the 9 mandatory players (MG). Table 4.2 shows the means and standard deviations on game scores. Contrary to our expectations, we did not find a significant difference between the voluntary and mandatory players on their performance in the game, expressed in the game scores.

A t-test revealed that there were no significant differences in game score between male and female participants. However, gamers did achieve a higher game score than non-gamers ($F(1,17) = 8.4$, $p < 0.01$). Participants aged 40 and below scored significantly higher in the game ($F(1,17) = 15.6$, $p < 0.01$) than participants over the age of 40.

Measurement 2: Test score. Test scores ranged from 25 to 77. Table 4.2 shows the means and standard deviations on test scores. Contrary to our expectations, we did not find a significant difference between the voluntary and mandatory players on their performance in the test after playing the game.

A t-test revealed that there were neither significant differences in test score between male and female participants, nor was there a difference between gamers and non-gamers for test score. Participants aged 40 and below scored significantly higher on the test ($F(1,17) = 4.9$, $p < 0.05$) than participants over the age of 40.

Table 4.2: Means and SD of results for VG and MG conditions

Measure	**Gameplay**			
	VG n = 10		MG n = 9	
	M	*SD*	*M*	*SD*
Game score	1092	1085	2723	1332
Test score (%)	44.9	11.3	48.7	18.3

Note. In the VG group (n = 10), 3 participants chose not to play the game. Their game scores were 0.

Measurement 3: Time spent playing the game. We found a considerable variation in length of gameplay. In the VG group, 3 participants did not play at all, while 2 participants in the MG group played for more than half an hour. The number of tries varied from 0 to 22.

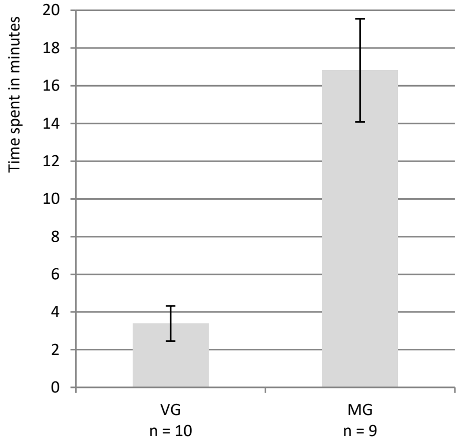


Figure 4.7: Means and SE for Time spent playing the game in Experiment 1

We had anticipated seeing two subsets of players in both the VG and the MG conditions: (1) a subset with players who played only as long as required (less than 12 minutes), and (2) a subset with those who continued playing (more than 12 minutes). Table 4.3 shows counts and percentages for these subsets. In the MG group, 3 participants played less than 12 minutes, and the other 6 played longer. Surprisingly, all 10 players in the VG group played less than 12 minutes. Within the VG group, we also expected to find players who did not play at all, and players that only played to get an idea of the game by playing three tries or less. In total, 3 players did not play at all and 4 players played three tries or less (Table 4.4).

Table 4.3: Subsets in Voluntary and Mandatory Gameplay groups

Condition	**Time spent playing**	**Gender**		**Gaming interest**	
		Male n=10	Female n=9	Non-Gamer n=11	Gamer n=8
Voluntary (VG)	Less than 12 minutes	4	6	7	3
n=10	More than 12 minutes	0	0	0	0
Mandatory (MG)	Less than 12 minutes	1	2	2	1
n=9	More than 12 minutes	5	1	2	4

Table 4.4: Subsets in Voluntary Gameplay group

Subset	**Number of tries**	**Gender**		**Gaming interest**	
		Male n=4	Female n=6	Non-Gamer n=7	Gamer n=3
Less than	No play	2	1	3	0
12 minutes	3 tries or less	2	2	2	2
n=10	4 tries or more	0	3	2	1

B. Gameplay experience

For the gameplay experience in Experiment 1, we will look at the results for Measurement 4: Enjoyment and Measurement 5: Obligation.

Measurement 4: Enjoyment. In the post-experiment questionnaire (Q2), all participants that played the game (n = 16) were asked how much they had enjoyed playing the game on a scale from 1 to 10 ($M = 6.6$, $SD = 1.6$). We found that younger participants enjoyed the game more than older participants ($F(1,17) = 9.0$, $p < 0.01$), and gamers enjoyed it more than non-gamers ($F(1,17) = 5.5$, $p < 0.05$). We had expected voluntary players to enjoy the game significantly more than mandatory players. Instead, we found that the difference was small and that the mandatory players (MG) even reported a slightly higher enjoyment (see Figure 4.8).

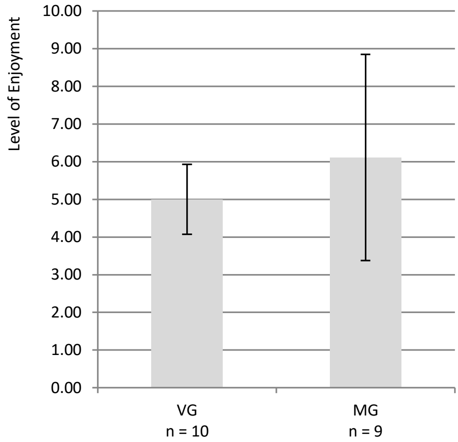


Figure 4.8: Means and SE for Enjoyment in Experiment 1

Measurement 5: Obligation. Mandatory players were asked how they felt about being obliged to play the game for a minimum amount of time; bad, neutral or good. In general, they were neutral about this ($M = 2.1$, $SD = 0.8$). When asked whether they would play the game if they were given a choice, almost 78% of the mandatory players indicated they would. This percentage was higher than the percentage of voluntary players that actually chose to play the game, which was 70%. Furthermore, the duration of intended gameplay indicated by the mandatory players was higher than the average time played by the voluntary players, which was 3.4 minutes. Although these differences were not significant (as a result of the small sample of participants), they are opposite to expectation and as such a remarkable result.

A correlation for the data revealed that the feeling about being obliged to play and the decision to play the game if not mandatory were not significantly related, $r = 0.44$, n $= 9$, $p = 0.23$. A positive decision to play the game, if it were not mandatory, was not associated with a neutral or positive feeling about being obliged to play the game. Voluntary players were asked about the amount of freedom they experienced in choosing to play or not play the game on a scale from 1 to 10. The experienced levels of freedom ranged from 6 to 10, with a mean of 8.20 ($SD = 1.7$) and did not differ between gamers and non-gamers, male and female players or younger and older participants.

4.2.6 Discussion

The first experiment in the explorative study yielded interesting results with regard to the learning effect and the gameplay experience. In the results of Experiment 1, we also found results with regard to motivation and non-gamers. Below, we will discuss these four topics.(A) learning effect, (B) gameplay experience, (C) motivation, and (D) non-gamers.

A. Learning effect

This study aims to investigate the effect of voluntariness in a serious game on the learning effect. The learning effect of the serious game is measured by a test taken shortly after the training. We expected voluntary players to play the game longer and then perform better on the test than mandatory players. In reality, the data shows that mandatory players did spend more time playing the game. However, the time spent on training does not appear to be a factor. Performance does not differ statistically between the two groups. There are several candidate causes for this. We mention four of them. First, the group of voluntary players may have been able to extract knowledge from the game more efficiently than the mandatory players. Second, they may have been more successful in studying the written materials. Third, there may be design issues with the game or the test. Fourth, the game may not be as effective as expected, or the test may not be valid.

B. Gameplay experience

The second topic of interest is gameplay. Contrary to our expectations, voluntary players played for a shorter period of time than mandatory players and made fewer attempts. All voluntary players decided to quit playing the game within ten minutes. This raises the question of why they did so. Apparently, voluntary players did not become fully engaged in the game, even though they rate the game about the same for enjoyment as the mandatory players do. We observe that two-thirds of the mandatory players play more than two minutes beyond the ten-minute minimum. This shows that the game can be engaging. This outcome may indicate that a minimum time requirement is beneficial for gameplay, as it forces the participant not to give up at the first setback.

C. Motivation

In the pre-experiment question about their motivation to participate, players in the MG group indicated to be more motivated prior to the experiment than players in the VG group (one-way ANOVA: $F(1,17) = 9.3$, $p < 0.05$). At the time of answering this question, participants did not know yet which to group they had been assigned.

One-way analysis of variance controlled for motivation (ANCOVA) was used to control for the possible effects of the group difference that was found on motivation prior to the experiment. However, the effect of the covariate on Measurement 1 (game score), Measurement 2 (test score) and Measurement 3 (time spent playing) was not significant.

Participants may have been extrinsically motivated to participate in the experiment by the chance of winning a € 100 gift card. This extra motivation can be expected to have been equal between the voluntary (VG) and mandatory (MG) players. In line with the findings by Fulton and Schweitzer [67], we expected freedom of choice to motivate voluntary players and encourage them to accomplish better results. Additionally, it would be understandable for a mandatory player to have a negative feeling about the obligation to play. However, voluntary players did neither do better on the test, nor did they score higher on the level of enjoyment than mandatory players. Mandatory players reported a neutral feeling about having to play the game for a minimum amount of time, not a negative one. The fact that one participates voluntarily in the experiment may change the way one feels about an obligation to play the game. Alternatively, these outcomes may be caused by the small number of participants or the game design. Mandatory players even indicate that they would still play the game if it were not mandatory. Although the following results were not significant considering the number of participants in the current study, they do indicate an interesting trend. The percentage of mandatory players, who said they would play the game without the obligation, was higher than the percentage of voluntary players who actually did. The gameplay duration estimated by the mandatory players was also higher than the time played by the voluntary players.

D. Non-gamers

We found that non-gamers played shorter and achieved lower scores than gamers. This may be indicative of the general gaming skills of this group. However, they did not perform worse on the test. These outcomes do not support the findings of Heeter et al. [84], who concluded that non-gamers are likely to be at a disadvantage in GBL. Also, the negative affect that Heeter et al. [84] found has not been established in the current study, even though non-gamers enjoyed the game less than gamers.

4.2.7 Section conclusion

Experiment 1 aimed to determine to what extent the learning effect and gameplay experience of a serious game are affected by the freedom to choose to play or not to play; i.e., whether playing the game is voluntary or mandatory. Due to the small number of participants who completed the experiment, no strong statistical conclusions can be drawn from the study.

We were surprised to find that voluntary players played shorter than mandatory players. As both groups reported equal enjoyment of the game, this difference does not need to be attributed to engagement. The outcomes suggest that mandatory players do not feel much pressure and that the obligation is mostly experienced as a stimulus.

We expected that using the game voluntarily as a learning tool would result in improved player performance in a test, in comparison to the results after mandatory gameplay (Measurement 1). We expected that voluntary play would have a positive effect on learning effect (RQ 2a). This result was not found.

With regard to gameplay (RQ 2b), we expected that voluntary players would enjoy the game more than mandatory players. Contrary to our expectations, we found that mandatory players played longer, not shorter (Measurement 3), and showed equal enjoyment (Measurement 4). Mandatory players were neutral about being obliged to play (Measurement 5).

This leads us to believe that mandatory gameplay in the *CloudAtlas* game does not ruin the enjoyment in the game. This contradicts the assumption of many game design theorists and practitioners that games need to be played voluntarily in order to be engaging, fun, and effective.

Recommendation

The findings of Experiment 1 indicate that the motivation of participants may be influenced by the way they have been recruited to participate, as well as by the incentives and rewards offered. We recommend that in the second and third experiment the factor of motivation is taken into account by conducting the experiments in a more formal setting.

4.3 Experiment 2: Formal Setting

The second experiment served to determine whether voluntary gameplay in a learning tool in a formal setting would have the same effects, as we found in Experiment 1. In the formal setting, the primary motivation to participate would either be voluntary or mandatory. Experiment 2 had the same set-up as Experiment 1, but the experimental design was expanded with a NG. Moreover, the participants for the second experiment were recruited through institutions for higher education to be either voluntary (VP) or mandatory (MP) participants.

The new experimental design will be described first (Subsection 4.3.1), followed by the participants (Subsection 4.3.2), and the procedure (Subsection 4.3.3). Subsection 4.3.4 focuses on the adaptations that were made to the materials from the first experiment. Then, the results are reported in Subsection 4.3.5. A discussion is presented in Subsection 4.3.6, and conclusions on Experiment 2 are drawn in Subsection 4.3.7.

4.3.1 Design

The second experiment had a 2x3 experimental design (see Table 4.5). Participants were randomly assigned to one of the three Gameplay[3] groups.

1. **The voluntary gameplay group (VG)** in which players were free to choose how long to play the game or not to play the game at all.
2. **The mandatory gameplay group (MG)** in which players had to actively play the serious game for a minimum of 10 minutes.
3. **The No Game control group (NG)** in which players had no access to the game.

Remarks

1. The independent variables were (1) Participation and (2) Gameplay.
2. Participants were recruited either as voluntary (VP) or mandatory (MP) participants to the experiment. VP participants volunteered, while for MP participants the training was assigned as homework.
3. As an incentive, VP participants were offered a chance to win a € 100 gift certificate. They were informed that their chances of winning were related to completing all parts of the experiment, not to personal results.

[3]Please note that in order to avoid confusion between participants and players, we use the abbreviation *P* for participation/participants and *G* for gameplay/players.

4. However, VP participants receiving school credits for participating were not eligible for the gift certificate, neither were MP participants doing it as a homework assignment.
5. Our focus was on all seven measurements, viz. (1) game score, (2) test score, (3) time spent playing the game, (4) enjoyment, (5) obligation, (6) motivation, and (7) engagement.

Table 4.5: Participation and Gameplay conditions in Experiment 2

Participation	**Gameplay**		
	Voluntary (VG)	Mandatory (MG)	No Game (NG)
Voluntary (VP)	**Group VPVG** Volunteered to participate Free to choose to play	**Group VPMG** Volunteered to participate Minimum 10 minutes of gameplay	**Group VPNG** Volunteered to participate No access to game
Mandatory (MP)	**Group MPVG** Participation assigned Free to choose to play	**Group MPMG** Participation assigned Minimum 10 minutes of gameplay	**Group MPNG** Participation assigned No access to game

4.3.2 Participants

To create an obligation for students to participate, a formal learning setting was required in which lecturers assign the training as homework. For that reason, participants were recruited through (applied) universities. Students were informed that the experiment was related to aviation, but the focus on gaming remained undisclosed. Teachers and lecturers from sixteen faculties in twelve institutions were asked to assign participation in the experiment as a homework task to their students, creating a sense of obligation from the students toward their teacher. If a teacher was unable to assign homework for any reason, he informed the students about the experiment and invited them to participate without obligation.

Four teachers from four different institutions assigned homework to a total of approximately 90 students. One teacher posted the experiment on the ERAS network for Psychology students, who have to participate in experiments to get school credits. As these students are free to choose the experiments in which to participate, they are considered to be voluntary participants in the current study. Thirteen teachers from seven different institutions invited over 1000 students to participate voluntarily.

A total of 93 participants completed the experiment; homework had been assigned to 36 of them (MP), 31 participated for school credit (VP), and 26 volunteered (VP). Teachers did not report reasons for the high level of non-response. There were 42 men and 51 women with a mean age of 21.7 ($SD = 3.6$). The groups did not differ significantly in terms of sex, age, motivation prior to the experiment and number of gamers. However, of the 93 completed experiments, 19 participants spent less than 3 minutes studying the written materials combined with less than one minute playing the game, apart from the required time. They were considered non-legitimate participants, and their results were removed from the analyses. Another 7 participants were removed, as they were unable to play the game due to technical difficulties.

All in all, 67 participants completed the experiment; 33 men and 34 women with a mean age of 21.9 (SD = 3.9). In total, 45 students volunteered to participate, including the students who received school credit, and 22 students participated as part of a homework assignment. This will be referred to as voluntary (VP) and mandatory (MP) participation, respectively. Hence, Experiment 2 had 45 VP and 22 MP participants.

All participants were randomly assigned to a Gameplay group, resulting in a voluntary gameplay (VG) group of 22 participants, a mandatory gameplay (MG) group of 21, and a control group (NG) without access to the game of 24. The distribution of participants is shown in Table 4.6.

The test groups did not differ significantly in terms of sex, age, motivation prior to the experiment, and number of gamers.

Table 4.6: Distribution of participants for Participation and Gameplay in Experiment 2

Participation	**Gameplay**		
	VG n = 22	MG n = 21	NG n = 24
VP n = 45	**Group VPVG** 17	**Group VPMG** 15	**Group VPNG** 13
MP n = 22	**Group MPVG** 5	**Group MPMG** 6	**Group MPNG** 11

The participants' prior knowledge on aviation and meteorology was tested by a set of five questions in the pre-experiment questionnaire (Q1). After the test (Q2), participants were asked to indicate how much prior knowledge they had before the training. The average score on the prior knowledge assessment was 51.4 (SD = 14.8), and the average self-reported score on prior knowledge was 2.6 (SD = 2.2) on a scale of 1 to 10. These scores did not differ significantly between test groups. See Appendix B for the Q1 and Q2 questionnaires.

Furthermore, the two Participation groups did not differ in terms of sex, age, prior knowledge, and number of gamers. However, the VP participants (n = 45, $M = 7.5$, SD = 1.1) did report a significantly higher motivation prior to the experiment than the MP participants (n = 22, $M = 5.5$, $SD = 2.5$); $t(25.2) = -3.7$, $p < 0.05$. One-way analysis of variance controlled for motivation (ANCOVA) was used to control for the possible effects of this difference.

4.3.3 Procedure

The second experiment's procedure was identical to that of the first experiment (see Figure 4.4 on p. 63). Participants could complete all parts online, at their convenience, through a web page with the experiment instructions and materials.

Table 4.7: IMI subscales and items

IMI subscale		Items
1. Interest/Enjoyment		This task was fun to do
		I thought this was a boring task (R)
		This task did not hold my attention at all (R)
		I would describe this task as very interesting
		I thought this task was quite enjoyable
2. Perceived Competence		I am satisfied with my performance at this task
3. Effort/Importance		I put a lot of effort into this task
		I didn't try very hard to do well at this task (R)
		I tried very hard on this task
		It was important to me to do well at this task
		I didn't put much energy into this task (R)
4. Value/Usefulness		I believe this task could be of some value to me
		I think that doing this task is useful for training airline pilots
		I think this is an important task
	*	I believed playing the game could be beneficial to me
	*	I thought playing the game was an important activity
5. Pressure/Tension		I was very relaxed in doing this task (R)
		I was anxious while working on this task
		I felt pressured while doing this task
	*	I felt like I was expected to play the game (R)
	*	I believed I had a free choice about playing the game
6. Perceived Choice		I felt like it was not my own choice to do this task (R)
		I felt like I had to do this (R)
		I did this task because I wanted to

4.3.4 Adaptations to the materials

For Experiment 2, the materials from Experiment 1 were slightly adapted to accommodate the introduction of the control group (NG), as well as improve their usability. We will first discuss (A) the three questionnaires, followed by (B) the training materials, and (C) the test.

A. Questionnaires

A prior knowledge test was added to the pre-experiment questionnaire (Q1), and changes were made to the post-experiment (Q2) and final (Q3) questionnaires.

Pre-experiment questionnaire (Q1). Five questions about the cloud types and the associated risks were added to the pre-experiment questionnaire. These questions were used to establish an objective measurement of prior knowledge, in addition to the self-reported prior knowledge in the post-experiment questionnaire. Also, some questions were modified to reflect the changes in the experimental design (see p, 173, Appendix B).

Post-experiment questionnaire (Q2). Three changes were made to the post-experiment questionnaire. First, a post-experiment questionnaire was added for the no-gameplay (NG) control group. Second, the post-experiment questionnaire for all participants was expanded with a set of twenty questions (Table 4.7) from the Intrinsic Motivation Inventory (IMI) [91, 172]. The IMI is a multidimensional instrument to measure a participant's subjective experience with regard to the activity in an experiment. The current version of the IMI instrument offers six subscales: (1) Interest/Enjoyment, (2) Perceived Competence, (3) Effort/Importance, (4) Value/Usefulness, (5) Pressure/Tension, and (6) Perceived Choice. Intrinsic motivation is considered to be measured with the Interest/Enjoyment subscale. Perceived Competence and Perceived Choice are thought to be positive predictors of intrinsic motivation, while Pressure/Tension is a negative predictor. Relevant items from the IMI subscales can be selected and modified to fit specific activities. Third, an additional set of four questions relating to the IMI subscales of Value/Usefulness and Pressure/Tension was added to the post-experiment questionnaire for the VG group. In Table 4.7, these four questions are marked with *.

Final questionnaire (Q3). A new final questionnaire was constructed for Experiment 2. It contained 13 questions (see p. 189 in Appendix B). The participants were asked to indicate how they had been recruited, what their main reason to participate was, and how much they knew about the experiment beforehand. A set of statements about motivation were added, as well as a set of IMI statements [91, 172], in accordance with Q2.

B. Training materials

The website where the materials were made available was adapted to allow participants to be assigned to the NG control group. Furthermore, some changes were made to allow the use of Internet Explorer to play the game.

Written materials. No new information was added to the written materials, but they were slightly rearranged to improve the presentation. Also, learning objectives were added, and the navigation through the pages was made more evident, to give participants more control over their learning process. The written materials are presented in B.4.

The CloudAtlas Game. No changes were made to the game itself.

C. Test

The test was unchanged, except for a few minor textual corrections.

4.3.5 Results

In total, 67 participants completed the experiment by using the presented training materials, taking the test and answering the pre- and post-experiment questionnaires. The game was part of the training materials of 43 participants in the experiment (22 VG, 21 MG), of whom 37 played the game. A total of 6 participants assigned to the VG group chose not to play the game. Below, we discuss the results with regard to (A) the learning effect, and (B) the gameplay experience.

A. Learning effect

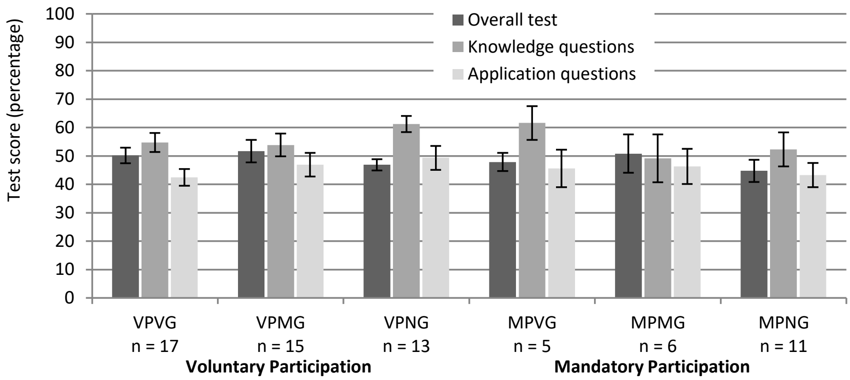


Figure 4.9: Means and SE for Test score in Experiment 2

Measurement 3: Time spent playing the game. The time spent playing varied widely as 6 participants in the VG group did not play, while in the MG group 5 participants played for more than 15 minutes. Figure 4.10 shows that MG participants spent more time playing the game than VG participants. On average, they spent 11.4 minutes more. The main part of this difference can be explained by the required minimum of 10 minutes of gameplay for the MG group. If we consider the time that is played beyond the 10 minutes to be voluntary, on average, MG participants show longer voluntary play than VG participants, but this difference is not significant (p = 0.17).

Table 4.8: Means and SD of results for Participation and Gameplay conditions in Experiment 2

Participation		**Gameplay**							
		VG n = 22		MG n = 21		NG n = 24		Total n = 67	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
VP n = 45		**Group VPVG** n = 17		**Group VPMG** n = 15		**Group VPNG** n = 13		**Total** n = 45	
	Game score	698	605	2343	735	N/A	N/A	1047	1120
	Test score	50.2	11.4	51.7	15.3	46.9	7.1	49.2	12.4
	Test - Knowledge	54.8	13.9	53.9	15.4	61.2	10.2	56.4	13.3

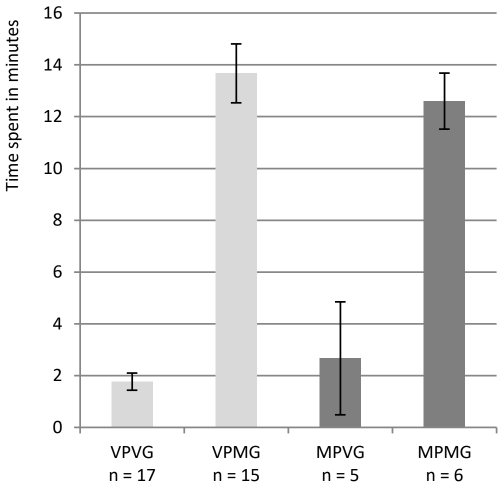


Figure 4.10: Means and SE for Time spent playing the game in Experiment 2

B. Gameplay experience

For the gameplay experience in Experiment 2, we will look at the results for Measurement 4: Enjoyment; Measurement 5: Obligation; and Measurement 6: Motivation.

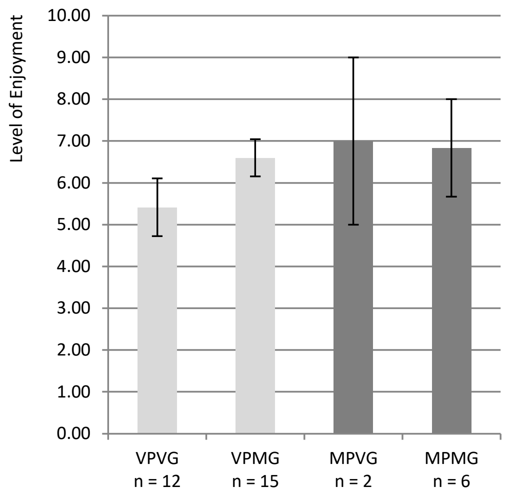


Figure 4.11: Means and SE for Enjoyment in Experiment 2

Measurement 5: Obligation. MG participants were asked how they felt about having to play the game for at least 10 minutes; bad, neutral or good. Overall, MG participants were a bit negative in the second experiment (n = 21, $M = 1.7$, $SD = 0.6$). No difference was found between the voluntary (VP) and mandatory (MP) participants. In the post-experiment questionnaire (Q2), MG participants were asked if they would play the game voluntarily. The NG participants were asked a similar question after they were informed that other participants had played a game. These questions offered four choices: (1) no, (2) probably not, (3) probably yes, and (4) yes. Table 4.9 shows the percentages of VG participants who actually played the game combined with the percentage of MG and NG participants expressing they would play the game voluntarily. An independent-samples t-test shows that the willingness of MG and NG participants does not differ significantly from the actual percentage of gameplay of the VG participants. The data reveal that less

VG participants who were obliged to participate (MPVG, 40%) played the game than VG participants who volunteered to participate (VPVG, 82%). However, this difference is not significant ($p = 0.07$).

Measurement 6: Motivation. In the pre-experiment questionnaire (Q1), participants were asked to indicate their motivation to participate in the experiment on a scale of 1 to 10 (Figure 4.12). An independent-samples t-test revealed a significant difference. The motivation reported by VP participants is significantly higher than that of MP participants, $t(25.6) = 3.4$, $p < 0.01$. This is in accordance with the general expectation that volunteers are more motivated.

The post-experiment questionnaire (Q2) contained a set of twenty questions in regard to motivation, based on the IMI scales [91, 172], as described in Subsection 4.3.4. Two-way ANOVA tests were conducted to examine the influence of Participation and Test Group on the six IMI subscales. The significance levels are shown in Table 4.10. As was to be expected, a simple main effect showed that VP participants reported experiencing significantly more choice than MP participants ($p < 0.01$). No interaction effects or other main simple effects have been found.

Table 4.9: Actual gameplay versus reported willingness to play the game voluntarily

Participation	**Actual gameplay**		**Reported willingness to play**			
	VG n = 22		MG n = 21		NG n = 24	
VP n = 45	n = 17	82%	n = 15	67%	n = 13	77%
MP n = 22	n = 5	40%	n = 6	33%	n = 11	82%
Total	n = 22	73%	n = 21	57%	n = 24	79%

Table 4.10: Significance levels of between-subject effects for the IMI subscales

IMI subscale	**Between Subjects Effects**		
	Participation (VP, MP)	Gameplay (VG, MG, NG)	Interaction of Participation and Gameplay
Interest	.45	.85	.57
Pressure	.06	.49	.12
Choice	.00*	.48	.43
Value	.47	.98	.25
Effort	.80	.88	.39
Competence	.24	.80	.58

Note. * $p < 0.01$

4.3.6 Discussion

The outcomes of Experiment 2 confirm what we have found in Experiment 1. Again, the mandatory (MP) participants and players did not seem to experience a negative effect from the obligation. No new surprises were encountered, but there were findings with

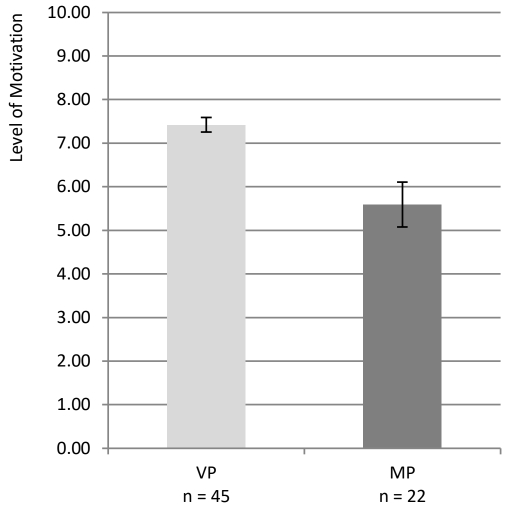


Figure 4.12: Means and SE for Motivation in Experiment 2

regard to the incentives and rewards, and cultural aspects. Below, we will discuss (A) learning effect, (B) gameplay experience, (C) motivation, (D) non-gamers, (E) incentives and rewards, and (F) cultural aspects.

A. Learning effect

The study sought to investigate the effect of voluntariness on the learning effect of a serious game. A test, taken shortly after the training, measured the learning effect of the serious game, in combination with the game scores and the time spent playing the game. The data showed that mandatory players (MG) spent more time playing the game. However, performance on the test does not differ statistically between the test groups, similar to what we found in Experiment 1. Therefore, time spent on training does not appear to be a factor. The topic of the training and the game may have been outside the area of interest for most participants, or the game may not be as effective as expected.

B. Gameplay experience

Almost half of the voluntary players (VG) chose not to play the game at all, and the participants who did play played for a shorter period of time than mandatory players (MG). This difference can be explained by the required minimum of 10 minutes of gameplay for the MG group. Only one VG participant played for more than 10 minutes, and all others played less than 4 minutes. Even after correcting for the required minimum of 10 minutes, MG participants played significantly longer. This may indicate that MG participants become more engaged in the game than VG participants. This seems to be unrelated to the fun of the game, as participants in the VG and MG groups report an equal score on enjoyment.

On the one hand, mandatory (MG) players from the mandatory participation (MP) group played, almost two minutes longer than MG participants from the VP group; an interesting although not significant difference. No explanation has been found for this difference, but it could be the effect of the obligation toward the lecturer. On the other hand, the VG participants in the MP group play half a minute shorter than the VG participants in the VP group, on a total gameplay time of two minutes. It seems that, contrary to the MG participants, VG participants do not feel obliged to keep playing.

C. Motivation

Motivation plays an essential role in this study, both intrinsic and extrinsic motivation. We found that VP participants were more motivated than MP participants (Measurement 7). A possible explanation for this is that participants with low motivation may not participate if they have the choice (as is the case in VP), but in MP, they are obliged to participate, which in effect may reduce the overall score for motivation.

We expected freedom of choice to motivate voluntary players and encourage them to accomplish better results. However, voluntary players (VG) did neither do better in the game and on the test, nor did they score higher on the level of enjoyment than mandatory players (MG), irrespective of whether they participated voluntarily (VP) or as part of a homework assignment (MP).

Additionally, it would be understandable for a player to experience negative feelings when obliged to play the game, but mandatory players (MG) reported a neutral feeling about having to play the game for a minimum amount of time. The data suggest that a negative feeling about the minimum time is neither related to voluntary (VP) or mandatory participation (MP) nor is it related to a participant's motivation to participate in the experiment.

The majority of both mandatory players (MG) and control group participants (NG), indicated that they would play the game if they were offered a choice. The percentage of no-gameplay (NG) participants, who said they would play the game without the obligation, was higher than the percentage of voluntary players (VG) who actually did play the game.

D. Non-gamers

In Experiment 2, we did not examine the differences between gamers and non-gamers, as it was not the focus of our study. Besides, the results of Experiment 1 had shown that the difference did not have an effect on our measurements.

E. Incentives and rewards

In the experiment, incentives and rewards were offered to students for their participation. Similar to the first experiment, voluntary participants (VP) who were invited to participate by their teacher, were offered a chance of winning a € 100 gift card, while participants through the ERAS network received school credit and were not eligible to win the gift card. Based on the individual lecturer's choices, some mandatory participants (MP) were offered the chance of winning the gift card, some received school credit and others did not get any reward.

However, offering a reward may have had an adverse effect on participants. A meta-analysis of studies on the effect of extrinsic rewards on intrinsic motivation has shown that tangible rewards for interesting tasks may diminish the intrinsic motivation [47, 48].

F. Cultural aspects

The participants in the voluntary participation (VP) group were all enrolled in schools in the Netherlands, whereas the students in the mandatory participation (MP) group come from schools in the Netherlands, Thailand, and Lebanon. As these countries have different cultures, cultural differences may have had an effect on the outcomes of the experiment. Among other things, students in Thailand and Lebanon may have a more formal relationship with their teachers than Dutch students, possibly resulting in a stronger sense of obligation.

4.3.7 Section conclusion

Based on the test scores (Measurement 1) on the pretest and post-test, we conclude that the *CloudAtlas* game does not have a significant learning effect. Therefore, it was not possible to determine the effect of voluntary and mandatory play on the learning effect. Hence, Experiment 2 does not provide an answer to RQ 2a.

Experiment 2 confirms the outcomes of Experiment 1 with regard to RQ 2b: the obligation to play the game, and even the obligation to participate in the experiment, appears to have no negative effect on the time spent playing (Measurement 3) and the enjoyment of the game (Measurement 4). We found that a little coercion increases the time spent in the game, which in turn may improve the learning effect. Moreover, the results indicate that mandatory gameplay is just as much fun as voluntary gameplay.

Recommendation

Despite our efforts, the distinction between voluntary (VP) and mandatory participation (MP) was insufficient, partly because of the rewards offered. We recommend that in the third experiment the voluntary participants (VP) should volunteer out of their personal interest without any rewards, and the mandatory participants (MP) should be instructed to participate by a person who has a strong influence on their education or career.

4.4 Experiment 3: Formal setting with mandatory participation

The third experiment was set up to determine, once again, the effect of voluntarily using a game as a learning tool on the learning outcome and gameplay experience of the serious game.

There were four differences with the previous experiments: (1) a stronger distinction between voluntary and mandatory participation, (2) participants for whom the topic of the training materials was more relevant, (3) the NG control group was eliminated, and (4) no incentives or rewards were offered. Participants were divided into four test groups based on Participation and Gameplay.

The new experimental design is discussed first (Subsection 4.4.1), followed by the participants (Subsection 4.4.2) and the procedure (Subsection 4.4.3). Subsection 4.4.4 discusses the adaptations that were made to the materials from the previous experiments. Then, the results are presented in Subsection 4.4.5. The discussion is in Subsection 4.4.6, and the conclusion in Subsection 4.4.7.

4.4.1 Design

The experimental design for the third experiment was similar to that of the second experiment, but with four conditions as a result of eliminating the NG control group (Table 4.11). From Experiment 1 and 2, we concluded that the serious game did not have a learning effect. Therefore, there was no need to have an NG control group in Experiment 3 to compare the effect of the game with that of the written materials.

The independent variables were (1) Participation and (2) Gameplay. Participants were recruited either as voluntary (VP) or mandatory (MP) participants to the experiment. In both Participation groups, participants were assigned to one of two Gameplay[4] groups.

1. **The voluntary gameplay group (VG)** in which players were free to choose how long to play the game or not to play the game at all.
2. **The mandatory gameplay group (MG)** in which players had to actively play the serious game for a minimum of 10 minutes.

Our focus was on all seven measurements, viz. (1) game score, (2) test score, (3) time spent playing the game, (4) enjoyment, (5) engagement, (6) obligation, and (7) motivation.

Table 4.11: Participation and Gameplay conditions in Experiment 3

Participation	**Gameplay**	
	Voluntary (VG)	Mandatory (MG)
	Group VPVG	**Group VPMG**
Voluntary	Volunteered to participate	Volunteered to participate
(VP)	Free to choose to play	Minimum 10 minutes of gameplay
	Group MPVG	**Group MPMG**
Mandatory	Participation assigned	Participation assigned
(MP)	Free to choose to play	Minimum 10 minutes of gameplay

[4]Please note that in order to avoid confusion between participants and players, we use the abbreviation *P* for participation/participants and *G* for gameplay/players.

4.4.2 Participants

For the third experiment, an educational population was chosen for whom the topic of the training was more relevant, in order to have a higher level of *perceived utility* [34, 121, 168, 170] (see also Definition 4.8 on p. 60). A sense of utility is believed to have a positive effect on a person's motivation [34, 203]. Recruitment was aimed at persons working on obtaining their PPL and licensed pilots with a small amount of flight experience. In contrast to the first and second experiment, the third experiment offered no incentives or rewards to any of the participants.

To create the required formal learning setting, we contacted the Chief Flight Instructors of four Dutch flight academies. The students in their academies wish to become licensed pilots with the connected airlines. Therefore, students will feel obliged to participate in activities assigned by the flight instructors. A total of 101 students and 11 pilots were instructed to participate; 70 participants registered for the experiment and 54 of them completed the test.

Voluntary participants (VP) were recruited through (1) the Royal Netherlands Aeronautical Association (KNVvL), (2) the Airwork bulletin board, and (3) flight schools for leisure aviation. An announcement was included in the KNVvL newsletter in May and July of 2017, and the announcement was also published on their website. The same announcement was used on the Airwork bulletin board in May and July 2017. In May 2017, some PPL pilots and flight instructors forwarded the invitation to participate in the experiment to their flight school members. A total of 81 VP registered, 34 of whom completed the experiment.

Initially, the experiment was completed by 89 participants; 34 were voluntary participants (VP), 55 were recruited through the flight academies (mandatory participants, MP). There were 85 men and 4 women with a mean age of 33.3 (SD = 16.3).

However, the results of 12 participants were excluded from the analyses. In the VG condition, 9 participants reported that they were unable to play the game due to technical difficulties. There were 3 participants (2 MP, 1 VP) who finished the test without spending any time on the game and the written materials. They were considered non-legitimate participants. Another 2 participants spent less than 3 minutes on the game and the written materials combined, but they were not removed, as their decision to skip part of the materials may have been based on their personal assessment of their prior knowledge of the topic.

Hence, 77 participants completed the experiment; 73 men and 4 women with a mean age of 32.0 (SD = 16.0). The distribution of participants is shown in Table 4.12.

Although recruitment was focused on pilots in training and pilots with little experience, 4 pilots participated with a larger number of flight hours and a background as a professional pilot. However, there was no indication that these 4 pilots deviated strongly from the other participants in other aspects.

The test groups differed in a number of ways. The voluntary (VP) participants (n = 25, M = 50.4, SD = 14.4) were older than those in the MP group (n = 52, M = 23.1, SD = 6.0); $t(28.1)$ = -9.1, $p < 0.01$. Within the VP group, post hoc testing using the Bonferroni correction revealed that Group VPVG (n = 12, M = 61.6, SD = 8.5) was

Table 4.12: Distribution of participants for Participation and Gameplay in Experiment 3

Participation	**Gameplay**	
	Voluntary (VG) n = 38	Mandatory (MG) n = 39
Voluntary (VP) n = 25	**Group VPVG** 12	**Group VGMG** 13
Mandatory (MP) n = 52	**Group MPVG** 26	**Group MPMG** 26

older than Group VPMG (n = 13, M = 40.1, SD = 10.5); $p < 0.01$. However, ANCOVA testing showed that age as a covariate had no significant effect on the outcomes. Hence, the covariate was removed from the analyses.

The VP participants (n = 25, M = 7.8, SD = 1.1) reported a significantly higher motivation prior to the experiment than the MP participants (n = 52, M = 7.2, SD = 1.1); $t(75)$ = -2.4, $p < 0.05$. Post hoc testing using the LSD correction showed that only Group VPMG was more motivated than Group MPMG ($p < 0.01$) and Group MPVG ($p < 0.05$).

The participants' prior knowledge on meteorology was tested with a set of five questions in the pre-experiment questionnaire (Q1). After the test (Q2), participants were asked to indicate on a 10-point scale how much prior knowledge they had before the training. The average score on the prior knowledge assessment was 67.5 (n = 77, SD = 12.1), and the average self-reported score on prior knowledge was 6.1 (n = 77, SD = 1.8) on a scale of 1 to 10. No significant differences were found between the VP and MP groups, the VG and MG groups, or the four separate test groups.

4.4.3 Procedure

The third experiment's procedure was identical to that of the first and second experiments (see Figure 4.4), except for the automatic assignment to the Gameplay condition. In the third experiment, participants were automatically assigned to a Gameplay condition according to a schedule (Table 4.13) instead of randomised assignment. This method was chosen to control the number of completed participations in each group. However, the assignment was blinded and was not influenced by the individual participants.

Table 4.13: Assignment of registered participants to Gameplay condition in Experiment 3

Registration	**Assignment**
1-10	MG
11-20	VG
21-30	MG
31-40	VG
41 and following (uneven)	MG
42 and following (even)	VG

4.4.4 Adaptations to the materials

For Experiment 3, the materials from Experiment 2 were adapted to accommodate the recruitment of participants, and for the training materials to have a closer fit with the study materials used in flight schools. We added a third questionnaire, to be answered by the participants after completion of the experiment. We will first discuss (A) the three questionnaires, followed by (B) the training materials, and (C) the test.

A. Questionnaires

Pre-experiment questionnaire (Q1). The third experiment used the pre-experiment questionnaire from the second experiment, with the exception of six questions that had been added before to identify participants as voluntary (VP) or mandatory participants (MP). In the third experiment, this distinction was made through the experiment website.

Post-experiment questionnaire (Q2). Questions that were specific to the participants of the second experiment were replaced with questions about pilot licenses, flight training and meteorology exams. All other questions were identical to the previous versions of the post-experiment questionnaire.

Final questionnaire (Q3). The final questionnaire was adapted for Experiment 3 (see p. 191 in Appendix B). It contained 7 questions. Questions about the recruitment that were no longer relevant were removed. The participants were asked about the amount of obligation that had experienced and how they had used the learning materials. They were asked to express their opinion about the experiment. Furthermore, the questionnaire contained a set of IMI statements [91, 172].

B. Training materials

Website. Changes were made to the website to provide separate URLs for voluntary (VP) and mandatory participants (MP). The flight instructors received personal URLs to hand out to their students, linking their students to them. A generic URL was used to invite voluntary participants (VP).

Written materials. The written materials were adapted to provide a closer match with the Meteorological Theory study materials [13] for PPL courses. Also, some small typographical errors were corrected. The written materials are presented in B.4.

CloudAtlas game. For Experiment 3, the game was adapted to give the player feedback on dangerous actions. A player will be warned for the possible consequences when flying through a dangerous cloud for the first and second time (see Figure 4.13). The third and following incidents will not trigger the feedback anymore. Furthermore, the adapted game shows the names of the clouds together with the abbreviations that are commonly used in aviation.

Figure 4.13: CloudAtlas screenshot: feedback on dangerous action

C. Test

In the third experiment, the same test was used as in the second experiment. No changes were made.

4.4.5 Results

After removing the results of the participant's who completed the experiment in an invalid way, 77 completed participations remained. Of the 38 VG participants, 3 did not play the game. Below, we discuss the results with regard to (A) the learning effect, and (B) the gameplay experience.

A. Learning effect

For the learning effect in Experiment 3, we will look at the results for Measurement 1: Game score, Measurement 2: Test score, and Measurement 3: Time spent playing the game.

Measurement 1: Game score. A total of 74 participants played the game, and their game scores ranged from 462 to 4978. A significant main effect of both Participation ($F(1,70) = 4.5$, $p < 0.05$) and Gameplay ($F(1,70) = 29.2$, $p < 0.01$) was found. However, the interaction effect of Participation and Gameplay on game score was not significant.

Table 4.14 shows the means and standard deviations on game scores.

Measurement 2: Test score. Overall, test scores ranged from 28 to 83. For a more detailed analysis, the overall test results of all participants were split into a score for knowledge questions and one for application questions (Figure 4.14). No significant effects were found for the overall test score, the score for knowledge questions, and the score for application questions.

Table 4.14 shows the means and standard deviations on test scores. As in the previous experiments, no significant effects of Participation or Gameplay on test scores were found.

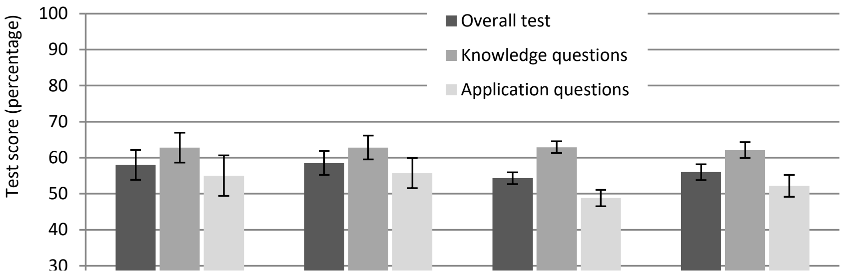
Measurement 3: Time spent playing the game. Gameplay length varied widely (Figure 4.15). In the VG group, 3 participants did not play the game at all, and 19 participants played the game three times or less. In the MG group, 10 participants played for more than 15 minutes. None of the VG participants played more than 13 minutes. In fact, only 10 VG participants followed the recommendation on the website and played for a minimum of ten minutes. All but one of them were part of the MP group. On average, MG participants spent 9 minutes more playing the game than VG participants. This difference can be explained by the required minimum of 10 minutes of gameplay for the MG group. Two-way analysis of variance shows a significant effect of voluntary and mandatory gameplay on the length of gameplay, $F(1,73) = 113.8$, $p < 0.01$. Furthermore, there is a significant effect of the interaction of Participation and Gameplay on the length of gameplay, $F(1,73) = 11.1$, $p < 0.01$. Looking at voluntary playtime only, by subtracting the mandatory ten minutes from the total time played for MG participants, a significant effect of the interaction of Participation and Gameplay on the length of gameplay remains, $F(1,73) = 11.1$, $p < 0.01$.

The same effect is shown when comparing the voluntary playtime for the four test groups. Post hoc testing using the Bonferroni correction for the four test groups shows significant differences between Group MPMG and Group MPVG ($p < 0.01$) and Group MPVG and Group VPVG ($p < 0.05$).

B. Gameplay experience

For the gameplay experience in Experiment 3, we will look at the results for Measurement 4: Enjoyment; Measurement 5: Obligation; Measurement 6: Motivation; and Measurement 7: Engagement.

Measurement 4: Enjoyment. The 74 participants that played the game rated their enjoyment on a scale of 1 to 10 ($M = 5.8$, $SD = 2.0$). Figure 4.16 shows the means and standard error for the enjoyment scores. One-way ANOVA shows no significant effects between the four test groups, nor between the VP and MP groups, and the VG and MG groups.



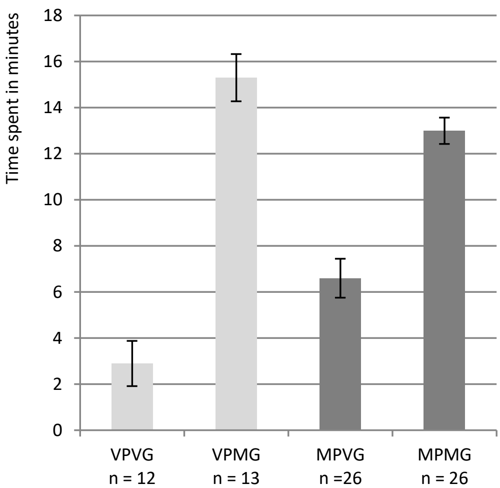


Figure 4.15: Means and SE for Time spent playing the game in Experiment 3

Table 4.14: Means and SD of results for Participation and Gameplay conditions in Experiment 3

Participation		Gameplay					
		VG n = 38		MG n = 39		Total n = 77	
		M	*SD*	*M*	*SD*	*M*	*SD*
		Group VPVG n = 12		**Group VPMG** n = 13		**Total** n = 25	
	Game score	899	675	2564	996	1765	1194
VP	Test score	58.0	14.4	58.5	11.9	58.3	12.9
n = 25	Test - Knowledge	62.8	9.8	62.8	15.4	62.8	12.7
	Test - Application	55.0	19.5	55.7	15.1	55.4	17.0
		Group MPVG n = 26		**Group MPMG** n = 26		**Total** n = 52	
	Game score	1764	947	2749	891	2256	1038
MP	Test score	54.3	8.2	56.0	11.2	55.2	9.7
n = 52	Test - Knowledge	62.9	9.3	62.1	11.7	62.5	10.5
	Test - Application	48.8	11.7	52.2	15.5	50.5	13.7
		VG n = 38		**MG** n = 39			
	Game score	1491	953	2687	918		
Total	Test score	55.5	10.5	56.8	11.3		
n = 77	Test - Knowledge	62.9	9.3	62.4	12.8		
	Test - Application	50.8	14.6	53.3	15.3		

Note. In the VG group (n = 38), 3 participants chose not to play the game. Their game scores were 0.

As in the first and second experiment, MG participants rate their enjoyment equally as VG participants. The same is true for MP participants. They indicate as much enjoyment in the game as the VP participants. In fact, the participants in the MP groups give a higher score for enjoyment than the VP participants, although this is not a significant difference.

Measurement 5: Obligation. MG participants were asked how they felt about having to play the game for at least 10 minutes; bad, neutral or good. Overall, MG participants were a bit negative in the experiment (n = 39, $M = 1.8$, $SD = 0.7$). An independent-samples t-test shows that the participants in Group VPMG are significantly more positive than the participants in Group MPMG; $t(37) = -3.8$, $p < 0.05$.

Measurement 6: Motivation. In the pre-experiment questionnaire (Q1), participants were asked to indicate their motivation to participate in the experiment on a scale of 1 to 10. Table 4.15 shows the means and standard deviations. A t-test revealed that the motivation reported by VP participants is significantly higher than that of MP participants, $t(75) = -2.4$, $p < 0.05$.

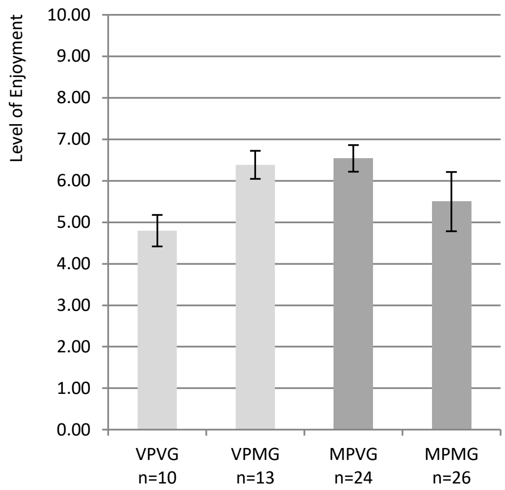


Figure 4.16: Means and SE for Enjoyment in Experiment 3

The post-experiment questionnaire (Q2) contained a set of twenty questions in regard to motivation, based on the IMI subscales [91, 172]. Two-way ANOVA tests were conducted to examine the influence of Participation and Gameplay on the six IMI subscales. The significance levels are shown in Table 4.16.

Simple main effects showed that VP participants reported experiencing significantly more interest than MP participants, and VG participants reported significantly more choice than MG participants ($p < 0.05$). No interaction effects or other main simple effects have been found.

Table 4.15: Levels of Motivation separated for the Participation conditions in Experiment 3

Participation		**Gameplay**					
		VG n = 38		MG n = 39		Total n = 77	
		M	*SD*	*M*	*SD*	*M*	*SD*
		Group VPVG n = 12		**Group VPMG** n = 13		**VP** n = 25	
VP n=25	Motivation	7.5	0.7	8.1	1.3	7.8	1.1
		Group MPVG n = 26		**Group MPMG** n = 26		**MP** n = 52	
MP n=52	Motivation	7.2	0.9	7.1	1.3	7.2	1.1
		VG n = 38		**MG** n = 39		**Total** n = 77	
Total n=77	Motivation	7.3	0.8	7.4	1.4	7.4	1.1

Table 4.16: Significance levels of between-subject effects for the IMI subscales in Experiment 3

IMI subscale	Between Subject Effects		
	Participation (VP, MP)	Gameplay (VG, MG)	Interaction of Participation and Gameplay
Interest	.001*	.99	.06
Pressure	.26	.13	.45
Choice	.09	.04*	.55
Value	.24	.40	.18
Effort	.96	.33	.37
Competence	.98	.88	.70

Note. * $p < 0.05$

Measurement 7: Engagement. All participants rated their engagement within the entire training on a scale of 1 to 10 (n = 77, $M = 7.0$, $SD = 1.6$). Table 4.17 shows the means and standard deviations for the engagement scores. One-way ANOVA shows no significant effects between the four test groups. However, a one-way ANOVA showed a significant difference between the VP and MP groups; $F(1,75) = 4.9$, $p < 0.05$. The VP participants reported a higher engagement.

Table 4.17: Means and SD of Engagement for Participation and Gameplay conditions

Participation		Gameplay					
		VG n = 38		MG n = 39		Total n = 77	
		M	*SD*	*M*	*SD*	*M*	*SD*
		Group VPVG n = 12		**Group VPMG** n = 13		**VP** n = 25	
VP n=25	Engagement	7.3	1.4	7.9	1.2	7.6	1.3
		Group MPVG n = 26		**Group MPMG** n = 26		**MP** n = 52	
MP n=52	Engagement	6.9	1.5	6.7	1.8	6.8	1.6
		VG n = 38		**MG** n = 39		**Total** n = 77	
Total n=77	Engagement	7.0	1.5	7.1	1.7	7.0	1.6

4.4.6 Discussion

The outcomes of Experiment 3 are in line with to those of the previous experiments. Experiment 3 shows that the outcomes of the previous experiments hold up in a more formal and more relevant setting. Mandatory participants (MP) and players (MG) do not report significant negative effects of the obligation.

There were new findings with regard to the age of the participants and technical difficulties. Below, we will discuss (A) learning effect, (B) gameplay experience, (C) motivation, (D) non-gamers, (E) incentives and rewards, (F) cultural aspects, (G) age, and (H) technical difficulties.

A. Learning effect

The third experiment in the study of voluntary play was aimed to determine the effect of voluntariness with mandatory participation (MP) in a formal setting. After Experiment 1 and 2, we concluded that the *CloudAtlas* game has no learning effect and that time spent on training is not a factor. In Experiment 3, we found no significant difference in test scores between the four test groups. The participants in the MG groups played longer than the VG participants but did not achieve a higher test score.

The participants in the third experiment did achieve higher test scores than participants in the previous experiments. This may be related to the background of the participants. All participants of Experiment 3 were involved in aviation and flight training, whereas in the previous experiments only a few individuals were.

The lack of learning effect from the game most likely indicates issues with the game or the test. The game is not as effective as intended, or the test is not valid.

B. Gameplay experience

Only three participants deliberately chose not to play the game, but again, most VG participants ended their gameplay within the advised ten minutes, that was also the amount of mandated gameplay for the MG participants.

The reasons why VG participants stop playing so soon remains unknown. They report a similar enjoyment of the game and a similar engagement of the entire training. Almost two-thirds of the MG participants play more than two minutes beyond the ten-minute minimum, showing that the game, in fact, can be engaging. These outcomes may again indicate that a minimum time requirement is beneficial for gameplay, as it forces the participant not to give up at the first setback.

C. Motivation

A significant effect of the Participation group was found on motivation. This is in accordance with our expectation that volunteers are more motivated than participants who do so out of obligation. In the VP group, a participant who did not feel attracted to the study could decide not to participate. In the MP group, a participant with a similar feeling had to participate and hence may have reported a lower motivation. This is also supported by the outcome that VP participants score higher on the IMI subscale of Interest. We have found that VP participants feel more positive about being obliged to play the game for a minimum amount of time and that they report a higher engagement in the entire training.

VG participants reported that they experienced more freedom in the experiment, but they do not rate the game or the training different from the MG participants.

D. Non-gamers

In Experiment 3 we did not focus on differences between gamers and non-gamers, as the results of Experiment 1 showed that this did not have an effect on our measurements.

E. Incentives and rewards

In Experiment 3, no incentives or rewards were offered to any of the participants.

F. Cultural aspects

In Experiment 3, all participants were recruited within the Netherlands.

G. Age

Participants in Group VPMG and Group VPVG are significantly older than the participants in Group MPMG and Group MPVG. This is inherent to the way the participants were recruited. The MP participants are currently enrolled in flight schools to obtain their pilot licences. Most of them are in their early twenties. The VP participants have been invited to participate through newsletters and forum messages targeted at pilots who may have had their licences for quite some time.

Within the VP group, the participants in Group VPVG are significantly older than those in Group VPMG. As the assignment to the gameplay groups was done before starting the experiment, this is a random effect.

Age is strongly related to several outcomes (Table 4.18). Older participants achieve lower game scores and do not play as long as younger participants. They report to experience a higher engagement, higher interest and a more positive feeling about the obligation, but they also experience more pressure. Despite these correlations, ANCOVA testing shows that age does not have a significant effect on the outcomes of the analyses.

H. Technical difficulties

The technology used to develop the game limited its use to specific internet browsers on desktop and notebook computers. Smartphones and tablets could not be used. Due to this restriction, six participants in the VG group reported technical difficulties. As MG participants with technical difficulties could not finish the experiment and share their remarks, they will most likely have abandoned the experiment altogether. As the participants who reported the technical difficulties were unable to play the game, they have been left out of the analyses. However, some participants may have run into these difficulties and switched to a different device or internet browser. This may have had an effect on the enjoyment of the game, and the overall appreciation of the experiment that we cannot discern.

4.4.7 Section conclusion

Experiment 3 is in line with the outcomes of the previous experiments. Consistent with Experiments 1 and 2, we did not find a learning effect from playing the *CloudAtlas* game. Therefore, we cannot answer RQ 2a.

Despite a higher sense of freedom, voluntary players do not perform better in the game or on the test (Measurement 1) or play longer (Measurement 3). We were surprised to find that mandatory players (MG), and even mandatory participants (MP), enjoy the

Table 4.18: Outcomes significantly correlating with Age

Outcome	Correlation		
	N	r	*p*
Self-reported prior knowledge	77	0.23	<0.05
Highest game score	77	-0.37	<0.01
Time played in the game	77	-0.24	<0.05
Engagement in the training	77	0.24	<0.05
IMI subset Interest	77	0.28	<0.05
IMI subset Pressure	77	0.24	<0.05
Feeling about the mandatory time of gameplay (MG only)	39	0.39	<0.05

game as much as voluntary players and participants (Measurement 4). With regard to RQ 2b, we may conclude that the obligation does not take the fun out of the game; an interesting outcome.

4.5 Overall discussion of the experiments

Initially, we set out to show the effect of voluntariness on the learning effect of a serious game. The voluntary part turned out to be easy. However, we have established that it is very hard, perhaps impossible, to create a genuinely mandatory setting. This made it hard to compare voluntary gameplay with a type of gameplay that would resemble assigned coursework in an educational or vocational setting.

After having all volunteers in the first experiment, we tried to create a stronger distinction between voluntary and mandatory gameplay by adding voluntary (VP) and mandatory participation (MP) to the second experiment. This proved to be difficult. The Dutch educational system requires a teacher to publish all requirements of a higher education course. It does not allow adding extra requirements later on. As a result, it was difficult to enforce the students' participation, because they still had a possibility not to participate. Hence, students were still somewhat free to decide whether to participate or not. The amount of obligation perceived depended strongly on the personality of the student.

In the third experiment, we tried again. We recruited our participants from Dutch flight schools. As these institutions fall outside the regular Dutch education system, we expected them to have more room to require participation from their students. Moreover, we expected aspirant pilots to have a certain respect for their flight instructors. The third experiment did have a higher percentage of participation in the mandatory participation (MP) group, but still, some students did not participate. Apparently, they did not experience the obligation as such.

Mandatory participation is not a dichotomous variable. Some of the mandatory participants (MP) felt they had volunteered, others did feel somewhat obliged, but did not have negative feelings about it. Also, there were students who did not participate, despite being assigned to do so by their instructors. None of our experiments had a situation of undeniable mandatory participation.

4.6 Limitations

In the experiments, we faced two types of limitations that may have influenced the results. First, the experiments had a small number of participants (Subsection 4.6.1). Second, we were unable to create a strong feeling of obligation in the mandatory participants (Subsection 4.6.2).

4.6.1 Number of participants

Experiment 1 had a small number of participants. By recruiting through social media, we aimed to reach a large number of participants, but in fact, the number of participants was small. The group difference on prior motivation would probably not have occurred with a larger sample size or a different assignment strategy (pair matching).

In Experiment 2, recruiting was done through institutions for higher education rather than social media. In Experiment 3, participants were recruited through flight schools and aviation-related organisations. This led to the recruitment of more participants, but overall, the number of participants was still small.

4.6.2 Mandatory participation

In Experiment 1, all participants were voluntary participants. There was no obligation to participate in the study. Mandatory participation in the study (as a part of a regular course) would be of interest as this would provide a normal motivation setting for students in which the effects of voluntary gameplay can be observed without self-selection issues.

In the design of Experiment 2 and 3, we attempted to counteract the limitations of Experiment 1. In Experiment 2 and 3, the self-selection issue was addressed by having participation assigned by teachers and flight instructors instructors respectively. The assigned participation seems to have resulted in a stronger obligation, but it still was not as strong as we expect it to be in a setting of game-based learning.

4.7 Chapter conclusion

We conducted three experiments to measure the effect of voluntary play on the outcomes of a serious game. In our experiments, we were unable to create a strong sense of obligation through mandatory participation.

We will address the research question in Subsection 4.7.1. Next, we will discuss the implication of our outcomes in Subsection 4.7.2. Finally, we will look at future research in Subsection 4.7.3.

4.7.1 Answering research question 2 (RQ 2)

This explorative study aimed to answer RQ 2 and its subquestions.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

RQ 2a: *To what extent does the voluntary play of a serious game affect the learning effect?*

RQ 2b: *To what extent does the voluntary play of a serious game affect the gameplay experience of the player?*

To answer RQ 2a, we look at the outcomes of the game, measured with the knowledge and application questions in the test in all three experiments. The *CloudAtlas* game was developed specifically for this study. The outcomes indicate that players may need some time to get engaged in the game. This may have to do with the quality, playability, difficulty, or even graphical design of the game. In an ideal situation, a serious game will lead to a distinct improvement of player performance in a test regardless of voluntary or mandatory use. Initially, we expected that using a serious game voluntarily would lead to a greater improvement, in comparison to mandatory use. However, the *CloudAtlas* game seems to have no learning effect at all. Playing the game does not make a difference in the test scores, regardless of whether the game was played voluntarily or mandatorily (Measurement 1).

To answer RQ 2b, we look at the enjoyment, engagement (Measurement 3) and the feelings about being obliged to play (Measurement 4). In all three experiments, mandatory players report a similar enjoyment or engagement as voluntary players. They do not have strong negative feelings about the obligation (Measurement 4). Moreover, they play longer than the voluntary players (Measurement 2).

In none of the three experiments, we found that voluntary play has an effect on the learning effect or the gameplay. We did not find evidence that the voluntariness of gaming, highly rated by many game theorists and practitioners, is essential in order for the game to be fun. On the contrary, our findings indicate that participants with a stronger obligation play as long and as well as participants who were free to play the game. Also, they enjoy the game equally. Furthermore, we found that a little coercion increases the time spent in the game, which in turn may improve the learning effect.

The surprising finding that mandatory gameplay in the game does not appear to ruin the enjoyment and engagement in the game challenges the assumption of many game design theorists and practitioners that games need to be played voluntarily in order to be engaging, fun, and effective. The findings in our three experiments indicate that mandatory playing of a serious game is just as much fun as playing it voluntarily.

4.7.2 The implications of the outcomes

As voluntary play is thought to be indispensable for gaming, and thus for GBL, using a serious game in a training curriculum would disadvantage students who do not wish to play the game. Prensky [160] believes that a choice needs to be offered when using games for learning, to keep the voluntary aspect of gaming intact. If not playing the serious game would mean that the student does not learn, an alternative should be available. An alternative method would have to be offered to give them a fair chance of successfully completing the course, leading to higher training expenses.

Our experiments indicate that mandatory play of a serious game does not negatively affect the learning outcome or the player experience. If the findings of our study hold up in continued research, it may be concluded that providing the alternative method is not necessary, as mandatory players are not negatively affected by the obligation of playing a game. The absence of a negative effect of mandatory gameplay may open doors for education and professional training to implement GBL in their curriculum.

4.7.3 Future research

Our study found no evidence that voluntary gameplay is necessary for GBL. We found that mandatory participation (MP) and mandatory gameplay (MG) did not have significant negative effects on the enjoyment of the game at hand.

However, we used a game that turned out not to have a learning effect. In future research, it would be of interest to look at the effects of voluntary and mandatory participation and gameplay on the outcomes of a serious game that has been validated and proven effective. This would allow a conclusion to be drawn about the effect of voluntary play on the actual learning outcomes of the serious game.

Furthermore, future research should answer the question whether the effect of voluntary gameplay on the enjoyment of a serious game remains negligible as the type of game, the players and the intended learning outcomes are varied.

Thus, to definitively answer the question about the effect of voluntary play, further research is needed in various areas. Still, it is our expectation that voluntary play will not play as big a role as some games experts believe it does.

Chapter 5

Creating Shuttle to Mars: a game to provide experience

In this chapter, we will discuss the preparations that we have made to be able to answer RQ 3. The preparations contain the design and development of the *Shuttle to Mars* game.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

The natural start of our research in this chapter is determining what competencies the *Shuttle to Mars* game would aim to train. In Section 5.1, we will identify the competencies that are essential for airline pilots to act adequately in critical situations. In Section 5.2, we will describe the important ins and outs of the *Shuttle to Mars* game. Next, in Section 5.3, we will elaborate on the design of the *Shuttle to Mars* game, based on our SG4CD model. The game is intended to be fun as well as instructive, as it should keep the player playing and reach the learning objective at the same time. After the analysis in Section 5.2 and the design discussed in Section 5.3, the game has been developed and tested in Section 5.4. There, we will playtest, analyse, and discuss the outcomes of the test. The outcomes of this test will be taken as conditions for the further development of the *Shuttle to Mars* game. Finally, in Section 5.5, we will give our conclusions about the design and development of our serious game. They will be collected as the preparations for answering RQ 3. RQ 3 itself will be answered in Chapter 6.

The contents of this chapter are based on the following two publications:

1. Kuindersma, E. C., van der Pal, J., van den Herik, H. J., & Plaat, A. (2016b). Shuttle to Mars: Training airline pilots for critical situations. Poster and handout presented at the Meaningful Play Conference. East Lansing, MI.
2. Kuindersma, E. C., van der Pal, J., van den Herik, H. J., & Plaat, A. (2017). Building a game to build competencies. In J. Dias, P. A. Santos & R. C. Veltkamp (Eds.), *Games and Learning Alliance, 6th international conference* (pp. 14-24). Heidelberg, Germany: Springer.

5.1 Competencies for critical situations

In Chapter 2, we have described and defined the terms *airline pilots* (see Definition 2.1), *competencies* (see Definition 2.6) and *critical situations* (see Definition 2.5). In this section, we will identify the competencies that airline pilots need in critical situations.

In Subsection 5.1.1, we will look at the ICAO core competencies that all airline pilots are expected to possess. Next, we will identify which competencies are essential in critical situations. To do so, we have performed a job analysis (Subsection 5.1.2).

5.1.1 Airline pilot competencies

The eight core competencies, identified by ICAO, the IATA and the IFALPA, are divided into behavioural indicators (see Appendix C.2) that describe the technical and non-technical knowledge, skills and attitudes that are needed to operate safely, effectively and efficiently in a commercial air transport environment [129, 207].

At any time during a flight, the main task of the pilot is to keep control over the aircraft. A safe flight path must be ensured before accomplishing any non-normal checklist or attempting to solve any (potential) problem. In non-normal situations, pilots may be surprised. The natural tendency of human beings to life-threatening situations is to fight, flight or freeze [119]. For pilots, this tendency often means that they tend to take actions right away, instead of taking the time to assess the situation. However, only a few situations require immediate action. Even severe situations do not need to become emergencies if the pilots act adequately.

To cope with critical situations, pilots need (1) the knowledge and psychomotor skills of manually flying an aircraft under non-normal conditions, (2) cognitive skills such as problem solving and decision making, and (3) stress management skills. Our research focuses solely on cognitive tasks.

In the following section, we will identify which cognitive tasks are essential in critical situations.

5.1.2 A job analysis to identify the essential competencies

Keller et al. [103] have described the pilot tasks to include visual, auditory, cognitive, and psychomotor elements. These tasks can be translated into the required competencies and their corresponding behavioural indicators. To determine which of the ICAO core competencies are essential in critical situations, we performed a job analysis. Below, we discuss (A) the methodology, (B) the outcomes and (C) the results of the job analysis.

A. Methodology

We apply a partial job analysis that includes cognitive task analysis elements. Cognitive task analysis is aimed at understanding tasks that require many cognitive activities from the performer, such as decision making, problem solving, memory, attention and judgement. Cognitive task analysis applies several methods for collecting information on the knowledge, skills, and cognitive processes that form the basis of observable behaviours when performing specific tasks [175].

We used three methods, viz. (A1) document study, (A2) observation, and (A3) semi-structured interviews, to determine which of the ICAO core competencies are essential in critical situations.

A1. Document study. The document study was aimed at finding both formal and informal sources on the tasks that a pilot has to perform during normal and non-normal situations. The document study yielded scientific articles, public documents, websites and weblogs. Attention was paid to non-scientific materials, as relatively few scientific articles are published about the airline pilot's job. Additionally, the references in the articles retrieved were used to find other relevant sources.

A2. Observation. The observation was informal. It was performed in a Boeing 777 full flight simulator. Two captains were observed during a simulator training session, that was part of a series of twelve. The training was aimed at the captains qualifying for their type rating (i.e., licence) for Boeing 777. The simulator session consisted of non-normal situations and emergencies initiated by the instructor/examiner. During the session, the captains switched roles and seats a number of times. One of them would take on the role of captain, and the other would play the role of first officer. Thereafter, the roles reversed. The pilots were scored on (1) communications, (2) performance of technical operations, and (3) their adherence to procedures and checklists.

A3. Interviews. Interviews were conducted with four captains and one first officer from two different airlines; 4 men and 1 woman. They were all experienced airline pilots, with their experience ranging from 15 to 25 years, and from 5,000 to 14,000 flight hours. The interviews were semi-structured (see Appendix C). The questions addressed the pilot's background, experience with non-normal situations and view on the relevant competencies, based on the ICAO core competencies. Each interview lasted about 60 minutes.

B. Results

The three methods that we applied, have yielded the following results.

B1. Document study. During every non-normal situation, the primary task of the pilots is to fly the aircraft. The document study, the observation and the interviews all corroborate this view.

A safe flight path must be ensured before accomplishing any non-normal checklist. The pilots should focus on communication and flight path management. The pilot who has control over the aircraft must focus on stabilising the aircraft and call out immediate actions. The other pilot will accomplish these actions and start the appropriate checklist [82]. Pilots should sit on their hands for a moment to stay calm and let the shock subside [98].

In non-normal situations, pilots may have to deal with surprise or startle [185]. In actual emergencies, pilots may suffer from stress and panic. They will experience an increased workload and stress. In non-normal situations and emergencies, there may be additionally complicating factors (such as cognitive limitations, choices with uncertain outcomes, and time pressure) [125]. Teamwork and leadership are important in handling a non-normal situation correctly [64].

In the document study, we compared several sources [82, 98, 148] on how to handle non-normal and emergency situations. Each source provides their own guidelines. Although the phrasing of the guidelines varies, we identified eleven common guidelines and linked them to the ICAO core competencies (see Table 5.1).

Table 5.1: Combining handling guidelines with ICAO core competencies

Handling guideline	ICAO core competencies
Be aware of changes in situation	7. SA
Perform your primary task	1. AP 3. AFPM-A 4. AFPM-M
Stay calm	8. WM
Identify source of the problem	6. PS&DM
Determine severity	6. PS&DM
Come up with a plan	6. PS&DM
Prioritise duties	6. PS&DM 8. WM
Delegate duties	8. WM
Use non-normal checklists	1. AP 6. PS&DM
Take action	5. L&T 6. PS&DM
Communicate	2. COM

B2. Observation. The pilots observed in the simulator training session had extensive experience in different types of aircraft. As a result, they were familiar with all situations and procedures. Only small variations in the design of the cockpit and the behaviour of the aircraft make the observed training different from their previous experiences. The pilots were also aware that they were in a training session and that a large number of different situations would be offered. They may have been hardly surprised at all by the events, as they are 'on the edge of their seat' and highly vigilant. The captains showed good situation awareness and communication. Only once, there was some surprise as one of the three screens of the flight management system malfunctioned. For one second they did not know how to access the information without this screen, but then they quickly found a workaround by using one of the other screens. This is only one example of problem solving and decision making. It serves as an idea generator for other situations that need a fast reaction or a creative solution.

The way in which the pilots handled the situations in the simulator corresponded with the handling guidelines (Table 5.1) found in the document study. The pilots might hear an alarm or notice a deviation in the systems, and then they would find out what could be the cause of the problem, while still operating the aircraft. They would communicate and divide tasks between them.

B3. Interviews. For the interviews, we invited five pilots connected to NLR. We did not select them on their experience with critical situations. Each of the interviewees had only experienced a few non-normal situations in their careers, and they would not consider most of these situations an emergency. They also indicated that although following procedures is essential in aviation, a pilot is allowed to turn to creative solutions if necessary. This may happen if the pilot believes it to be a better way to prevent or resolve an emergency, or in the case that following the procedures might create a harmful situation.

The pilots selected the ICAO core competencies that they considered essential in critical situations and subsequently ranked their selection. We take into account only the competencies that were selected by at least three of the pilots to be essential competencies. They all agreed that PS&DM (Competency 6) is important. All five pilots selected this competency, and it received the highest average ranking. Furthermore, flying the plane (Competencies 3 and 4: Aircraft Flight Path Management) was identified, together with SA (Competency 7). Only two pilots selected WM (Competency 8), but on top of that, both of them gave it the highest possible ranking. Therefore, we do consider it an essential competency. The selection of PS&DM, AFPM-A, AFPM-M, SA and WM corresponds with the handling guidelines found in the document study (Table 5.1).

C. Conclusion

Both the document study and the interviews confirmed that real emergencies are rare. However, non-normal and even critical situations do occur. The job analysis has led to the selection of three competencies that we consider most important in critical situations.

- Problem Solving and Decision Making
- Situation Awareness
- Workload Management

Based on the outcomes of our analyses, we identified a total of 14 behavioural indicators that are relevant within the setting of the *Shuttle to Mars* game. In Appendix C.2, the selected behavioural indicators have been marked with *. These competencies and behavioural indicators will form the basis for the meaningful events in the *Shuttle to Mars* game.

Aircraft Flight Path Management, both Automation and Manual, was identified by the airline pilots as important in critical situations. These competencies are closely related to the primary task of airline pilots and, therefore, they are related with their technical skills. Developing these skills is outside the scope of our research. However, we do address the cognitive aspects of these competencies in our game, by using a recognisable primary task that needs to be performed continuously.

5.2 The Shuttle to Mars game

As no off-the-shelf game was available by which the complete set of identified essential competencies could be trained, a prototype game had to be developed for this specific purpose. We did so by developing a serious game that we call *Shuttle to Mars*. In this title, *Shuttle* refers to the familiarity of a common activity, whereas *Mars* appeals to unknown situations and a sense of adventure. In the design, we aimed to create gameplay that engages the players and appeals to them to play the game out of their own accord.

The work we have done with the *Shuttle to Mars* game has been carried out with beta versions, which we will describe in Subsection 5.2.1. Then, we will give a general description of the game in Subsection 5.2.2.

5.2.1 Beta versions

Shuttle to Mars was designed by the author of this thesis and developed by a team of undergraduate students in Gametechnology from Utrecht University as their bachelor project. The game was developed using the Unity 3D platform.

Initially, the game was developed for iPad. The iPad was the device of choice because many airline pilots own an iPad and it is easy to bring along on flights. Moreover, the iPad is commonly used for casual gaming, and using an iPad to play a serious game may contribute to the appeal of that game.

During the technical realisation of the *Shuttle to Mars* game, it proved unfeasible to build it entirely as it was designed. To meet the deadlines, we had to decide to leave several features and functions out of the beta versions of the game. Many of the features and functions that were omitted, were mentioned by the participants as suggestions for improving the game (see also Subsection 5.5.2).

The playtest (see Section 5.4) was performed with an early beta version of the *Shuttle to Mars* game on iPad. We will refer to this version as *Beta 1*.

After the playtest, during the further development of the game, technical issues arose making the use of iPads impossible. For that reason, the game was recompiled to be played on a personal computer. The study described in Chapter 6 was performed with the *Shuttle to Mars* game on laptops. It was still a beta version of the game, but in a later stage than the version used for the playtest. We will refer to this version as *Beta 2*.

5.2.2 Game description

In this subsection, we will give an overview of the game design. We will describe (A) the storyline, (B) the game environment, and (C) the tutorial and levels of the game.

A. Storyline

In *Shuttle to Mars*, the player takes on the role of the captain of a Mars shuttle, transporting cargo through outer space. The player's job in each mission is to navigate the spaceship safely to its destination to deliver the cargo. The player must protect the cargo, the crew and the spaceship against damage and loss. To reach the destination with the highest score possible, the player has to perform multiple tasks: the spaceship has to be controlled, resources need to be managed and supplemented, passage through all space sectors has to be arranged, and all kinds of situations need to be dealt with. The player needs to stay calm, stay focused and use problem-solving skills to succeed.

As a part of the story, the player will interact with non-player characters; two crew members, Galaxy Traffic Control, other cargo- and passenger spaceships, and potential enemies. Messages, requests and orders are received through on-screen notifications or audio calls. All notifications and signals must be dealt with in a timely manner to prevent

Figure 5.1: Shuttle to Mars screenshot: cockpit

C. Tutorial and levels

The Beta 2 version of the *Shuttle to Mars* game consists of a tutorial and fifteen game levels.

Tutorial. When a player first plays the game, he can only start with the tutorial. In the tutorial, the player is guided through his first *Shuttle to Mars* mission.

On-screen instructions (for an idea, see Figure 5.2) explain what the player has to do, how to do it and what to expect from the *Shuttle to Mars* missions. The player needs to follow the instructions given in order to proceed through the tutorial. The player receives feedback when completing the actions. By doing so, he explores how the spaceship is operated and what rules apply in the game.

Figure 5.2: Shuttle to Mars screenshot: on-screen instructions in tutorial

Levels. After the tutorial, the player can continue to the next, unguided mission. In the Beta 2 version, there are fifteen levels. The levels become available in a fixed order to create a sequence with increasing complexity. Once all fifteen levels have been played, all levels become available for replay.

At the start of each level, the spaceship is intact and supplied with resources, such as fuel and ammunition. Each level consists of two or more space sectors through which the player must travel to reach his destination. The player plans his journey by clicking each leg of the journey on the space map. One unit of fuel is needed for each leg. At the end of the sector, the player will have to cross a border. Based on his performance in the sector, he may have to buy resources or pay additional taxes.

The designated flight path of the spaceship is shown as a blue bubble trail (see Figure 5.3). Staying on course and avoiding obstacles are the player's primary tasks in combination with monitoring the spaceship's status.

During a mission, the player will run into a variety of situations. Events will occur that the player has to respond to, and that may require him to perform specific tasks. For example, an asteroid field will force the player to change his course, and a nebula will force him to use his radar instead of the view from the cockpit. In total, fourteen different events may occur (see Table 5.2). At first, the situations will be relatively simple, and only one event will happen at a time. Later on in the game, the events become more difficult. Moreover, situations become more complex as events occur close together or even simultaneously. The situations may become very complex and difficult to handle, combining events requiring complicated tasks in combination with dangerous circumstances and time pressure.

Figure 5.3: Shuttle to Mars screenshot: flight path shown as blue bubble trail

The challenges in the game will build up to meaningful events that have a strong link to the actual situations that a pilot may encounter in his job. The parallels created with these events are intended to stimulate transfer of the competencies from the game to the actual work environment. This will be discussed in more detail in Subsection 5.3.2.

The level is finished when the player succeeds in bringing the spaceship to its destination. The level ends if a player runs out of fuel or his spaceship is destroyed. The player only has one chance to perform well in a game level. The levels cannot be replayed immediately to prevent the player from practising and finding shortcuts.

Table 5.2: Shuttle to Mars events

Primary task	System failures	Obstacles	Encounters	Orders
Plan journey	Fuel meter	Asteroid field	Passing ship	Enter authorisation code
Follow flight path	Headlight	Large asteroid	Pirate attack	Push button when light is on
Steer spaceship	Hull meter	Nebula		
	Radar			
	Steering			
	Weapon system			

5.3 Game design based on the SG4CD model

In Chapter 3, we have introduced the SG4CD model. This model provides guidelines on how to design serious games for competency development. The characteristics that support competency development are connected to the elements that are needed in a serious game to make it a successful game and an effective learning method.

In Subsection 5.3.1, we describe how we have designed the *Shuttle to Mars* game to support the characteristics for competency development. In Subsection 5.3.2, we will discuss the design of meaningful events in the *Shuttle to Mars* game. The meaningful events provide the authentic learning tasks needed for competency development.

5.3.1 Designing the elements of Shuttle to Mars

We will first describe how the game design addresses (A) the game elements and the internal learning elements, (B) the external learning elements, and (C) the characteristics for competency development. The elements that have a purpose both for gameplay and learning are marked with *.

A. Game elements and (internal) learning elements

Non-linearity. The game consists of missions that have to be played in linear order. Within a mission, a player can choose his own route. The routes may differ in difficulty or cost. This feature was designed but omitted in the beta versions (see also Subsection 5.2.1).

Players. A single-player game design was chosen to enable the game to be played at any time. As airline pilots travel around the world, their co-workers have different work schedules and may be in different time zones. Therefore, an airline pilot may be unable to find a co-worker to play with, as a partner or an opponent, at the time he wishes to play the game.

Theme. We have chosen a space game to have a connection to aviation, but with room for fictional elements. In both *worlds*, the tasks are connected to transportation, such as navigating, dealing with threats and dilemmas (e.g., the balance between time and cost). Within the space theme, there can be all kinds of surprising events that aim to throw the player off balance.

Levels.* Each level of *Shuttle to Mars* consists of a mission in which the player starts with a fully functional spaceship and a supply of resources. The missions are played in a fixed order, with the complexity and difficulty of the missions gradually increasing. In the Beta 1 version, two missions were implemented, the Beta 2 version had fifteen missions. A final version will even need to have a larger number of missions.

Genre.* *Shuttle to Mars* is an adventure game. This genre is often used for serious games.

Reality.* The level of reality is low. The game does not offer a recognisable aircraft cockpit, and the tasks do not resemble actual piloting, but the individual aspects of tasks and situations strongly correlate to those of flying. The game is designed to prepare airline pilots for critical situations during flights. Operating the spaceship is not like flying an aircraft, but interruptions and distractions occur in the game as well as in reality.

Narrative.* *Shuttle to Mars* has a space-themed narrative that allows for (1) a motivating adventure, as well as for (2) a continuous primary task, (3) a high workload with secondary tasks, and (4) opportunities for surprising events.

Rules.* A set of rules guides the game. For example, the weapon can only be fired when at least one crew member staffs it. More tax must be paid if the weapon has been fired. Colliding with asteroids will damage the spaceship. Procedures must be followed to the letter to be successful. Some rules have been omitted in the beta versions of the game.

Goals.* The player's job is to bring cargo to a destination. The goal of each mission is to reach the destination. Otherwise, the player will lose the mission. However, a player can set additional goals for himself, such as arriving at the destination with as much cargo as possible, with as many resources, or with as little damage as possible.

Rewards.* No rewards are given in the game. However, some penalties will be given upon the use of undesired behaviours, such as using the weapon or not responding to an authorisation call.

Feedback.* The game offers feedback through the game score. In the design, we planned to provide feedback to the player on how he is doing and how he can improve his score. However, in the beta versions, this was not implemented, and due to technical issues, the score is not presented to the player.

Assessment. Creating an assessment based on game data, such as answers and reaction speed, is possible. However, in the beta versions of the game implementation of assessment was not completed.

Learning content. The learning content of *Shuttle to Mars* relates to the development of the competencies. This is embedded in the gameplay. By handling the game events, the player uses and strengthens the competencies of PS&DM, SA, and WM.

B. External learning elements

The external learning elements, which are part of the SG4CD model, provide instructional support but are not part of the game. Therefore, they are not addressed in the *Shuttle to Mars* game design. However, instructional support elements contribute to the learning effect. They are offered outside the game, in support of the game. They should be considered when making a plan for implementation of the game in a curriculum.

Collaboration. Collaboration is not directly relevant for *Shuttle to Mars* as it is a single-player game. However, there are ways to incorporate collaboration into the use of *Shuttle to Mars*. For example, players may work together and discuss how to handle the situations. In the current beta versions, no collaboration has been incorporated.

Briefing. Before gameplay commences, the airline pilots can be briefed about the game by the instructor. The instructor can identify the learning objective of the game and the competencies involved. As an *advance organiser* [68], this will focus the attention of the players to the relevant actions, which may result in a stronger learning effect.

Reflection. After playing (parts of) the game, reflection helps the player to focus on the learning content of the game. Players can reflect on how they handled a situation. They can compare their actions with those of other pilots or with the optimal solution presented by the instructor.

C. Characteristics for competency development

The third part of the SG4CD model consists of the characteristics for competency development. In the *Shuttle to Mars* game, we have addressed these characteristics as follows.

Sequencing. The missions in the *Shuttle to Mars* game are sequenced in increasing complexity and difficulty. The player starts with simple, straightforward missions. Gradually, more complex events are presented to the player.

Strengthening routine aspects. Particular actions, such as repairing the radar or the steering, need to be performed repeatedly. This leads to automation of these tasks, which diminished cognitive load and frees up cognitive capacity for other tasks. Furthermore, the gameplay requires the player to be alert to changes in the situation, thus strengthening the routine task of scanning the instruments.

Authentic learning tasks. Each mission contains several meaningful events that provide authentic learning tasks. The design of meaningful events is discussed in more detail in Subsection 5.3.2.

Conditions. Tasks need to be practised in different situations and under different conditions. The game provides a variety of working conditions and complexity factors such as visibility, time pressure, multitasking, and distractions. The situations are varied to make the gameplay diverse and surprising. In contrast, the conditions and complexity factors are not varied, but they are sequenced to provide an increasing level of difficulty.

Support and feedback. Support and feedback keep a low profile in the game. Support is offered only to keep the player in the game. Feedback is provided through the game score.

Integrated knowledge. A choice was made not to include explicit knowledge or learning content in the game. The game does not provide explanations on how, or why, a task should be performed. The feedback on the player's action gives sufficient support for implicit learning. This learning can be made more explicit through instructional elements, such as briefing and reflection.

5.3.2 Meaningful events

In critical situations in aviation, complicated incidents are combined with dangerous circumstances and time pressure. *Shuttle to Mars* was designed to have multiple levels of increasing complexity, to raise the airline pilots' level of experience to prepare them for critical situations. Moreover, increasing the complexity and difficulty will create engaging gameplay by keeping the player challenged [42, 204].

In the game, each mission (i.e., level) consists of a journey during which a series of events occur. The events in the game mimic reality, by offering a variety of circumstances.

To achieve transfer [212] from the zero fidelity simulation [192] of *Shuttle to Mars* to the actual work environment of an airline pilot, parallels need to be established. During the design phase, we discussed both the game and reality with experienced airline pilots, to identify viable parallels. The game events are matched with job tasks, based on (1) the essential competencies, (2) their behavioural indicators, (3) working conditions and (4) characteristics of the tasks. See also Figure 3.5 on p. 44.

We have distinguished parallels in three categories, viz. (1) the work environment, (2) the tasks, and (3) the situations. They are briefly described below. These categories are closely connected. Competencies form the common denominator. Competencies are required to interact with the work environment, to perform the tasks and to react to situations. The tasks are partly driven by input or cues from the work environment, and by the situation at hand.

Work environment. Although the spaceship environment is extremely simplified, the similarities between the spaceship and an aircraft are apparent. Both the spaceship and an aircraft are controlled from the cockpit. The cockpit has a dashboard with gauges and dials to monitor the status of the vehicle. There are signals, prominent as well as discrete, indicating issues with the vehicle. The window allows the pilot or player a view on the environment, albeit airspace or outer space. There are co-workers on board doing their job, but who of the co-workers can be called upon to help, and with whom can the player communicate?

Tasks. The main parallel with regard to the tasks is that a pilot or a player must continue to perform his primary task at all times. During a flight or a mission, situations may occur that require action. To control the situation the pilot or player will need to perform secondary tasks. Circumstances (i.e., working conditions) may increase the difficulty of performing those tasks.

Situations. The game has been designed to provide situations similar to situations which a pilot experiences during a flight. In normal situations, nothing out of the ordinary is happening, and the pilot or player is in control of his vehicle. The game events are designed as equivalents to non-normal situations in an aircraft. In non-normal situations, the pilot or player must act. In most cases, he will be trained for this. In the game, combinations of events are designed to represent critical situations to test and develop the competencies of the player.

The events are designed to be meaningful and to provide authentic learning tasks in which the competencies can be developed [201]. The meaningful events are intended to stimulate transfer [212] of the competencies from the game to the actual work environment. To ascertain relevant parallels, airline instructors were consulted during the design of the meaningful events.

Table 5.3 on p. 115 lists the game events that are matched with job tasks. Each game event comprises one or more game tasks that are connected to the ICAO core competencies (Comp.) and behavioural indicators (BI). The events and tasks are described in the first two columns. The third column shows the number and abbreviation of the connected ICAO competencies, and the number and letter of the relevant BI or BIs. In the fourth column, relevant working conditions (WCo) and task characteristics (TCh) are listed. The fifth column shows the description of an actual job task that matches the game event.

The individual events appeal to specific competencies. When events happen simultaneously, the combination also appeals to WM as interruptions must be managed, and tasks must be prioritised. Moreover, simultaneous events lead to more complex situations requiring a stronger competency of WM and PS&DM.

5.4 Playtesting Shuttle to Mars

Many game designers and researchers stress the importance of playtesting within the game design process [19, 66, 143, 173, 174, 180]. Some even consider it one of the most important activities that should be performed early on and repeatedly [19, 66, 173].

In Subsection 5.4.1, we will take a brief look at the purpose of playtests. Next, we will discuss the method of the playtest (Subsection 5.4.2). In Subsection 5.4.3, we will report on the results of the playtest. Subsequently, we will draw a conclusion in Subsection 5.4.4.

5.4.1 The purpose of playtesting

A playtest serves to determine whether a game produces the experience that the designers intended to reach [19]. It also identifies pacing and balancing problems [49].

Playtesting provides information as to whether the game controls are understandable and tractable, and the game is playable for the target group. The game's functionality and technical quality are not tested in a playtest [19].

Furthermore, for a serious game, playtesting is done to determine whether the target audience will be engaged in the game. Without engagement, the educational objective may not be reached.

To perform a playtest, it is not necessary to have a large number of participants. In usability studies, such as playtests, a sample of five users will identify almost as many problems as a larger group [145].

5.4.2 Shuttle to Mars playtest

Below, we describe (A) the method, (B) the participants, (C) the materials and (D) the setup and procedure of the playtest.

Table 5.3: Meaningful events matched with job tasks

Game event	Game task	Comp. & BI*	WCo & TCh**	Actual job task
Primary task	Plan journey legs	3. AFPM-A: 3d, 4. AFPM-M: 4e		Plan and program route
	Follow blue bubble line	4. AFPM-M: 4a, 4b, 4f	WCo: distractions TCh: accuracy	Stay on course
System failures	Notice system failure	7. SA: 7a	WCo: distractions TCh: difficulty, shared attention	Notice system failures
	Diagnose and choose solution	6. PS&DM: 6b, 6c, 6g 7. SA: 7f	WCo: time pressure	Diagnose and choose best solution
	Follow procedure to repair system	1. AP: 1b, 1f	WCo: time pressure	Use checklists to perform procedures
	Contact crew to repair system	8. WM: 8d	WCo: time pressure	Communicate with crew, delegate tasks
Obstacles	Notice and identify objects around spaceship	7. SA: 7c, 7f	WCo: visibility, distractions TCh: shared attention, impact	Notice and identify objects around the aircraft
Asteroid	Adjust course	4. AFPM-M: 4b, 4e	WCo: visibility, time pressure TCh: difficulty	Adjust course if needed
Asteroid (big)	Blow up asteroid to free path	6. PS&DM: 7. SA: 7h,	WCo: time pressure TCh: solution multiplicity, accuracy	Resort to extreme measures if needed
Beacon	Adjust course	4. AFPM-M: 4a, 4b	TCh: need for multitasking	Adjust course to reach destination
Encounters				
Pirate	React to encounter (negotiate or fight)	7. SA: 7h	WCo: danger, information availability TCh: solution multiplicity	Balance safety and commercial interests when handling a situation
Passing ship	Observe passing spaceship and answer crew question	7. SA: 7c	WCo: distractions, time pressure	Pay attention to details in surroundings
Orders				
Authorisation call	Respond to audio call by inputting correct code	1. AP: 1c 8. WM: 8g	WCo: distractions, time pressure	Pay attention and follow protocol
Dashboard alarm	Notice red light and respond by pushing button	1. AP: 1b, 1d 7. SA: 7a	WCo: distractions, time pressure	Stay alert and follow protocol

* Comp. & BI: Competencies and behavioural indicators (see Appendix C.2).

** TCh & WCo: Task characteristics and Working conditions.

A. Method

During playtesting, a player's experience can be identified using a variety of methods [49, 66]. For the *Shuttle to Mars* playtest the following four methods were applied.

Questionnaire. A questionnaire was presented prior to and after the playtest to gather information on the gaming experience, enjoyment and understanding of the game.

Thinking aloud protocol. Each participant was asked to vocalise all his thoughts on what he saw, what he did and what he was expecting to happen, during the playtest and while answering the questionnaire.

Observation. The participants were observed in person and on video, to register their responses and facial expressions.

Interviews. During and after the playtest, each participant was interviewed to gather background information on their responses and expectations during the game.

B. Participants

Five male participants played *Shuttle to Mars* during the playtest; four airline pilots and one flight simulator engineer. Recruiting the pilots allowed us to test the game with the intended target audience. Although the flight simulator engineer is not trained as a pilot, he has a similar educational level and an interest in aviation.

C. Materials

The playtest was performed with the Beta 1 version of the *Shuttle to Mars* game. This version was played on iPad. It consisted of four missions, two of which were used during the playtest in addition to the tutorial. In the Beta 1 version, not all features were implemented. After the playtest, the game was developed further to be used in the small-scale study described in Chapter 6.

In all playtest sessions, participants received three assignments in a fixed order.

1. Play part of an extended mission without any events.
2. Play the in-game tutorial.
3. Play a short mission with consecutive events; some simple, others more complex.

A protocol, including interview questions (Appendix C.3) and a questionnaire (Appendix C.4), was used to debrief the participants about their experience with the game during the playtest. The questionnaire had 21 questions that had to be scored on a 5-point scale.

D. Setup and procedure

The playtest was conducted in a meeting room. The playtest set-up involved one participant, one test supervisor and two observers (see Figure 5.4).

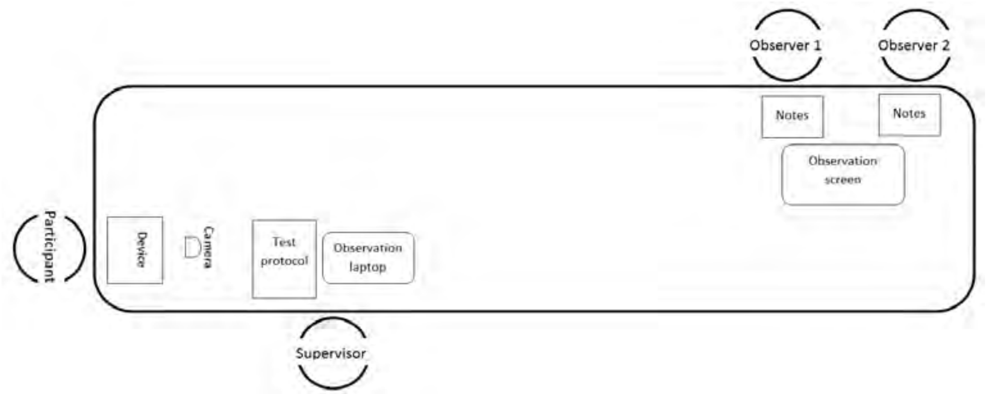


Figure 5.4: Shuttle to Mars playtest setup

Using mirroring software, the iPad screen was shared on the observation laptop, so that the supervisor could see what the participant did without directly looking at him. The laptop screen was replicated to the observation screen to allow the same for the observers. A webcam was directed at the participant to register facial expressions and responses, and a microphone was used to capture all verbal communications. Recordings were made of the gameplay on the iPad screen, the webcam images and the audio tracks for later analysis.

In the playtests, a protocol (see Table 5.4 and Appendix C.3) was used to assure an identical approach for all participants.

The participants played the Beta 1 version of the *Shuttle to Mars* game on an iPad. They played selected parts of the game and were asked to think aloud during the entire playtest. This allowed us to observe the intended gameplay, and to see whether the gameplay works for players from the target group.

Before starting the playtest and in between assignments, the participants were interviewed, and they filled out a questionnaire.

Table 5.4: Playtest protocol

1. Supervisor	Welcome and short explanation of the purpose of the playtest
2. Questionnaire	First page of questionnaire
3. Supervisor	Short introduction to the game setting
4. Game	Playtest assignment 1
5. Supervisor	Short interview
6. Game	Playtest assignment 2
7. Supervisor	Short interview
8. Game	Playtest assignment 3
9. Questionnaire	Remaining pages of questionnaire
10. Supervisor	Interview on the overall experience and the answers to the questionnaire

During the playtest, the supervisor asked questions about the player's behaviour in the game, when the participant had completed a mission. During the interviews, the

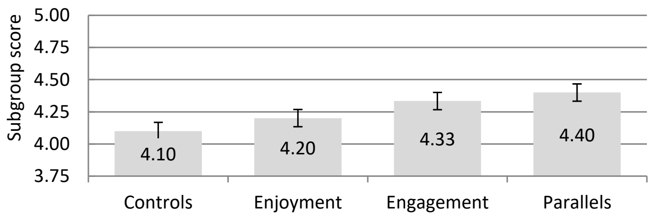


Figure 5.5: Means and SE for playtest questionnaire results

5.4.4 Playtest conclusion

The playtest was aimed at establishing the playability of *Shuttle to Mars*, not at finding statistical proof of its learning effect. The outcomes of the playtest give us confidence that *Shuttle to Mars* will be fun to play and has the potential to generate a positive learning effect.

After the playtest, improvements were made to the *Shuttle to Mars* game (see Subsection 5.5.2). The improved version of the game, Beta 2, was used in the study to answer RQ 3 (see Chapter 6).

5.5 Chapter conclusion

In this chapter, we have described the design and development of the *Shuttle to Mars* game. The game design is based on the SG4CD model and addresses the characteristics needed for competency development.

In the design, special attention was paid to meaningful events to provide authentic learning tasks. Subsequently, we have performed a playtest of the game to establish the playability of the game. The outcomes of the playtest were positive and gave confidence for the further development of the game.

Below we conclude on the outcomes of the playtest (Subsection 5.5.1) and provide improvements to the game (Subsection 5.5.2).

5.5.1 Outcomes of the playtest

The playtest showed that the game controls of the *Shuttle to Mars* game were understandable and that the participants enjoyed the game. They were able to distinguish the parallels between the game and aviation reality. Moreover, three of the four participants spontaneously identified the competencies which the game aims to reinforce.

Based on the playtest, we are confident that the *Shuttle to Mars* game will be fun to play and has the potential to generate a positive learning effect.

5.5.2 Improvements to the game

Designing a game is an iterative process. Improvements are made to the game as a result of testing. Within our research, we had only a few iterations available. Although the quality of the game was not a point of evaluation in the playtest (Section 5.4), the participants gave several suggestions for improvement. These and other improvements (see Subsection 6.4.2) should be considered when the development of the *Shuttle to Mars* game is continued.

Suggestions from the playtest participants

The Beta 1 version used in the playtest had only a few missions, which were played partially. Participants played the game on an iPad. Technical issues in the game hampered gameplay. Also, there was some delay in the gameplay due to the software used to record the playtest.

Technical issues. During the playtest, participants played parts of missions to avoid known technical issues. These were resolved to allow the missions to be played completely.

More events. Participants in the playtest indicated that they had wanted to come across more events in the mission. The Beta 1 version was boring at times.

After the playtest, the Beta 1 version was further developed into Beta 2 for the *Shuttle to Mars* study (Chapter 6). Many of the technical issues were solved, and a set of fifteen missions was developed.

Chapter 6

Measuring the Shuttle to Mars experience

In this chapter, we will present a small-scale qualitative study conducted to investigate how airline pilots experience the *Shuttle to Mars* game. We will answer RQ 3, which reads as follows.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

The design of the *Shuttle to Mars* game aims at developing airline pilot competencies for critical situations. It was described in Chapter 5. For the design of *Shuttle to Mars*, we attempted to apply the guidelines for serious games for competency development, presented in Chapter 3.

In Section 6.1, we will discuss why and how the game experience of the *Shuttle to Mars* game should be evaluated. In Section 6.2, we will describe the setup of our study, including the methodology and materials. Then, in Section 6.3, we will present our findings. Subsequently, in Section 6.4, we will evaluate and discuss our findings. Finally, in Section 6.5, we will answer RQ 3 and give recommendations for further research.

6.1 Evaluating the Shuttle to Mars game experience

Training of professionals aims to improve the professional's performance on the job, which leads to benefits for the organisation. This is the top of the pyramid in Kirkpatrick's model of training evaluation [105, 106] (see Figure 6.1).

The pyramid represents the hierarchical nature of the model. The higher levels are of greater importance [17], and can be reached when the lower levels are satisfied [76]. The three top levels are based upon the reaction (i.e., the affective responses) of the participants to the quality or relevance of the training [17]. When participants are positive about the course (level 1), there is a better chance that they will learn (level 2) and

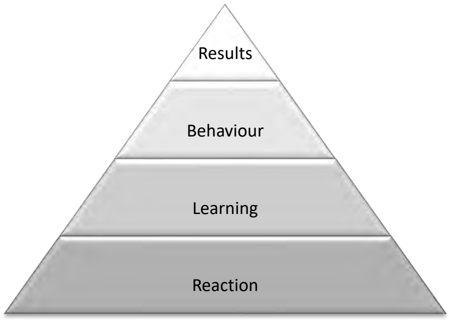


Figure 6.1: Kirkpatrick's four levels of training evaluation

change their behaviour (level 3), resulting in improvements for the organisation (level 4). However, Kirkpatrick's model is not a prescriptive model. A positive reaction alone is not sufficient.

In our research, we aim to determine whether a serious game can be used to train airline pilots to act adequately in critical situations. We investigate the reaction that airline pilots have towards a serious game that was designed specifically for that purpose.

For the organisations involved in aviation, the intended result of such a training is a further decrease in aircraft accidents that can be attributed to human error. Part of accomplishing such a reduction in accidents is to train airline pilots to change their behaviour in the cockpit. The idea is that behaviour resulting from the competencies identified in Section 5.1, will enable the pilots to act adequately in critical situations.

A change in behaviour should be the intended result of the learning that takes place in the training environment. In our research, the intended result is the development of essential competencies through playing the *Shuttle to Mars* game. To allow this learning to take place, the learners should have a positive reaction to the serious game and accept it as a valid way of developing their competencies.

A reaction of accepting the training is the first level of the training evaluation pyramid [105, 106]. It is essential for the higher levels of effect to be reached. Therefore, it is important first to assess the reaction of the players to a game. We will study their experience in order to ascertain the extent to which the learners will accept the game as a training method.

We expect that a player who gives a response of accepting the game will be more motivated to play the game and to continue the experiment. Therefore, we will take the participants' level of motivation as a measure of their positive attitude towards the game.

In the design of a serious game, attention needs to be paid to the balance between fun and learning [65, 128, 171]. Consequently, the experience of a serious game involves fun as well as learning. Both types of experience should be measured when evaluating a serious game.

In our study, we will investigate how the participants experience the *Shuttle to Mars* game. We will address their enjoyment of the game, and their expectations about developing their competencies.

6.2 Research setup

In this section, we will describe the setup of our study. We will start with the methodology (Subsection 6.2.1). Next, we will discuss the participants (Subsection 6.2.2). Then, we will explain our procedure for measuring the experiences with the *Shuttle to Mars* game (Subsection 6.2.3). Finally, we will discuss the materials used (Subsection 6.2.4).

6.2.1 Methodology

In our research, we aim to measure airline pilots' reaction to our *Shuttle to Mars* game, and the experience they have playing the game. For this purpose, we used (1) online questionnaires (see Appendix D) to collect qualitative data including some demographic information, as well as some quantitative data, and (2) audio-recorded semi-structured interviews (see Appendix D.5) to collect qualitative data.

For the qualitative study, we have chosen the research strategy of *grounded theory* [74]. The grounded theory approach aims to allow a theory to emerge from data about a reality that is being investigated. It uses a systematic set of procedures to inductively derive a theory from data that is collected and analysed pertaining to a specific phenomenon [186]. A grounded theory represents a reality. Therefore, it should make sense to the persons who were the object of study as well as those who practise in the same area.

6.2.2 Participants

All participants were recruited through connections with Dutch airline companies. Our research is aimed at providing experience for airline pilots with little experience. In consultation with airline pilots and a flight instructor, we quantified *little experience* as a maximum of 5 years and 2500 flight hours with an airline. After an open call for participation, initially, sixteen pilots showed interest to participate. However, at the start of the experiment, only five pilots were available to participate due to conflicting schedules. Each participant was informed about the purpose of the study and signed a consent form.

All pilots were male, with a mean age of 31.2 years ($SD = 6.3$). They were first and second officers with three different airlines. On average, they had 2.6 years of experience working as a pilot for an airline company ($SD = 1.1$). In flight hours, their experience ranged from 1000 to 2300, with a mean of 1880 hours ($SD = 870$).

One participant reported to play games daily, on average an hour per day. Three participants said that they play games a few times per week. The last participant rarely plays games. On average, the pilots say to play games for 30 minutes per week.

In addition to the young airline pilots, we invited three experienced flight instructors to participate in the study. The procedure for the flight instructors was identical to that for the airline pilots.

All flight instructors were male. They were older than the other group ($M = 39.3$, $SD = 7.6$) and their flight hours ranged from 5000 to 9000. All instructors were captains affiliated with an airline.

Participants and instructors all received reimbursement for time and travel expenses, in the amount of €100. As an incentive to complete all parts of the study, a modern smart-watch was raffled upon completion of the experiment by way of a random draw. Pilots and instructors all had an equal chance of winning the watch.

6.2.3 Procedure

The procedure consisted of five parts, pictured in Figure 6.2. Participants had a Start session in the NLR offices in which they acquainted themselves with the game by playing the tutorial (see Subsection 5.2.2). Then, in their own time and on their own personal computers, they played the game. It was divided into three blocks. Each block consisted of approximately 1 to 1.5 hours of gameplay and, on top of that, a questionnaire. Participants had one week to complete each block. They did not have to complete a block all at once. After completion of the game, the participants were invited back to the NLR offices for the final interviews. The interviews lasted 30 to 40 minutes per participant.

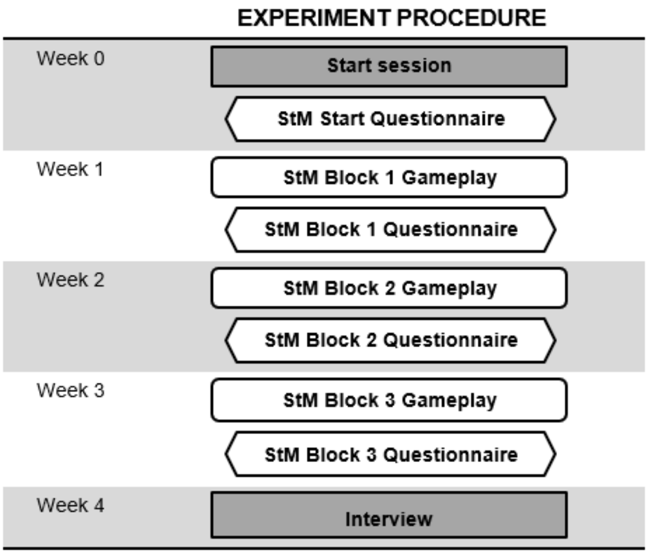


Figure 6.2: Procedure of the small-scale qualitative study for Shuttle to Mars (StM)

6.2.4 Materials

Playing the *Shuttle to Mars* game is the central part of the current study. To record the players' experiences with the game, four questionnaires and a semi-structured interview scheme were developed. Data generated by playing the game was stored in the game database for further research of in-game behaviour and learning effect. However, as our study focused on determining the acceptance of the game by airline pilots and not on finding a statistical proof of its learning effect, the game data was not used for the purpose we had in mind.

The design of the *Shuttle to Mars* game has been discussed in Chapter 5. In this subsection, we will discuss (A) the questionnaires and (B) the interview structure.

A. Questionnaires

Each participant was presented the StM Start questionnaire during the Start session, and then an StM Block questionnaire after completing each of the three game blocks. In addition to questions about the gameplay, each questionnaire consisted of a set of repeating questions and a validated tool. We used three validated tools: (1) the UEQ, (2) the IMI, and (3) the CEGEQ.

1. The UEQ is a tool to evaluate the quality of the user experience of an interactive product [164, 181].
2. The IMI is a multidimensional instrument to measure a participant's subjective experience about the activity in an experiment IMI [91, 172] (see also Chapter 4).
3. The CEGEQ is an instrument to assess the presence of elements that are necessary but not sufficient for a positive game experience [28, 29].

Repeating questions relating to motivation. Each of the StM Block questionnaires had a set of repeating questions to gauge the motivation of the participant. These questions enquired after:

1. time spent playing the *Shuttle to Mars* game and other games,
2. types of other games played,
3. feeling about and attitude towards the game and the experiment.

Repeating questions relating to gameplay and the relation to the job. Each of the StM Block questionnaires had some questions to reflect on the gameplay and its relation to an airline pilot's job.

Below, we describe the four questionnaires for (i) Start session, (ii) Block 1, (iii) Block 2, and (iv) Block 3. The validated tools included in the questionnaires will also be described. See Appendix D for complete questionnaires.

A1. StM Start questionnaire

The StM Start questionnaire gathered demographic and gaming related information. Moreover, it enquired after the participant's attitude towards innovations and their motivation to participate. As this questionnaire was answered right after the first gameplay session, questions were asked about whether it was clear how the game should be played.

A2. StM Block 1 questionnaire (with the UEQ)

The StM Block 1 questionnaire comprised the UEQ [164, 181]. The UEQ contains 26 items on six scales [181], describing distinct quality aspects, such as 'boring - exciting'. The six scales are as follows.

1. **Attractiveness.** Do users like or dislike the product?
2. **Perspicuity.** Is it easy to get familiar with the product? Is it easy to learn how to use the product?
3. **Efficiency.** Can users solve their tasks without unnecessary effort?
4. **Dependability.** Does the user feel in control of the interaction?
5. **Stimulation.** Is it exciting and motivating to use the product?
6. **Novelty.** Is the product innovative and creative? Does the product catch the interest of users?

Scores have to be given spontaneously and have to reflect the personal opinion of the participant. Each pair is scored on a 7-point scale. In the analysis, the scores are transformed to a range from -3 (horribly bad) to 3 (extremely good). Scores between -0.8 and 0.8 are considered neutral.

Rauschenberger et al. [164] have grouped the six UEQ scales into "*pragmatic* and *hedonic* quality" (Table 6.1). Pragmatic quality describes task-related quality aspects, viz. perspicuity, efficiency, and dependability. Hedonic quality describes non-task-related aspects, viz. stimulation and novelty. According to Rauschenberger et al. [164], attractiveness is neither pragmatic nor hedonic. Therefore, they label it as a "pure *valence* dimension" [164, 181].

Table 6.1: Categorisation of UEQ scales

Pragmatic	Hedonic	Valence
Perspicuity Efficiency Dependability	Stimulation Novelty	Attractiveness

A3. StM Block 2 questionnaire (with the IMI)

The StM Block 2 questionnaire comprised the questions of the IMI [91, 172]. The IMI consists of twenty statements concerning six subscales (see Table 4.7 on p. 76). Agreement with each statement is scored on a 7-point Likert scale, ranging from *not at all true* to *very true*. The items of the IMI instrument are divided [172] into six subscales.

1. Interest/Enjoyment,
2. Perceived competence,
3. Effort,
4. Value/Usefulness,
5. Pressure/Tension,
6. Perceived choice.

In addition to the original IMI statements, we added three statements in the same fashion about their attitude towards gaming [197] to the StM Block 2 questionnaire. For a full list of all statements, we refer to the StM Block 2 questionnaire in Appendix D.

A4. StM Block 3 questionnaire (with the CEGEQ)

The StM Block 3 questionnaire comprised the CEGEQ [28, 29]. With the Core Elements of Gaming Experience (CEGE) framework, Calvillo-Gamez [28, 29] presents a series of elements that are indispensable for a positive game experience. According to Calvillo-Gamez, these elements are "necessary but not sufficient". If all are present, the gaming experience will not be negative, but they do not guarantee a positive experience.

The CEGE are based on the idea that a positive experience playing a game comes from the player's perception of the game (*video game* construct) and his interaction with it (*puppetry* construct) [28, 29]. The constructs of enjoyment and frustration were added [28, 29] to the Core Elements of Gaming Experience Questionnaire (CEGEQ) to create a total of four scales.

1. Enjoyment,
2. Frustration,
3. Puppetry,
4. Video games.

The CEGEQ is the instrument to assess the presence of these elements. The CEGEQ consists of 38 items that the participant must score on a 7-point Likert scale.

B. Interview structure

The interview was structured in correspondence with the levels of Kirkpatrick's model for training evaluation [106] (see Figure 6.1 on p. 122). The questions focused on the three bottom levels of the model: (1) reaction, (2) learning and (3) behaviour. Eight interviews were conducted according to a semi-structured approach, allowing room to elaborate on participants' specific answers and statements. The interview structure can be found in Appendix D.5.

All eight interviews were recorded using a smartphone, and handwritten notes were taken. For each interview, an informal report was written by the interviewer; the recordings were not transcribed verbatim.

6.3 Results

In this section, we will present the outcomes of the four parts of the study. We look at the quantitative and qualitative data from the questionnaires and the outcomes of the eight interviews. We also take into consideration the researcher's impression of the participants during the meetings.

We will first report on the Start sessions in Subsection 6.3.1. Next, we will report the outcomes the three game blocks in Subsections 6.3.2, 6.3.3 and 6.3.4, respectively. Then, we will report on the repeating questions from all four questionnaires in Subsection 6.3.5. Finally, we will report on the eight interviews in Subsection 6.3.6.

6.3.1 Start session results

To start with the experiment all participants visited the offices of NLR in Amsterdam. After a short introduction, the participants played the first game block of the *Shuttle to Mars* game, consisting of the tutorial and the first mission. After this, they answered the StM Start questionnaire.

Playing the first game block

All participants appeared to be enthusiastic about participating in the experiment and playing the game. They were interested in the research and the game.

Six participants played the game on laptop computers, two on desktop computers. On the laptop computers, the game was controlled using the touchpad or the keyboard. Three participants had difficulties operating the game via the touchpad.

While playing the tutorial, four participants requested additional information or explanation from the researcher. The researcher answered their questions to make sure they were able to play the game.

Five participants played the game quietly, while the other three were more outspoken. They expressed their engagement in the game with outcries or comments.

Initial questions

The initial questions were related to the participants' attitude towards innovations and their motivation to participate. All participants felt positive about the use of innovative training methods for airline pilots. Also, they were all positive about the use of virtual training or a serious game for training. Two participants, an instructor and a pilot, indicated that they were not usually pioneers in the use of new technology or software. The others were more supportive of the positive statement towards innovation.

The participants gave an average of 8.5 out of 10 (SD = 1.1) for their motivation to participate in this experiment. Except for one participant who gave a score of 3, all participants looked forward to playing the game.

With regard to playing the first part of the game, the participants were not convinced that the tutorial and the first mission gave a sufficient explanation of the game and provided sufficient practice (M = 4.0, SD = 1.2).

ICAO core competencies

Part of the StM Start questionnaire was related to the ICAO core competencies (see Appendix D.1). The participants were asked to score the importance of each of the eight ICAO core competencies in normal and non-normal situations as well as in emergencies. The competencies were scored on a 7-point Likert scale, ranging from *not at all important* to *very important*.

We observed differences between the opinions of the instructors and those of the pilots. Therefore, we show them separately in Figure 6.3. Due to the small number of instructors and pilots involved, the results must be interpreted carefully.

Overall, the pilots in our study believed that all competencies become more important in non-normal situations and emergencies. The instructors indicated that the importance of COM, L&T, SA and WM remains the same in all situations.

Interestingly, the pilots indicated that they believe AP becomes more important in emergencies, while instructors indicated a decrease in importance. A second interesting difference can be seen in the importance of COM. The instructors in our study attributed a higher importance to COM than the pilots did.

To complete the StM Start questionnaire, the participants were asked which training delivery method they believed to be most suitable for each competency (see Table 6.2). A description of training delivery methods is available in Appendix A.1. The ICAO core competencies are presented in Appendix C.2.

Pilots, as well as instructors, preferred the full flight simulator for training the competencies AFPM-A, AFPM-M, PS&DM, and SA. Also, the full flight simulator and the pc-based simulator were also mentioned for the training of AP and WM competencies. For the training of COM and L&T, other methods than simulators were preferred. Serious games were mentioned in relation to the training of AP, PS&DM, SA, and WM.

6.3.2 Block 1 results

In Block 1, each participant played the set of five missions and answered the StM Block 1 questionnaire. All participants finished Block 1 on schedule. Two participants contacted the researcher during Block 1, enquiring after the number of missions in Block 1, the game controls and the need to follow the designated route.

The participants spent between 1 and 2 hours playing the *Shuttle to Mars* game (M = 1.38, SD = 0.4), according to their estimates in the StM Block 1 questionnaires. Two participants played other games during the Block 1 period.

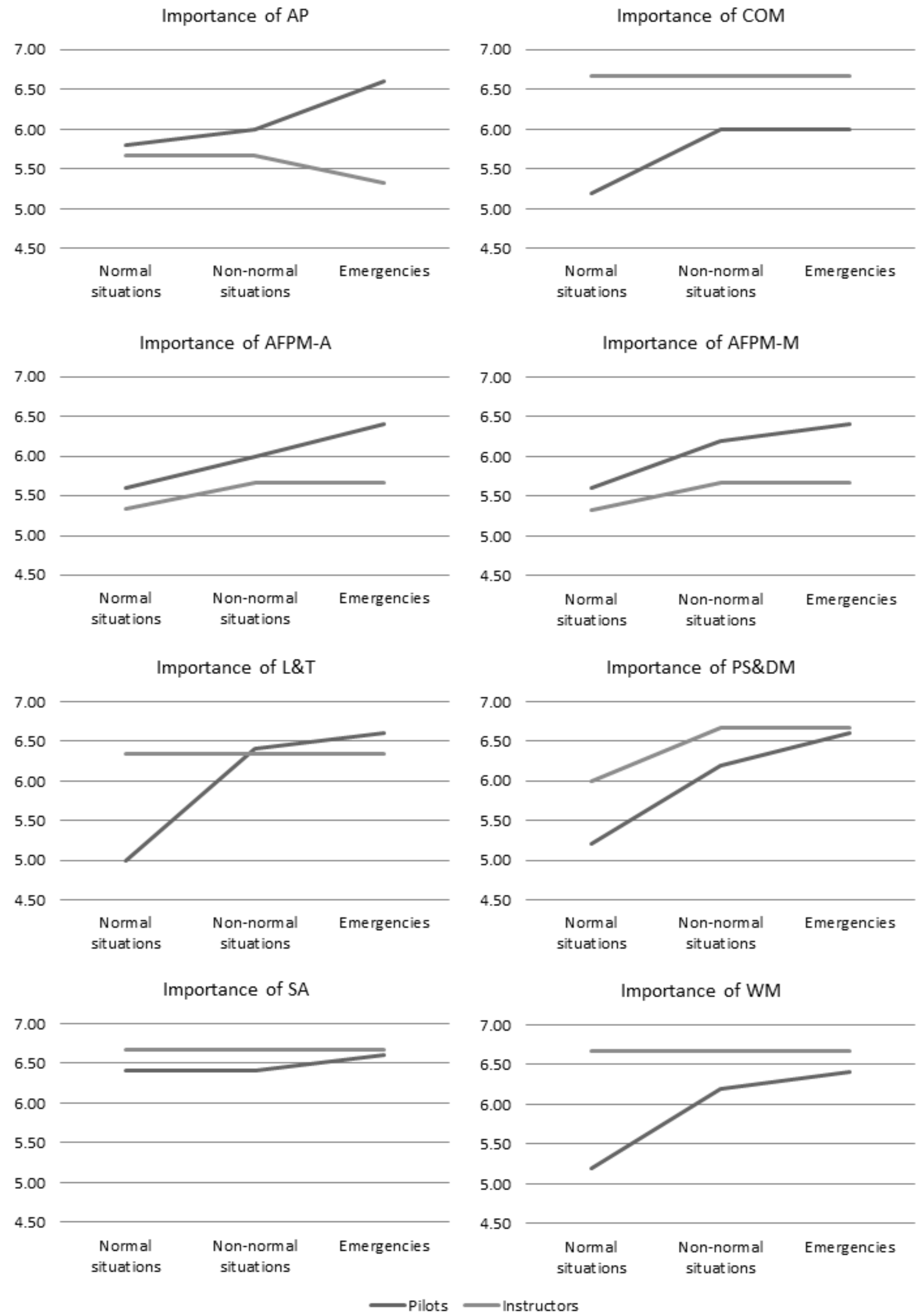


Figure 6.3: Importance of ICAO core competencies: comparing instructors with pilots

Table 6.2: Participants' votes for most suitable training method per ICAO core competency

Training method	**ICAO core competencies**															
	AP		COM		AFPM-A		AFPM-M		L&T		PS&DM		SA		WM	
	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I
Book/syllabus	2								1		1					
CBT		1	2													
Full flight simulator	2	1			4	3	5	3			2	2	3	3	1	1
Lecture/presentation				1						1		1				
PC based simulator		1	1		1										1	
Serious game	1										1		2		3	2
[illegible]			[illegible]	[illegible]					[illegible]	[illegible]	[illegible]					

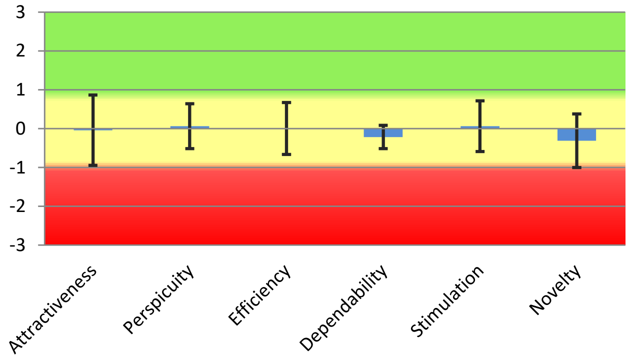


Figure 6.4: Shuttle to Mars' average UEQ scores per subscale with error bars

Using the UEQ benchmark, *Shuttle to Mars* can be compared to other interactive products. Products are classified into five categories per scale: (1) excellent, (2) good, (3) above average, (4) below average, and (5) bad. Based on the results, *Shuttle to Mars* falls into the lowest category *bad*, which contains the 25% worst results (Figure 6.5).

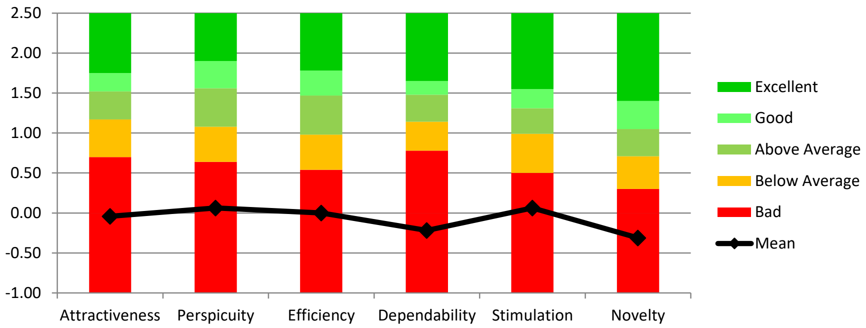


Figure 6.5: Shuttle to Mars comparison to UEQ benchmark

Reflective questions

The last part of the StM Block 1 questionnaire held reflective questions, to help the participants to relate the priorities in the game to the priorities in their daily jobs.

Participants could check a maximum of two priorities or enter their own. Six participants indicated that playing the game by the rules was a priority. Delivering the cargo to the destination was a priority for four participants. For only one participant having fun was a priority.

Participants were asked to elaborate on their choice of priorities and to compare them to their priorities in their work. The participants recognised similarities but did also see differences. Below, we reproduce four quotes, taken from the questionnaires.

> *"Setting priorities and swiftly adjusting them when circumstances dictate to do so is recognisable from my work."*

> *"Somewhat comparable but a lot of things that make my work easier are overly complicated in this game."*

> *"During my work, I am more focused on flying the airplane first, rather than solving a problem first or entering a code or answering a call."*

> *"The game challenges you to become better with every new stage of the game in an enjoyable way."*

Most of the participants seem to have used their skills as a pilot to play the game. They tried to reach the game objective while playing by the rules, and they tried to improve their game score.

6.3.3 Block 2 results

In Block 2, the participants played four missions and answered the StM Block 2 questionnaire. All participants finished Block 2 on schedule.

The participants spent between 1 and 2 hours playing the *Shuttle to Mars* game ($M = 1.6$, $SD = 0.3$), according to their estimates in the StM Block 2 questionnaires. Five participants played other games during the Block 2 period. Time spent playing other games ranged from 15 minutes to 6 hours.

Intrinsic Motivation Inventory

The StM Block 2 questionnaire comprised the IMI [91, 172]. Intrinsic motivation is considered to be measured with the Interest/Enjoyment subscale. On the Interest/Enjoyment subscale, participants scored a mean of 4.2 ($SD = 1.6$), indicating that their intrinsic motivation was not strong. Perceived choice and Perceived competence are thought to be positive predictors of intrinsic motivation, whereas Pressure/Tension is a negative predictor [91, 172]. The subscale of Perceived choice was positive ($M = 5.42$, $SD = 0.6$), whereas Perceived competence was neutral ($M = 4.25$, $SD = 1.2$). The subscale of Pressure/Tension was low ($M = 2.6$, $SD = 0.5$).

We added three items at the end of the instrument to enquire about the extent to which participants felt taken seriously and felt it was important to play the game seriously. Two participants indicated that they did not feel like they were taken seriously as professionals. The others were neutral or positive ($n = 6$, $M = 5.5$, $SD = 1.2$). All participants played the game seriously ($M = 5.4$, $SD = 0.7$). Also, we asked if they thought that making errors in the game *should* feel the same as making an error during a (simulator) training flight. Conspicuously, one participant fully agreed with this statement, one participant fully disagreed. The others were neutral or in slight agreement.

Reflective questions

The first two reflective questions in Block 2 were related to the participants' reasoning around the pirate attacks. Participants were asked on which considerations they based their actions and why. Five out of eight participants took their amount of resources into consideration, to decide whether to pay off the pirates. Also, five out of eight looked at the physical state of the spaceship (the *hull integrity*) to decide whether they would be able to survive an attack.

Reasons to engage the pirates included not wanting to pay cargo, and wanting to defend the shuttle before the pirates attack. Two participants admitted that shooting the pirate was just fun. One participant avoided using the weapon because he did not understand how to use it. Reasons to pay the pirates included wanting to prevent damage, not wanting to pay a higher tax, and not wanting to go off track.

The other reflective questions were four questions enquiring about how the participants felt during the less eventful periods, and one open-answer question on how they deal with such periods in the cockpit. During the less eventful periods in the game, six participants became somewhat bored and did not pay as much attention during those periods. Four participants were somewhat distracted, and the other four were not. Five participants became a bit more watchful, as they expected that something would happen soon. For one participant, the less eventful moments did not change how he felt and played. The other participants indicated that these moments did have some influence.

Participants were asked to describe what they do in order to stay alert in the cockpit when not much is happening.

> *"I try to stay alert by talking with my co-worker. Now and then, I force myself to make a check around the flight instruments to see if everything is okay."*

Five participants indicated that they actively try to stay focused by checking their systems and by preparing for what lies ahead. Four participants said they talk to their colleagues to stay alert. The overlap is explained by one pilot who stated to do both.

6.3.4 Block 3 results

In Block 3, the participants played five missions and answered the StM Block 3 questionnaire. Again, all participants finished Block 3 on schedule.

The participants spent between 1 and 1.5 hours playing the *Shuttle to Mars* game ($M = 1.3$, $SD = 0.2$), according to their estimates in the StM Block 3 questionnaires. Two participants played other games during the Block 3 period, for 3 and 12 hours.

Three participants more or less enjoyed playing the game, but overall, the outcome was slightly negative ($M = 3.4$, $SD = 1.6$). For engagement, the scores were similar ($M = 3.3$, $SD = 1.7$). The three participants that enjoyed playing also indicated that they felt engaged in the game. Only one participant thought the assignments in the game were interesting. The others did not ($M = 2.1$, $SD = 1.4$). The participant who found the assignments interesting, was also the only one who would recommend the game to others. Five participants could see the resemblances between the game and their job as an airline pilot. The other three participants gave a score of 2, indicating they do not see the resemblances.

Core Elements of Gaming Experience Questionnaire

The StM Block 3 questionnaire comprised the CEGEQ. Participants were slightly negative about their enjoyment of the *Shuttle to Mars* game. They gave it an average score of 3.3 ($SD = 1.6$) on the enjoyment scale. Only two participants gave a positive score. Participants gave an average score of 3.4 ($SD = 1.5$) on the frustration scale, indicating they were not really frustrated by the game. One participant indicated to have been frustrated by giving a score of 6. The subscales of the video game construct and the puppetry construct were all neutral, with scores between 3.9 and 4.4 out of 7.

Reflective questions

In the StM Block 3 questionnaire, one reflective question asked the participants to connect the events that happened in the *Shuttle to Mars* game to airline pilot tasks. The entry of authorisation codes, following the designated path, and the passing of other spaceships were easily connected to airline pilot tasks. Most participants answered in similar ways for these events. Participants had more difficulties relating the pirate attacks and negotiations with their everyday job.

The other two reflective questions enquired whether the participants believe they could learn something from the game and whether it could help them do their job in the cockpit. They were asked to score these statements on a 7-point scale and then elaborate on that score.

Overall, the participants gave a neutral score ($M = 3.9$, $SD = 1.0$) on being able to learn from the game. Two participants were a bit negative, four were neutral and two slightly positive. Learning to prioritise, stay focused, follow procedures and continuously scan the systems are the learning objectives most mentioned. Below, we reproduce two quotes, taken from the StM Block 2 questionnaire.

> *"In this game, you need to decide which tasks have priority and which do not. Also, you need a structure to scan all the instruments, while performing other tasks."*

> *"To be able to learn, sometimes you need feedback and tips while you are doing it or after you have done your task."*

On the question of whether the game could help them do their job, participants were somewhat more negative ($M = 3.3$, $SD = 1.4$). Four participants gave a negative score, two were neutral and two slightly positive. Three participants stated that the game does not resemble the actual work environment sufficiently to be helpful. Others stated that they believe it could help them in prioritising, problem solving and multitasking. Also, it was mentioned that the game could be useful for memory items. Memory items are essential checklists that a pilot should not need to look up, but that should be committed to memory.

6.3.5 Repeating questions

Several questions in the questionnaire were asked multiple times. Three questions from the StM Start questionnaire were repeated in the StM Block 3 questionnaire. Furthermore, five questions were part of all questionnaires.

Questions asked after Start session and Block 3

Three questions were asked at the end of the StM Start questionnaire, and again in the StM Block 3 questionnaire. These questions were related to (1) Purpose, (2) Control, and (3) Graphics. Results for these repeating questions are visualised in Figure 6.6.

The first question asked whether the purpose of the game was clear to the participant. Throughout playing the game, the purpose of the game became less clear to the participants. After the Start session, only one participant gave a slightly negative score. On average, the participants were positive about how clear the purpose of the game was ($M = 5.3$, $SD = 1.0$). After Block 3, two participants indicated that the purpose of the game was not clear to them. The others were more positive, resulting in a neutral overall outcome ($M = 4.4$, $SD = 1.3$).

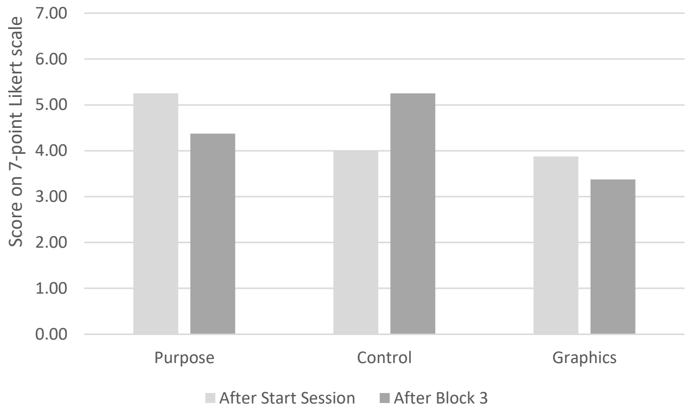


Figure 6.6: After Start session and StM Block 3: Purpose, Control, Graphics

The second question enquired about how much the participant felt he was in control of the game. Playing the game resulted in the participants feeling to be more in control over the game. The feeling of being in control improved in the period between the Start session (M = 4.0, SD = 1.1) and the end of the study after StM Block 3 (M = 5.3, SD = 0.9).

The third question asked how much the participant liked the graphics of the game. The low average scores showed that the participants did not really like the graphics of the game. At the end of the study, the appreciation of the graphics decreased. After the Start session, participants gave an average score of 3.9 (SD = 1.5). One participant did not like the graphics at all. He gave a score of 1. After Block 3, one participant indicated to like the graphics, but all others did not. This resulted in an average score of 3.3 (SD = 1.5).

Questions asked in all four questionnaires

Five questions were asked in every questionnaire. The first question asked how the participant felt after completing part of the game (Figure 6.7). Towards the end of the study, more participants were relieved to have completed an StM Block.

After the Start session, five participants expressed that they had wanted to continue playing, two were neutral, and one was relieved. After Block 1, three participants expressed that they had wanted to keep playing. Three were neutral, and two were relieved. After Block 2, four participants expressed that they had wanted to keep playing. Two were neutral, and two were relieved. After Block 3 was completed, only one participant expressed that he had wanted to keep playing. Two were neutral, and five were relieved.

The other four questions asked the participants to give a score from 1 to 7 on four different statements (see Figure 6.8).

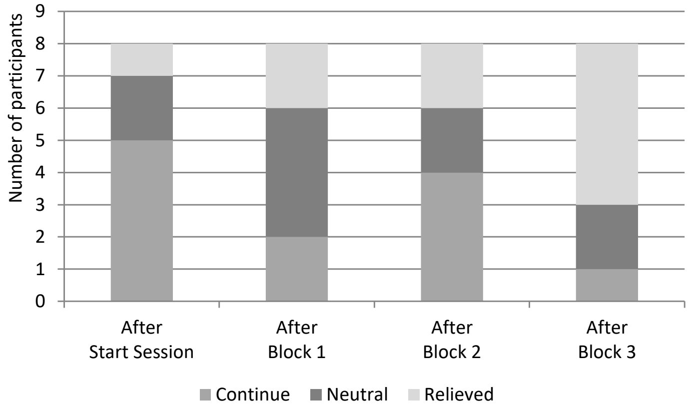


Figure 6.7: After each StM Block: Players feelings about completing the StM block

The first question of the remaining four, labelled as *Motivation*, showed that on average the participants were more motivated to complete the experiment than to play the game. Only after Block 2, two participants indicated this statement was not true, giving it a score of 3 out of 7.

The second question, labelled as *Look forward*, asked the participants how much they looked forward to playing the next mission. At first, participants looked forward to the next mission, but in the end, this anticipation decreased.

The third question, labelled as *Frustrated* enquired about the extent to which playing the game had frustrated the participants. Overall, the participants were not frustrated by the game, but there was a slight increase in frustration towards the end. One participant who did not look forward to the next mission scored a 5 on having been frustrated by playing the game after the Start session. After Block 3, three participants indicated that they had become frustrated by the game.

The fourth question, labelled as *Commercial* showed that the participants never thought the game could compete with commercial games. Playing the game did not change their opinion much. They became slightly more negative after playing Block 1 and then remained constant.

6.3.6 Interviews

We used a semi-structured interview to debrief the participants about their experience with the *Shuttle to Mars* game (see Appendix D.5). The interview was structured into three categories, that are related to the three lower levels of Kirkpatrick's model of training evaluation [106], viz. (1) reaction, (2) learning, and (3) behaviour.

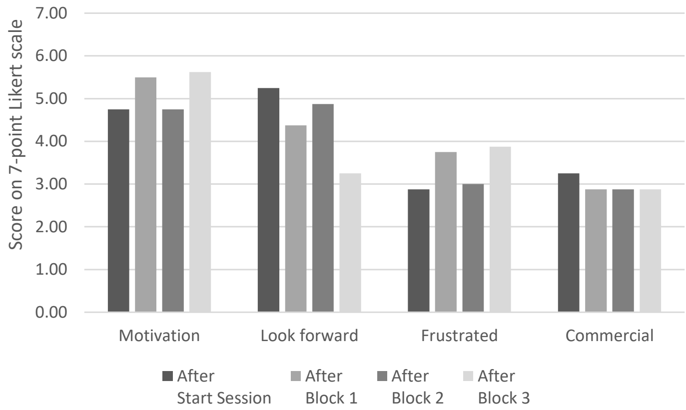


Figure 6.8: After each StM Block: (1) Motivation, (2) Look forward, (3) Frustrated, (4) Commercial

Question category: Reaction

The questions in the Reaction category aimed to gauge the participant's feelings about the game and about having to play the game.

Only one participant did not like the game; neither as a game nor as a training method. This participant classified himself as an experienced gamer. Four participants said that, later on in the game, they became bored or a bit annoyed with the game. In contrast, one participant did not like the game until later on, when he got the hang of it.

All participants could imagine the game being part of a training, but for most, it would have to be a module early on during initial training. Several participants suggested the game could be used as a tool for candidate selection for flight schools.

Most participants believed this game could not help them in their jobs. This was mostly because they thought the game would be more beneficial to less experienced pilots.

Several participants said that the Beta 2 version of the *Shuttle to Mars* game did not have sufficient quality. The visuals looked dated, and the gameplay was not sufficiently challenging. Some participants were bothered by the music. The main thing the game was lacking, according to participants, was feedback on their actions. They could not see how their score was influenced by what they did. Therefore, it was impossible for them to change their behaviour to improve their score. Some participants also indicated that the game should resemble an actual aircraft a bit more.

Question category: Learning

The questions in the Learning category asked about what the participants have learned and how they would compare the competencies between the game and their actual job.

Participants believed that novice pilots could learn about prioritising, working under stress, the importance of adhering to procedures and the importance of staying alert. However, they indicated that they themselves did not really learn anything from the game, more than how to play the game.

In the interviews, the participants indicated that they believed the competencies in the game were comparable to those in real life, although they were not identical. All participants recognised some of the ICAO competencies they used to play the game. The competencies named by the participants coincided with three of the competencies the game aimed to train, i.e., PS&DM, SA, and WM.

The participants believed that the competencies could be trained with a game, especially when dealing with less experienced pilots, but not with the *Shuttle to Mars* game in its current form. Hence, they did not believe their competencies had become stronger by playing the game.

Question category: Behaviour

The questions in the Behaviour category focused on possible effects of the game on their behaviour, especially their behaviour in the cockpit. Such effects could be considered an early sign of transfer [212].

Six participants did not spend time thinking about the game, besides playing the game or planning when to play the game. One participant showed a co-worker a video that he had made of the gameplay. They discussed the below-standard quality of the game. Another participant was reminded of the game when he was in a situation in which three things happened at once in the cockpit.

All participants believed that the *Shuttle to Mars* game could have a positive effect on novice pilots. However, they did also believe the game had not influenced how they themselves operate in the cockpit. Playing the game longer and more often may have more effect, but most participants also said that the game needed to be improved.

6.4 Discussion

In summary, we conducted the following investigations. During a four-week period, eight airline pilots participated voluntarily in the *Shuttle to Mars* study. They came to the offices of NLR for a Start session, then played the game for three weeks. After they completed the game, they returned to NLR for the final interview.

In this section, we will discuss the outcomes of our study. We will look at the participants' motivation (Subsection 6.4.1), the game experience (Subsection 6.4.2), and games as a training method (Subsection 6.4.3). Finally, we will briefly discuss the quality of the *Shuttle to Mars* game (Subsection 6.4.4).

6.4.1 Motivation

We look at motivation to determine whether airlines pilots would be willing to play the serious game and to keep playing it over a longer period of time.

The participants were motivated to participate in the experiment. From the questionnaires, we saw that their motivation was more about completing the experiment than about completing the game itself. This attitude remained stable throughout the experiment, from the start until Block 3 (Figure 6.8). Although several participants indicated that after some blocks of gameplay they were "done with the game", they remained motivated to continue, and all participants completed the experiment.

Overall, the participants were positive about innovative training methods and the use of virtual training or a serious game for training. This may have had a positive effect on their motivation to participate in this study.

The IMI data [91] indicated that only part of the participants' motivation is intrinsic. The participants also had an extrinsic source of motivation. This may have been the chance of winning the smartwatch, or it may have been the mere fact of participating in an aviation-related study. However, they did feel that they had a choice and were not pressured to participate and to play the game.

In a training setting, especially during initial training, aspiring pilots will be motivated to do whatever is needed to get their pilot licence. This would also contribute to the motivation to play the game.

Participants in the study showed a slight decrease in motivation over time but still appeared enthusiastic and motivated in the final interviews. This may indicate that, with improvements in the game, the game may become an enjoyable and thus motivational part of training.

6.4.2 Game experience

At the beginning of the study, participants were enthusiastic and motivated. During the interview at the end, they appeared still to be enthusiastic and motivated. However, from the data, we may conclude that playing the *Shuttle to Mars* game was not a truly positive experience.

Although the UEQ data [164, 181] was neutral, we may conclude that the *Shuttle to Mars* is not an adequate interactive product, which is confirmed by the CEGEQ data [28, 29]. The core elements of having a sufficient game experience are not convincingly present in *Shuttle to Mars*.

One of the repeating questions asked was whether the gameplay of the *Shuttle to Mars* game could compete with that of commercial games. During the experiment, this value was consistent (Figure 6.8). The score is slightly below neutral, indicating that the participants believed that the gameplay of the *Shuttle to Mars* game could not compete with commercial games. During the interviews, the participants made suggestions for improvements to the game.

In contrast, other data from the questionnaires indicated that playing the game was not an unpleasant experience either. With improvements to the game, the experience may become enjoyable. The UEQ and CEGEQ data may serve as guidance by which aspects of the game may be improved. Participants also made several suggestions on how to improve the game.

The suggestions for improvements to the game will be discussed in Subsection 6.4.4.

6.4.3 Games as a training method for competencies

Interestingly, most participants reported that they did not learn anything from the game, but they did believe that other, less experienced pilots may benefit from it. Participants acknowledged that the competencies of PS&DM, SA, and WM were addressed by the game, as well as AP. They were able to relate game events and game tasks to specific tasks in their jobs. The participants believed the game may best be used by aspiring pilots during initial training. The Beta 2 version of the *Shuttle to Mars* game was not ready to be used as a training method, but the participants did see the potential.

Some participants would like the game to resemble an actual aircraft. The game was intentionally designed as a zero-fidelity simulation [192, 193] to focus on the competencies instead of the environment. Using a game environment that resembles an actual aircraft may put the focus on the type of aircraft and the way in which the game environment deviates from reality.

6.4.4 Quality of the Shuttle to Mars game

Although the study was not aimed at evaluating the quality of the *Shuttle to Mars* game or its effectiveness, we did receive feedback on this. As many participants remarked, the quality of the game was insufficient. Before a final version can be implemented in the airline pilot training curriculum, improvements will have to be made, to make playing the game an enjoyable experience. In the questionnaires and during the interviews, several suggestions were made on how to improve the game (see Section 5.5.2). In addition to those suggestions, participants would like to see the game resemble current commercial games in visualisations and gameplay.

Suggestions from the small-scale study participants

The Beta 2 version that was used in the *Shuttle to Mars* study consisted of fifteen missions. Participants played on personal computers. There were no technical issues hampering gameplay. Most of the suggestions made by the participants in the *Shuttle to Mars* study are related to functions that were omitted in the beta versions or game content.

Game control. As the game was designed for touchscreen interaction, controlling it with a touchpad or mouse was not optimal. If the final version is going to be played on personal computers, the control needs to be improved for keyboard and mouse control.

Tutorial. The tutorial does not provide sufficient support to play the game well. Some actions remain unclear and should be addressed better in the tutorial. Moreover, the current tutorial raises expectations that the game does not meet. The tutorial should reflect the actual gameplay. It should not cover more than is needed. Possibly the tutorial could be replaced with a number of training missions.

Feedback. The game should provide feedback on what the player has done. This could be at the end of a section, a sector or a mission. It should address the behaviour that was (un)desirable, or that has influenced the score.

Score. It should be clear why a specific score was given. The player should know whether his choices or behaviour caused his score to be lower. This may take place either in advance or right after the first incident, so that he can improve his score.

Redundant tasks. Currently, the game has some redundant tasks. When playing, the player will come across them, but they do not make a difference in the game. For instance, each mission must be planned, but there is only one possible route in the beta versions. At the end of a sector resources can be bought and sold in order to continue the mission, but this is never necessary during the Beta 2 version of the game. These tasks should either be implemented or removed from the game.

Missions. The game should have a larger number of missions. Also, the missions need to be more complex and more challenging. The missions should be matched to situations that may actually happen in the cockpit. To achieve this, close cooperation with flight instructors is needed in designing the missions.

After the *Shuttle to Mars* study, no further developments have been done on the Beta 2 version. The improvements described here have not been applied.

When the development of the *Shuttle to Mars* game is resumed, we advise that the final version of the game be developed for use on iPads. Controlling the game through mouse or keyboards is difficult and the playability of the game will benefit from touchscreen interaction. Elements in the game environment that do not need to be used in the game tasks should be removed or their presence should enhance the narrative.

Also, from an instructional design point-of-view, there are improvements to be made. Although the game was designed according to our SG4CD model, not all elements were sufficiently developed. Improvements can be made in two areas specifically, viz. (1) support and feedback, and (2) the match between the game and aviation. First, the game should provide the player with more support and feedback. This will help the player to feel in control over the game and it will also support the learning effect. Giving more (cognitive) feedback during the game, will also help the player strengthen his competencies. Second, closer cooperation between flight instructors and aviation training professionals on the design of the meaningful events may result in a stronger transfer from game to job.

6.5 Chapter conclusion

In this section, we will draw our conclusions about the findings from our study. As we have discussed in the introduction of this thesis, younger pilots nowadays lack certain competencies. The purpose of this study was to see whether airline pilots would accept serious games as a training method to reduce this deficit.

We will answer the third research question in Subsection 6.5.1. Then, we will give our recommendations for future research in Subsection 6.5.2.

6.5.1 Answering research question 3 (RQ 3)

The *Shuttle to Mars* study was performed to answer research question 3.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

From the results of our research, we may conclude that airline pilots are open to the innovative approach of using a game to train the essential competencies. Playing the current version of the *Shuttle to Mars* game did neither provide a convincingly positive experience, nor was the experience fully negative. With improvements to the game, and embedding it in the initial training for airline pilots, the game has the potential of providing a positive and effective experience.

In terms of Kirkpatrick's model for training evaluation [105, 106], the outcomes of our study constitute a positive *reaction* (level 1). This positive reaction is ground for optimism about the use of serious gaming for the training of airline pilots.

We started out with the *Shuttle to Mars* game, aiming it to be used in the competency development of young, but graduated pilots. As a result of the study, we now think that aspiring pilots may benefit from the game during their initial training. Making sure that they develop these competencies during flight school, may give them a profound basis to start from as a professional. Still, we do believe that an improved version of the *Shuttle to Mars* game embedded in a learning package with sufficient feedback can also be useful for experienced pilots.

Applying the game in initial training may also move ahead the training of more complex scenarios and prepare the aspiring pilots for training sessions in the full flight simulator. This may provide some relief on the simulators, as later on in the programme, simulator sessions can be dedicated to technical skills.

Therefore, our provisional answer to RQ 3 is that airline pilots have a positive attitude towards the idea of game-based learning to develop competencies and are willing to accept it as a training method.

6.5.2 Future research

Before further research can take place, improvements to the *Shuttle to Mars* game are essential. Further research should then focus on (1) the learning effect of the game, (2) the transfer of competencies from the game to the cockpit, and perhaps (3) exploring possible effective applications for the *Shuttle to Mars* game. This may include selection of candidate pilots, training candidate or novice pilots (acquiring competencies), or training experienced pilots (maintaining/boosting competencies).

Measuring the learning effect of the game

The learning effect of the game can be determined by analysing the in-game data. Players are expected to improve their performance in the game over time. Ideally, this improvement can be attributed to the development of the competencies. Especially the performance in new situations may provide indications of the learning effect. These new situations should either be similar to earlier situations or they should address the same competencies as earlier situations under different circumstances.

Measuring the transfer of competencies

Once a learning effect of the game has been found, ideally it should transfer to the work environment. This transfer may be proven with a random controlled trial, using a flight simulator to assess participants' competencies in the work environment, before and after playing the game.

Using Shuttle to Mars as a selection tool

During our study, participants suggested the *Shuttle to Mars* game may be useful as a selection tool for flight school candidates. The performance of candidates in the game may be an indication of their potential performance in the cockpit, and their ability to become a good pilot. To test this use of the game, the game should be compared to selection tools that are currently being used to find qualified candidates.

Chapter 7

Conclusions and discussion

In this chapter, we will conclude our research by answering the three research questions and the problem statement. We will start by answering the research questions in Section 7.1. Armed with these answers, we will address the problem statement in Section 7.2. Finally, in Section 7.3, we will discuss the limitations of our research and give an outlook on future work.

7.1 Answers to the research questions

In the subsections below, we will summarise our findings and answer the three research questions. RQ 1 will be answered in Subsection 7.1.1, RQ 2 in Subsection 7.1.2, and RQ 3 in Subsection 7.1.3.

7.1.1 Answer to research question 1

In Chapter 3, we focused on RQ 1.

RQ 1: *How should a serious game be designed to support competency development effectively?*

From our interpretation of the literature, we identified three main requirements for serious games for competency development.

1. The game is playable and attractive.
2. The game supports learning.
3. The instructional elements address competency development.

To meet the three main requirements, the design of a serious game for competency development necessitates the application of (1) game design, (2) serious game design, and (3) instructional design.

In Chapter 3, we elaborated on each requirement and the type of design needed to meet the requirement. We identified and described six characteristics that should be incorporated in a serious game and its environment to support the development of competencies by playing that game. We then identified eleven elements for gameplay and ten elements for learning. We combined these elements into a series of sixteen elements to be used in our SG4CD model (see Figure 3.9 on p. 49). The SG4CD model identifies the three parts of a serious game that contribute to the development of competencies. The model distinguishes (1) game elements, and (2) elements for learning (serious elements and instructional support elements), which are connected to the characteristics of (3) competency development.

The most important characteristic for competency development is the use of authentic learning tasks. The learning tasks in a game, especially a zero-fidelity [192] game, need to match actual job tasks based on competencies, task characteristics, and working conditions (see Figure 3.5 on p. 44).

With our model, serious games for competency development can be designed in a more structured way. We have applied our SG4CD model, including the model to generate authentic learning tasks, by using it in the design of our serious game *Shuttle to Mars* (see Chapter 5).

7.1.2 Answer to research question 2

In Chapter 4, we reported on the explorative study to answer RQ 2.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

Considering the possible outcomes of a serious game, we decided to distinguish two types of outcomes, namely (1) the learning effect, and (2) the gameplay experience. The research question was split into two subquestions to reflect both types of outcomes.

RQ 2a: *To what extent does the voluntary play of a serious game affect the learning effect?*

RQ 2b: *To what extent does the voluntary play of a serious game affect the gameplay experience of the player?*

To answer RQ 2a, we measured the learning effect of a serious game by comparing scores of a pretest with those of a post-test. In an ideal situation, playing a serious game would result in learning, and the learning would lead to a distinct improvement of test performance. We expected voluntary use of the game to lead to a greater improvement (i.e., more learning).

However, there was no difference between pretest and post-test scores. Playing the game did not lead to better test scores. This was found, regardless of whether playing the game was voluntary or mandatory. Therefore, we may conclude that the *CloudAtlas* game that we used in the studies, has no learning effect. This may be caused by the quality, playability, difficulty, or even graphical design of the game as well as by the questions in the test.

Our findings did not allow us to answer RQ 2a conclusively. In all studies performed, we did not find strong differences between the voluntary and mandatory groups. Therefore, we believe that the influence of voluntary play on the learning effect will be at most quite small. We did find that after an obligatory minimum of play time, players also remain in the game voluntarily for a longer time. This increases the total time spent in the game, which in turn may improve the learning effect.

To answer RQ 2b, we looked at the participants' enjoyment, engagement, and their opinion about being obliged to play. In our studies, we found that voluntary play does not influence the gameplay experience. Mandatory players do neither report a lower enjoyment or engagement, nor do they have strong negative feelings about the obligation. Moreover, they actually play longer than the voluntary players. We did not find evidence that the voluntariness of gaming, highly rated by many game theorists and practitioners, is essential in order for the game to be engaging and fun. On the contrary, our findings indicate that participants with a stronger obligation play as long and as well as participants who were free to play the game. Also, they enjoy the game equally.

With the answers for the subquestions, we will now answer RQ 2 as a whole.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

The findings in our experiments (see above) indicate that voluntary play does not have a substantial effect on the outcomes of a serious game. The mandatory playing of a serious game is just as much fun as playing it voluntarily. Mandatory gameplay does not appear to ruin the enjoyment and engagement in the game. This statement challenges the assumption of many game design theorists and practitioners that games need to be played voluntarily in order to be engaging, fun, and effective [26, 69, 89, 133, 135, 160].

7.1.3 Answer to research question 3

In Chapter 6, we reported on the small-scale qualitative study aimed to answer RQ 3.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

The starting point for RQ 3 was that an effective training is based upon a positive reaction of the participants [105]. Without a positive reaction on the first level of training evaluation, it will be difficult to reach the upper levels of improved behaviour and organisational change.

The participants were not enthusiastic about the gaming quality of the beta version of the *Shuttle to Mars* game that they had to play, but they did respond to gaming positively. Hence, we conclude that with the envisaged improvements to the game (see Subsection 5.5.2), and embedded in the initial training for airline pilots, the game has the potential of providing a positive and effective experience.

From the study as it was now, we may conclude that airline pilots are positive about the innovative approach of using a game to train the essential competencies.

7.2 Addressing the problem statement

Now that we have answered the research questions, we can address the problem statement.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

Below, in Subsections 7.2.1 and 7.2.2, we will address the problem statement by the two perspectives outlined in Chapter 1: (1) the suitability of games to train competencies, and (2) the acceptance of game-based learning by airline pilots. Then, in Subsection 7.2.3, we will give our answer to the problem statement, followed by our conclusions in Subsection 7.2.4.

7.2.1 The suitability of games to train competencies

Serious games are predominantly used for knowledge acquisition [22, 38]. Our goal was to determine whether serious games can also be used for competency development. The SG4CD model (see Chapter 3 for more details) identifies the game elements and the serious (instructional) elements that should be implemented in the game to support competency development. The model shows that a serious game can support all characteristics that are needed for competency development.

We designed and developed our *Shuttle to Mars* game to study the actual use of a game to train competencies (see Chapter 5 for details). The pilots that played the *Shuttle to Mars* game (see Chapter 6) were critical about the quality of the game. Despite their criticism, they were confident that less experienced and aspiring pilots can develop their competencies with a game.

Our findings show that using a serious game development model does not guarantee an effective game within a short time span and with only a few iterations. Designing and developing good games for training takes time and patience, and more iterations than usually available in a research setting.

From our findings, we may conclude that a serious game can be useful for training competencies. Hence, it should be possible to design a serious game that contains the instructional support as well as incorporates the characteristics needed for competency development. Furthermore, according to our findings, the pilots who have participated in our small-scale study are confident that a game may contribute to acquiring and strengthening competencies. However, they believe that the *Shuttle to Mars* game is not successful in this and may be more appropriate for novice pilots.

7.2.2 The acceptance of game-based learning by airline pilots

For some time already, serious games are being used in various areas, such as the military, the health sector and education [20, 135, 188]. In aviation, and specifically the training of airline pilots, there have not been many projects on the use of serious games. This is due to legislation and unfamiliarity. As airline pilots are still mostly unfamiliar with GBL, part of our research focused on determining their reaction to and opinion about GBL.

The pilots involved in our experiments had a favourable opinion about the use of games for training, including the ones who indicated they did not play games very often. In general, airline pilots are open to GBL as a training method, and it does not seem to be problematic for the ones who are less positive. Our findings confirm that GBL is promising for a group of users such as airline pilots, that may be open-minded but somewhat sceptical.

Moreover, from our study on voluntary play in serious games, we found that voluntariness does not have a significant effect on the motivation and willingness to play a serious game. The enjoyment remains, even when a player is obliged to play the game. Hence, voluntariness is not necessarily imperative for GBL.

All in all, we believe, based on our findings, that there may now be reasons to apply serious games in the training for airline pilots.

7.2.3 Answer to the problem statement

Combining both dimensions, we will now address the problem statement (reproduced below) as a whole.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

From our investigations, as guided by the three research questions, we may conclude that a serious game can be a viable training method for airline pilots to develop the competencies they need in critical situations. We come to this conclusion based on our three main findings.

First, we have shown that a serious game can be used to develop competencies (see Chapter 3). All characteristics required for competency development can be supported in a serious game. In the *Shuttle to Mars* game, aimed at the development of the competencies needed in critical situations (see Section 5.1), the participants were able to recognise these competencies in the gameplay.

Next, we found that both pilots and instructors are open to serious games for training purposes (see Chapter 6). Thus, they were motivated to play the game.

Finally, our study on the effect of voluntary play showed that a serious game can be played mandatorily without adverse effects (see Chapter 4). Therefore, a serious game can also be effective for pilots who are less inclined to accept GBL as a training method.

However, from the current research we cannot draw any conclusions about the extent to which a serious game can be successful in the longer run in training airline pilots to act adequately in critical situations.

7.2.4 Conclusions

From the work described in this thesis, we draw four conclusions.

1. The SG4CD-model connects game design with competency development.
2. Mandatory gameplay in a serious game does not ruin the enjoyment and engagement.
3. Designing an effective serious game is a great challenge.
4. Airline pilots are willing to accept game-based learning as a training method for competency development.

7.3 Limitations and outlook

In our research, we were limited by two factors: (1) the difficulty of game design, and (2) the number of participants available for our studies. In Subsections 7.3.1 and 7.3.2, we will discuss these factors. In Subsection 7.3.3, we will look at three topics on which future research should focus. Finally, in Subsection 7.3.4, we will look ahead at the future of GBL for airline pilots.

7.3.1 The difficulty of game design

In our studies, we used two serious games which were designed by the researchers and developed by students.

Both games that we used, *CloudAtlas* and *Shuttle to Mars*, proved to be unsuccessful games. The games contained elements of successful games, but they did not reach their potential. Players were not positive about the gameplay. Admittedly, they did not have an overall negative opinion about the games, but neither one of the games triggered the players to keep playing.

Moreover, we did not succeed in creating games with a positive learning effect. In the *CloudAtlas* game, the fact that we did not find a learning effect may have had two causes. It may have been a result of (1) the game design, or (2) the quality of the tests.

With our *Shuttle to Mars* game, we aimed to measure the player experiences. However, we used a beta version of the *Shuttle to Mars* game, which did not have the quality for which we were aiming. The participants in the study found the quality and size of the game insufficient for training purposes. Therefore, we may conclude that our game in its current state is not able to train the competencies effectively.

If the game is to be the subject of further research, improvements will need to be made. A serious game for this purpose should be well designed, and the competencies must be activated correctly. The game design should be reconsidered and improved. Preferably, an experienced game designer should be consulted to make the game playable and attractive. The development of the game should be redone using a more modern visualisation to have a larger appeal to the players, and all elements that were designed need to be implemented. Furthermore, the game should offer a larger number of situations in which the learner can use and strengthen his competencies.

7.3.2 The number of participants

In all four experiments in our study, we had difficulties recruiting a sufficient number of participants.

For the three experiments with the *CloudAtlas* game (see Chapter 4), we recruited through social media, through institutions for higher education and flight academies. Through all three channels, we were able to recruit participants, but in none of the experiments we had the number of participants that would have given sufficient power to the analyses. Moreover, not all participants in the first and second experiments about voluntary play belonged to the target group of our overall research. In Experiment 1, none of the participants was involved in aviation, and only a few of the participants of Experiment 2 were enrolled in aviation-related studies.

For the experiment with the *Shuttle to Mars* game (see Chapter 6), we recruited through connections with Dutch airlines. As we were specifically looking for young airline pilots with little experience, the number of eligible participants was relatively small. In addition, the participants needed to be available in a specific period to attend two meetings and play the game. All in all, only a small number of pilots could participate.

As a result of the small number of participants, our results are not reliable and need to be interpreted carefully. Furthermore, we can neither generalise our findings to the entire population of airline pilots, nor to the players of serious games in general.

7.3.3 Outlook

With the work presented in this thesis, we have laid the groundwork for the implementation of GBL in aviation in general, and for the use of a serious game for the development of essential competencies in critical situations specifically (see Section 5.1).

For future work, the *CloudAtlas* game and the *Shuttle to Mars* game should be redesigned to overcome their shortcomings.

Now that we have shown that there is support for the use of serious games for the training of airline pilots for critical situations, future work should focus on determining (A) learning effect, and (B) creating blended learning environments, to optimise the learning effect [134]. Furthermore, further research should address (C) transfer of learning [212], (D) determining the validity of the SG4CD model and (E) determining the power of the serious game mechanics. The five topics will be discussed briefly below. Moreover, the effect of voluntary play remains of interest.

A. Determining the learning effect

The learning effect of a game can be measured in two ways: (1) within the game, using game results and game data, and (2) outside the game, using test results.

Development of the competencies within the game should lead to an improvement of game results. Analysis of game data, such as reaction speed, optimal prioritisation, and correct answers, will provide information about the improvement.

Subsequently, development of the competencies in the game should lead to improvement in test results outside the game. Players should perform better on the test than non-players, and the post-test should show an improvement over the pre-test.

B. Creating blended learning environments

GBL is not necessarily a stand-alone training method. Once a learning effect is determined, this effect may be strengthened by combining GBL with other training methods [46, 134]. For example, GBL may be implemented in a curriculum together with lectures and discussions. First, during a lecture prerequisite knowledge can be shared and explained by a teacher. Next, the game can be played, followed by a group discussion about strategies and results. A blended approach using both GBL and other training methods may lead to better results by strengthening the learning effect.

C. Determining transfer of learning

The development of competencies in a game should lead to improved behaviour outside the game, i.e., in the work environment.

The transfer [212] of the learning effect from the game to the actual working environment can be assessed with a quasi-transfer test, by observing the participants during flight simulator scenarios. Pilots who have the essential competencies to act adequately in critical situations should show specific behaviour indicative of those competencies. They should be able to respond faster to the situation and provide better solutions. In the simulator, this behaviour can be assessed by an examiner.

We would expect to see an improvement in the participants' performance as a result of the game. Furthermore, we would expect to find a difference between the performances in the simulator of participants who have played the serious game and participants who have not. This would indicate a positive, transferable learning effect of the serious game. To examine this effect, data coming from the game and surrounding activities should be combined with assessments made by the examiner in the simulator.

Ideally, such research is set up as a random controlled trial comparing the effect of a serious game with that of the currently common training on a topic. However, making a valid comparison is difficult, as the competencies we have identified as essential in critical situations are not being covered in one training in particular, but they are addressed over several courses. Moreover, if such a training were available, ethical questions may arise about withholding the most effective alternative from a group of participants.

D. Determining the validity of the SG4CD model

The validity of the SG4CD model introduced in this thesis has yet to be proven. When the Shuttle to Mars game is redesigned for further research, we suggest using the SG4CD model to guide the connection between the game elements and competency development. In addition to testing the redesigned game for learning effect and transfer of learning, the game may be used to test the validity of the SG4CD model.

E. Determining the power of the serious game mechanics

Finally, an interesting topic of research will be the separate serious game mechanics to determine which mechanics were successful, which were not and why. Such scrutiny may lead to insights into the question of how to improve the serious game mechanics, which in turn may contribute to improving the success of serious games designed specifically for learning.

7.3.4 The future of game-based learning for airline pilots

With the outcomes of our work and those of future research, game-based learning may become an effective and validated training method for aviation. We expect it to become a standardised training method that will be a part of initial and recurrent training for airline pilots. We consider game-based learning for aviation to be *cleared for take-off*.

"Ladies and gentlemen, welcome on board. We are preparing for take-off and expect to be in the air soon. We ask that you please fasten your seat belts at this time and secure all baggage underneath your seat or in the overhead compartments. Thank you and enjoy your flight."

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Appendices

Appendix A

Background

In this appendix, belonging to Chapter 2, we present an overview of training delivery methods commonly used in airline pilot training.

Appendix A.1
Training delivery methods

Training method	Description
Briefing & debriefing	During the briefing [56, 63, 92, 161], immediately before an exercise, the instructor explains what is expected of the student and answers any questions. Afterwards, the instructor gives a concise debrief of the student's performance, including strengths, weaknesses and suggestions for improvement. The student's own assessment of his performance should also be discussed.
Case-study	In a case study [12, 189], the instructor provides students with an account of a real world situation, for them to learn from the actions taken and outcomes achieved. Students work in groups to review and analyse the case, come to conclusions and think of possible solutions. Case study requires critical thinking.
Chair flying	Chair flying is a visualisation technique that allows the student to practice his thought processes, develop cockpit flows and go through manoeuvres [56, 92]. It is also useful for mentally preparing for a next exercise.
Computer-based training	Computer-based training [12, 56, 92, 189], or e-learning, comes in many formats. Multimedia technology is used to prepare and deliver learning content, and to engage students in their learning process. Computer-based training is usually an interactive tool that allows students to progress at their individual speed.
Demonstration-Performance	Before the demonstration [12, 63, 161, 189], the instructor explains what he is going to do. Then he demonstrates a certain skill, step-by-step. The students observe and then get the chance to practice their performance of each step under supervision, in order to master the skill.
Discussion	In a (guided) discussion [12, 63, 189], the instructor may present a short lecture or introduce a proposition, which is followed by an exchange of views and ideas to explore topics and investigate solutions to a problem. The instructor may encourage all students to participate through asking questions.
Drill & practice	The drill and practice method [12, 189] offers systematic repetition of certain knowledge or skills, to improve retention and to lead to habitual use. The instructor provides opportunities to practice and keeps students focused on the learning objective of the exercise.
Flight Training Devices	Flight training devices [56, 92, 189], or flight simulators, are used in scenario-based training. Different simulators may have different features, such as its fidelity or the use of motion. In the simulator, realistic conditions are created to allow the student to practice his performance in line-oriented situations.
In-seat instruction	In-seat instruction [61, 79, 129, 161] takes places in the actual aircraft and should follow a scripted scenario. After the pre-flight briefing, the instructor performs certain exercises for the purpose of monitoring or intervention by the student. The student should respond according to the behaviour that is expected in line operations.
Lecture	In a lecture or presentation [12, 63, 189], the instructor presents his knowledge on a particular subject. It is a, mostly uninterrupted, one-way transmission of information from the instructor to an audience that can be quite large.
Observation	Throughout an observation [56, 92], a student may observe the performance of other student or of a crew flying an actual aircraft and see how they handle operational issues and work as a team.

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Training method	Description
Print media	Print media, such as books, manuals and handouts, can be used to inform, instruct and motivate students [104]. The instructor can provide the materials, and supplement the reading with other media. Print media provide strictly one-way communication, but can be used in more interactive exercises.
Role-playing	In role-playing exercises [12, 189], two or more people act out different scenarios to practice the relevant behaviour. Students acquire new information, develop skills, connect and manipulate information. Role-playing promotes critical thinking.

Appendix B

The CloudAtlas game: Voluntary play in serious games

In this appendix, belonging to Chapter 4, we present the materials used in the CloudAtlas experiment. In the questionnaires, each group of participants had a set of specific questions relating to their experimental setup.

Appendix B.1
CloudAtlas pre-experiment questionnaire (Q1)

Welcome in the NLR CloudAtlas Project.

This questionnaire collects some general information about you and tests your prior knowledge. The information is used later on to analyse our data. Only the researchers will have access to any personal information. Before the research data is analysed, all results will be anonymised.

What is your age? *
Please write your answer here:

What is your gender? *
○ Female
○ Male

What pastimes/hobbies are you interested in? *

☐ Cooking/eating out	☐ Reading	☐ Theatre
☐ Computer games	☐ Shopping	☐ Watching TV
☐ Gardening	☐ Social Media	☐ Walking
☐ Movies	☐ Sports	☐ Other

On a scale from 1 to 10, how motivated are you to participate in this experiment? *

	1	2	3	4	5	6	7	8	9	10
Motivation	○	○	○	○	○	○	○	○	○	○

1 = not motivated at all, 10 = extremely motivated

>>> The following questions were asked only in the questionnaires for Experiment 1. <<<

What is the highest level of education you have completed? *
○ Primary education
○ Secondary education
○ Upper secondary education, or vocational
○ Bachelor, Master, Doctoral, or equivalent

For each of the following statements, please indicate how true it is for you.*

	1 Not at all true	2	3 Somewhat true	4	5 Very true
I am personally connected to one of the researchers involved	○	○	○	○	○
I am connected to the NLR, the research institute involved	○	○	○	○	○
I am participating because I would like to win a prize	○	○	○	○	○
I am participating because I am interested in NLR and aviation	○	○	○	○	○
I am participating because I am interested in training and education	○	○	○	○	○
I am participating because I am interested in clouds and meteorology	○	○	○	○	○

>>> The following questions were asked only in the questionnaires for Experiment 2. <<<

Please answer the following questions about your studies.

What school or university are you enrolled in? *
Please write your answer here:

What is your field of study? *
Please write your answer here:

Is this a Bachelor or Master study? *
Please write your answer here:

What is your student number? *
Please write your answer here:

Why are you participating in the CloudAtlas experiment? *
○ I signed up as a volunteer to participate.
○ Participation was assigned as homework.
○ Other.

>>> The following question was asked in the questionnaires for Experiment 2 and Experiment 3. <<<

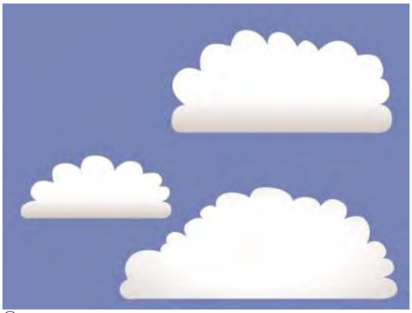
How do you feel about participating in the experiment? *
○ Positive
○ A bit positive
○ Neither positive nor negative
○ A bit negative
○ Negative

>>> The following prior knowledge questions were asked in the questionnaires for Experiment 2 and Experiment 3. <<<

In 1802 British chemist and amateur meteorologist, Luke Howard introduced a classification system for clouds. Which of the following are names that are now used for clouds based on his system? *

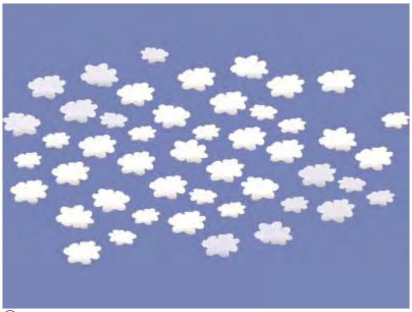
☐ Altocumulus
☐ Altostratus
☐ Altus
☐ Cirrocumulus
☐ Cirronimbus
☐ Cirrostratus
☐ Cirrus
☐ Cumulocirrus
☐ Cumulonimbus
☐ Cumulostratus
☐ Cumulus
☐ Nimboaltus
☐ Nimbocumulus
☐ Nimbostratus
☐ Nimbus
☐ Stratocirrus
☐ Stratocumulus
☐ Stratus

What is the name of these detached clouds with sharp outlines that look like cauliflowers? *



- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus

What is the name of these wide sheets of small brilliant white clouds, high up in the air? *



- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus

What is the name of this thick, grey layer of clouds that produce steady rain? *

- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus

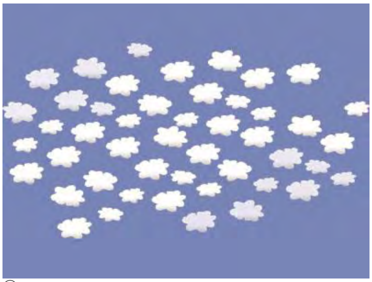
Appendix B.2
CloudAtlas post-experiment questionnaire (Q2)

This is the final survey of the first part of the NLR CloudAtlas Project. You will be asked some questions about clouds to see how much you have learned. Next, we will ask you some questions about the experiment.

*All questions marked with * are mandatory and must be answered.*
If you do not feel ready to take the test yet, you can return to your CloudAtlas Dashboard and spend some more time on the learning materials.

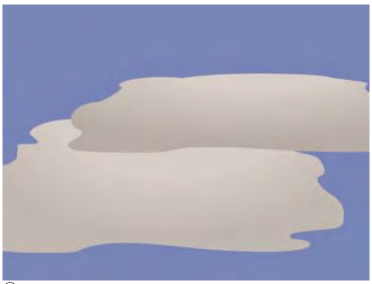
What are the ten main types of clouds? *

- ☐ Altocumulus
- ☐ Altostratus
- ☐ Altus
- ☐ Cirrocumulus
- ☐ Cirronimbus
- ☐ Cirrostratus
- ☐ Cirrus
- ☐ Cumulocirrus
- ☐ Cumulonimbus
- ☐ Cumulostratus
- ☐ Cumulus
- ☐ Nimboaltus
- ☐ Nimbocumulus
- ☐ Nimbostratus
- ☐ Nimbus
- ☐ Stratocirrus
- ☐ Stratocumulus
- ☐ Stratus



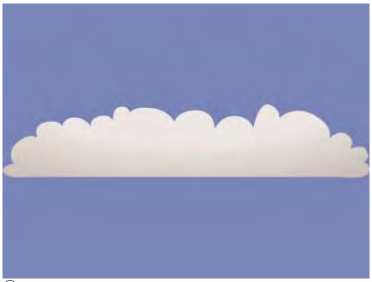
What cloud type is this? *

- ○ Altocumulus
- ○ Altostratus
- ○ Cirrocumulus
- ○ Cirrostratus
- ○ Cirrus
- ○ Cumulonimbus
- ○ Cumulus
- ○ Nimbostratus
- ○ Stratocumulus
- ○ Stratus



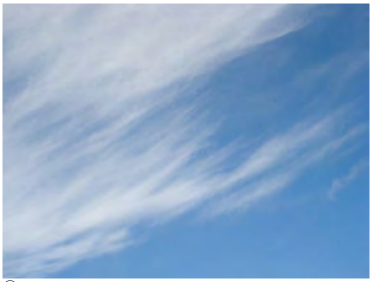
What cloud type is this? *

- ○ Altocumulus
- ○ Altostratus
- ○ Cirrocumulus
- ○ Cirrostratus
- ○ Cirrus
- ○ Cumulonimbus
- ○ Cumulus
- ○ Nimbostratus
- ○ Stratocumulus
- ○ Stratus



What cloud type is this? *

- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus



What cloud type is this? *

- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus

What cloud type is this? *

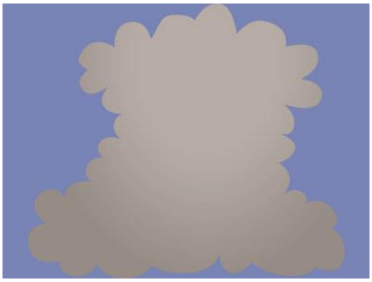
- ◯ Altocumulus
- ◯ Altostratus
- ◯ Cirrocumulus
- ◯ Cirrostratus
- ◯ Cirrus
- ◯ Cumulonimbus
- ◯ Cumulus
- ◯ Nimbostratus
- ◯ Stratocumulus
- ◯ Stratus

Which cloud types can be seen in this photograph? *
Select all cloud types that are in the photo.

☐ Altocumulus
☐ Altostratus
☐ Cirrocumulus
☐ Cirrostratus
☐ Cirrus
☐ Cumulonimbus
☐ Cumulus
☐ Nimbostratus
☐ Stratocumulus
☐ Stratus

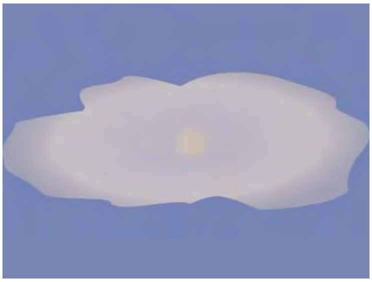
Which cloud types can be seen in this photograph? *
Select all cloud types that are in the photo.

☐ Altocumulus
☐ Altostratus
☐ Cirrocumulus
☐ Cirrostratus
☐ Cirrus
☐ Cumulonimbus
☐ Cumulus
☐ Nimbostratus
☐ Stratocumulus
☐ Stratus



What are the chances of icing, turbulence and lightning for Cumulonimbus? *

	No chance	Small chance	Chance	Good Chance	Certain
Icing	○	○	○	○	○
Turbulence	○	○	○	○	○
Lightning	○	○	○	○	○



What are the chances of icing, turbulence and lightning for Altostratus? *

	No chance	Small chance	Chance	Good Chance	Certain
Icing	○	○	○	○	○
Turbulence	○	○	○	○	○
Lightning	○	○	○	○	○

Which cloud(s) should you absolutely try not to fly through? *

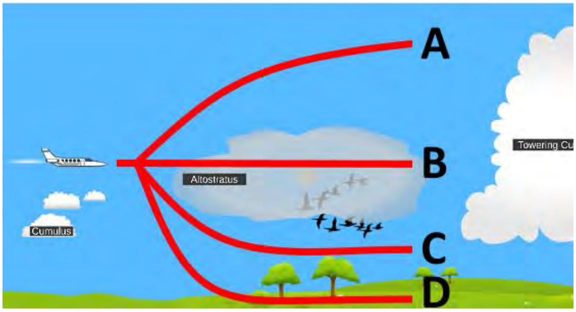
- ☐ Altocumulus
- ☐ Altostratus
- ☐ Cirrocumulus
- ☐ Cirrostratus
- ☐ Cirrus
- ☐ Cumulonimbus
- ☐ Cumulus
- ☐ Nimbostratus
- ☐ Stratocumulus
- ☐ Stratus

Clouds are generally divided into groups, based on their étage (level). There are high-level, mid-level and low-level clouds, and low-level clouds with vertical development.
Please indicate what level each cloud type is on. *

	High level	Mid level	Low level	Low level + vertical development
Altocumulus	○	○	○	○
Altostratus	○	○	○	○
Cirrocumulus	○	○	○	○
Cirrostratus	○	○	○	○
Cirrus	○	○	○	○
Cumulonimbus	○	○	○	○
Cumulus	○	○	○	○
Nimbostratus	○	○	○	○
Stratocumulus	○	○	○	○
Stratus	○	○	○	○

The following questions contain a picture of the sky with clouds and a short description of a situation. Also several routes are drawn. Which route would you choose for this specific situation?

Look and read quickly, because each picture and description will only be shown for 15 seconds. Select the route you would take and also the main reason(s) why.

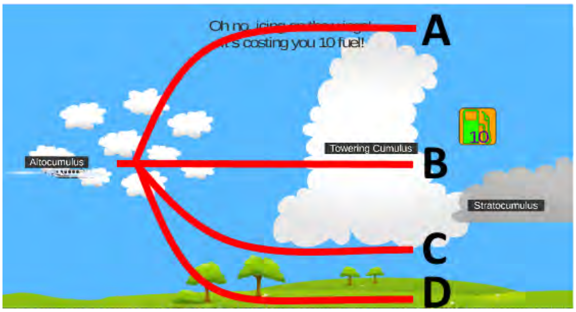


Which route would you choose? *

◯ Route A ◯ Route B ◯ Route C ◯ Route D

What are the main reasons for you to select this route? *

- ☐ This route is the fastest
- ☐ This route is the shortest
- ☐ This route is most fuel efficient
- ☐ To avoid the risk of icing
- ☐ To avoid the risk of turbulence
- ☐ To avoid the risk of lightning
- ☐ To avoid a collision
- ☐ To save oxygen
- ☐ To pick up the game bonus
- ☐ Random guess



Which route would you choose? *

◯ Route A ◯ Route B ◯ Route C ◯ Route D

What are the main reasons for you to select this route? *

- ☐ This route is the fastest
- ☐ This route is the shortest
- ☐ This route is most fuel efficient
- ☐ To avoid the risk of icing
- ☐ To avoid the risk of turbulence
- ☐ To avoid the risk of lightning
- ☐ To avoid a collision
- ☐ To save oxygen
- ☐ To pick up the game bonus
- ☐ Random guess

Which route would you choose? *

○ Route A ○ Route B ○ Route C ○ Route D

What are the main reasons for you to select this route? *

☐ This route is the fastest
☐ This route is the shortest
☐ This route is most fuel efficient
☐ To avoid the risk of icing
☐ To avoid the risk of turbulence
☐ To avoid the risk of lightning
☐ To avoid a collision
☐ To save oxygen
☐ To pick up the game bonus
☐ Random guess

You have now finished the NLR CloudAtlas test. Your answers have been stored in our database and will be used to generate test scores later on. If you wish to be informed about your test score afterwards, please contact us.

Please continue to answer the rest of the survey to finish up this part of the experiment.

How often do you play games in everyday life? *

○ Absolutely never
○ Very rarely, only a few times per year
○ A few times per month
○ A few times per week
○ Once every day
○ Multiple times per day

Please include all kinds of games, but not sports. For example: boardgames, video games, mobile games, rpg, puzzles.

What type of games do you play? *

☐ Card games (non-computer)
☐ Board games (non-computer)
☐ Puzzles (non-computer)
☐ Action and adventure games (computer)
☐ Shooter games (computer)
☐ Role playing games (computer)
☐ Strategy and puzzle games (computer)
☐ Card and board games (computer)
☐ Other

What do you think about the game controls? *

○ The game was very easy to control
○ The game was easy to control
○ The game was hard to control
○ The game was very hard to control

Please answer the following questions on a scale of 1 to 10. *

How familiar were you with clouds and meteorology before this experiment?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Did you enjoy the game?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Score 1 for the extreme negative, and 10 for the extreme positive answer.

>>> The following questions were asked only in the questionnaires for Experiment 1. <<<

Please answer the following questions on a scale of 1 to 10. *

How interesting do you find the topic of clouds and meteorology?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

How much did you learn from the experiment?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Score 1 for the extreme negative, and 10 for the extreme positive answer.

>>> The following question was asked only in the questionnaires for Experiment 1 for Voluntary Gameplay. <<<

Please answer the following questions on a scale of 1 to 10. *

Did you feel that you had the freedom to choose to play or not play the game?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Score 1 for the extreme negative, and 10 for the extreme positive answer.

>>> The following questions were asked only in the questionnaires for Experiment 2 and Experiment 3. <<<

Please answer the following questions on a scale of 1 to 10. *

How interested were you in learning more about clouds and meteorology?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

How engaging did you find this training about clouds?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Score 1 for the extreme negative, and 10 for the extreme positive answer.

For each of the following statements, please indicate how true it is for you.*

	1 Not at all true	2	3	4 Somewhat true	5	6	7 Very true
I was anxious while working on this task	○	○	○	○	○	○	○
I think that doing this task is useful for training airline pilots.	○	○	○	○	○	○	○
I think this is an important task	○	○	○	○	○	○	○
I am satisfied with my performance at this task.	○	○	○	○	○	○	○
I would describe this task as very interesting.	○	○	○	○	○	○	○
I felt like I had to do this.	○	○	○	○	○	○	○
I felt pressured while doing this task.	○	○	○	○	○	○	○
I thought this was a boring task.	○	○	○	○	○	○	○
I believe this task could be of some value to me.	○	○	○	○	○	○	○
I didn’t put much energy into this task.	○	○	○	○	○	○	○
I felt like it was not my own choice to do this task.	○	○	○	○	○	○	○
I put a lot of effort into this task.	○	○	○	○	○	○	○
It was important to me to do well at this task.	○	○	○	○	○	○	○
I tried very hard on this task.	○	○	○	○	○	○	○
This task was fun to do.	○	○	○	○	○	○	○
This task did not hold my attention at all.	○	○	○	○	○	○	○
I was very relaxed in doing this task.	○	○	○	○	○	○	○
I thought this task was quite enjoyable.	○	○	○	○	○	○	○
I did this task because I wanted to.	○	○	○	○	○	○	○
I didn’t try very hard to do well at this task.	○	○	○	○	○	○	○

Please answer the following questions on a scale of 1 to 10. *

Did the game help you learn about clouds?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Score 1 for the extreme negative, and 10 for the extreme positive answer.

>>> The following questions were asked in the questionnaires for <u>Experiment 2</u> and <u>Experiment 3</u> for <u>Mandatory Gameplay</u>. <<<

How did it make you feel that you were obligated to play the game for a minimum of 10 min.? *

○ Bad: I wanted to quit before the time was up.
○ Neutral: I did not really notice the time.
○ Good: I liked knowing when I could move on.

Would you have played the game if it wasn't mandatory? *

○ No
○ Probably not
○ Probably yes
○ Yes

How much time would you spend on the game if you were free to decide this? *

○ No more than 2 times
○ Less than 8 minutes
○ About 8 to 12 minutes
○ More than 12 minutes

>>> The following question was asked only in the questionnaires for Experiment 2 for No Gameplay. <<<

Part of the participants in this experiment were given a game to practice their knowledge and understanding of clouds.

Would you have wanted to play this game as part of the training? *

○ Yes
○ No

>>> The following questions were asked in the questionnaires for Experiment 2 and Experiment 3 for Mandatory Gameplay, and in the questionnaires for Experiment 2 for No Gameplay. <<<

Why would you choose to play the game? *

☐ Because it is part of the selected materials.
☐ Because I would hope it adds to the learning materials.
☐ Because I would think it is helpful for my learning process.
☐ Because I am curious and would want to see what it looks like.
☐ Because I like to have variation in learning materials.
☐ Because I like games.
☐ Other

Why would you choose not to play the game? *

☐ Because I don't need any extra material beside the learning materials.
☐ Because I think it is not helpful for my learning process.
☐ Because I think it would not add anything to the learning materials.
☐ Because I don't like to have so many learning materials.
☐ Because I don't like games.
☐ Other

>>> The following questions were asked only in the questionnaires for all three Experiments for Voluntary Gameplay. <<<

Did you play the CloudAtlas game? *

○ Yes
○ No

Why did you choose to play the game? *

☐ Because I don't need any extra material beside the learning materials.
☐ Because I think it is not helpful for my learning process.
☐ Because I think it would not add anything to the learning materials.
☐ Because I don't like to have so many learning materials.
☐ Because I don't like games.
☐ Other

>>> The following questions were asked in the questionnaires for all three Experiments for Voluntary Gameplay, only for participants who did not play the game. <<<

Did you take a look at the game or did you skip it completely? *

○ I skipped it completely.
○ I looked, but didn't play.
○ I tried the game once or twice.
○ I tried the game a couple more times.

Why did you choose not to play the game? *

☐ Because I didn't need any extra material beside the learning materials.
☐ Because I thought it would not be helpful for my learning process.
☐ Because I thought it would not add anything to the learning materials.
☐ Because I don't like to have so many learning materials.
☐ Because I don't like games .
☐ Other

>>> The following questions were asked only in the questionnaires for Experiment 2 and Experiment 3 for Voluntary Gameplay. <<<

For each of the following statements, please indicate how true it is for you. *

	1 Not at all true	2	3	4 Somewhat true	5	6	7 Very true
I believed playing the game could be beneficial to me.	○	○	○	○	○	○	○
I felt like I was expected to play the game.	○	○	○	○	○	○	○
I believed I had a free choice about playing the game.	○	○	○	○	○	○	○
I thought playing the game was an important activity.	○	○	○	○	○	○	○

>>> The following questions were asked only in the questionnaires for Experiment 2. <<<

How did you get involved in the experiment? *

○ I received an invitation by e-mail.
○ I saw an announcement on ERAS.
○ I saw an announcement on my class webpage.
○ I saw an announcement on the school website.
○ I was asked in person.
○ It was announced in class.
○ It was assigned as a homework task.
○ Other.

What is the name of the person who told you about the CloudAtlas experiment? *

Please write your answer here:

>>> The following questions were asked only in the questionnaires for Experiment 3. <<<

Do you have a PPL? *
- ○ No, I do not and I have never been enrolled in flight school.
- ○ No, I do not, but I have been enrolled in flight school in the past.
- ○ No, not yet, but I am enrolled in flight school at this time (for PPL, LAPL or RPL).
- ○ Yes, I have a PPL (or LAPL or RPL).
- ○ Yes, I have a PPL and more (CPL, ATPL or MPL).

How long have you had your PPL? *
- ○ Less than 1 year.
- ○ Less than 5 years.
- ○ More than 5 years.

What has been your primary reason to start flight training? *
- ○ To become a professional pilot.
- ○ Recreational purposes.
- ○ Other.

Did you take the Meteorology exam? *
- ○ No, I haven't started on Meteorology yet.
- ○ No, I am studying Meteorology but haven't taken the exam yet.
- ○ Yes, I took the Meteorology exam but didn't pass it yet.
- ○ Yes, I have taken and passed the Meteorology exam.

Are you or have you been a professional pilot? *
- ○ Yes, I am currently active as a professional pilot.
- ○ I have been, but not anymore.
- ○ No, never.

What is or was your line of work? *
- ○ Airline pilot.
- ○ Commercial pilot.
- ○ Both.

How many flight hours do you have? *
Please write your answer here:

>>> The following question was asked only in Experiment 3 for participants without PPL. <<<

Why did you participate in this experiment? *
- ○ I am interested in aviation.
- ○ I am interested in meteorology.
- ○ I am interested in teaching and learning materials.
- ○ I was curious to see what it was about.
- ○ Other.

>>> The following question was asked in the questionnaires for all participants in all three experiments. <<<

If you have any comments or remarks for us, please post them here.
Please write your answer here:

>>> The following statement was used in the questionnaires for Experiment 1 and Experiment 2. <<<

Thank you. This concludes the CloudAtlas project.

>>> The following statement was used in the questionnaires for Experiment 3. <<<

Thank you for finishing the first part of the NLR CloudAtlas Project. In a few weeks you will receive an e-mail inviting you to fill in a final survey.

Appendix B.3
CloudAtlas final questionnaires (Q3)

Final questionnaire for Experiment 1

How did you find out about the NLR CloudAtlas project? *
○ I was asked in person (verbally or by email).
○ Through a link on Facebook.
○ Through a link on Twitter.
○ Other

Who has asked you to participate in the project, or through whose Facebook or Twitter page did you find the project? *
Please write your answer here:

What was/were the most important reason(s) for you to register to participate?*
☐ I was asked to.
☐ I was curious to see the content of the project.
☐ I liked participating.
☐ I wanted to win the €100 gift card.
☐ Other:

Which of these statements applied to you?*
☐ I had difficulties with the English language.
☐ It took too long/cost me too much time.
☐ I think the project was uninteresting.
☐ I think the learning content was boring.
☐ I think the learning content was too easy.
☐ I think the learning content was difficult.
☐ I did not like playing the game.
☐ I think the game was too easy.
☐ I think the game was too difficult.
☐ Other:

We would appreciate some explanatory comments on your answers.
If you have any other comments you can write them here as well.
Please write your answer here:

Thank you. This concludes the CloudAtlas project.

Final questionnaire for Experiment 2

What was the main reason for you to participate in the NLR CloudAtlas experiment? *

- ○ Participation was assigned as homework
- ○ To earn school credit or participation points
- ○ I participated voluntarily
- ○ Other

How was the experiment structured for you? *

- ○ Learning materials > 10 minute game play > Test
- ○ Learning materials > optional gameplay > Test
- ○ Learning materials > Test

Did you experience technical problems during the experiment? *

- ○ Yes, therefore I could not play the game
- ○ Yes, but I could still play the game
- ○ No

Please describe the problems you had.

Please write your answer here:

How much of the learning materials did you read or study? *

- ○ I read and studied all pages
- ○ I read all pages once
- ○ I scanned all pages
- ○ I read/scanned a few pages
- ○ I did not look at the learning materials

With what you know about the experiment now, would you participate again? *

- ○ Yes
- ○ No

Please elaborate why you would or would not participate again.

Please write your answer here:

Would you play the CloudAtlas game in your free time? *

- ○ Yes
- ○ No

Please elaborate why you would or would not play the game in your free time.

Please write your answer here:

Before you participated in the experiment, did you know that: *

	Yes	No
the experiment contained a game?	○	○
the experiment contained reading materials?	○	○
the experiment would take about 30 minutes to complete?	○	○
you could win a gift voucher?	○	○
clouds would be the subject of the experiment?	○	○
this would be a training experiment?	○	○

How did you know in advance that: *

	My teacher told me	I read it in the experiment description	I wasn't sure, but I suspected it
the experiment contained a game	○	○	○
the experiment contained reading materials	○	○	○
the experiment would take about 30 minutes to complete	○	○	○
you could win a gift voucher	○	○	○
clouds would be the subject of the experiment	○	○	○
this would be a training experiment	○	○	○

Did your teacher tell you the experiment would contain a game? *

○ Yes
○ No

For each of the following statements, please indicate how true it is for you.*

	1 Not at all true	2	3	4	5 Very true	6	7
When it turned out there was no game in the experiment, my motivation decreased.	○	○	○	○	○	○	○
When it turned out there was no game in the experiment, I spent less time on the learning material.	○	○	○	○	○	○	○
The chance of winning the gift voucher was important to me.	○	○	○	○	○	○	○
Participating in experiments like this will help me to improve my performance in my study.	○	○	○	○	○	○	○
Learning about clouds will help me to improve my performance in my study.	○	○	○	○	○	○	○
I participated in this experiment because I wanted to contribute to science.	○	○	○	○	○	○	○
The school credit or participation points that I could earn were important to me.	○	○	○	○	○	○	○
I did my best to do well in this experiment.	○	○	○	○	○	○	○
I didn't try very hard to do well at this task.	○	○	○	○	○	○	○
I am satisfied with my performance at this task.	○	○	○	○	○	○	○
I believe this task could be of some value to me.	○	○	○	○	○	○	○
I think this is an important task.	○	○	○	○	○	○	○
It was important to me to do well at this task.	○	○	○	○	○	○	○
I wouldn't describe this task as very interesting.	○	○	○	○	○	○	○
I did this task because I wanted to.	○	○	○	○	○	○	○
I think that doing this task is useful for training airline pilots.	○	○	○	○	○	○	○
I thought this task was quite enjoyable.	○	○	○	○	○	○	○

If you have any comments or remarks for us, feel free to post them here.

Please write your answer here:

Final questionnaire for Experiment 3

Please rate the amount of obligation you felt on a scale of 1 to 10. *

	1	2	3	4	5	6	7	8	9	10
Obligation	○	○	○	○	○	○	○	○	○	○

1 = no obligation: My participation was totally voluntary
10 = extreme obligation: I had no choice but to participate

How much of the learning materials did you read or study? *

○ I read and studied all pages extensively
○ I read and studied all pages
○ I read all pages once
○ I scanned all pages
○ I read or scanned a few pages
○ I skipped the learning materials

Would you play the CloudAtlas game again? *

○ Yes
○ No

Please elaborate why you would or would not play the game again. *
Please write your answer here:

For each of the following statements, please indicate how true it is for you.*

	1 Not at all true	2	3	4 Somewhat true	5	6	7 Very true
I think that doing this task is useful for training airline pilots.	○	○	○	○	○	○	○
I think this is an important task.	○	○	○	○	○	○	○
I am satisfied with my performance at this task.	○	○	○	○	○	○	○
I would not describe this task as interesting.	○	○	○	○	○	○	○
It was important to me to do well at this task.	○	○	○	○	○	○	○
I thought this task was quite enjoyable.	○	○	○	○	○	○	○
I felt pressured while doing this task.	○	○	○	○	○	○	○
I did this task because I wanted to.	○	○	○	○	○	○	○
I didn’t try very hard to do well at this task.	○	○	○	○	○	○	○
I believe this task could be of some value to me.	○	○	○	○	○	○	○
Participating in experiments like this will help me to improve my performance in my study.	○	○	○	○	○	○	○
Learning about clouds will help me to improve my performance in my job or training.	○	○	○	○	○	○	○
I participated in this experiment because I wanted to contribute to science.	○	○	○	○	○	○	○
I did my best to do well in this experiment.	○	○	○	○	○	○	○

Which of these statements apply to you? *

☐ I had difficulties with the English language.
☐ It took too long/cost me too much time.
☐ I think the project was uninteresting.
☐ I think the learning content was boring.
☐ I think the learning content was too easy.
☐ I think the learning content was difficult.
☐ I did not like playing the game.
☐ I think the game was too easy.
☐ I think the game was too difficult.

If you have any comments or remarks for us, feel free to post them here.
Please write your answer here:

Thank you. This concludes the CloudAtlas project.

Appendix B.4
CloudAtlas written materials

1. Learning objectives

A pilot needs to be able to recognize and classify clouds, assess the risks and decide what to do. This learning material will tell you about the classification of clouds, the 10 main cloud types and the hazards associated with clouds. After studying this unit you should be able to:

- Recognize the 10 different cloud types from drawings and photographs.
- Indicate the levels (‘étages’) on which the 10 cloud types can be found.
- Indicate the chances for hazards in the 10 cloud types.
- Know what clouds are safe to fly through.
- Choose the best route in a situation with (a combination of) clouds.
- Explain why you have chosen a certain route.

The learning material consists of 13 pages. It has approximately 2000 words and it should take about 10 minutes to read through once.

>>> The learning objectives were added for Experiment 3. <<<

2. Cloud classification

The importance of meteorology for the safety of civil aviation has been acknowledged since the early days of aviation. Clouds are part of the meteorological conditions that impact aviation.

Clouds are formed when humid air cools down around small particles in the air (like smoke or dust). When the saturation point is reached, the invisible water vapour changes into a visible state. They are the visible indicators of current weather and they are often indicative of future weather.
While clouds appear in infinite shapes and sizes, they all fall into some basic forms. The cloud naming system was introduced by Luke Howard in 1803 and is based on the Latin language. Clouds are classified according to the height of their base in the sky and they are named for their height, shape and behaviour.

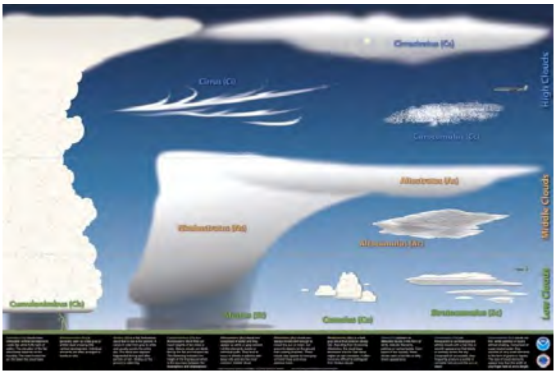
- **Cirriform**: cirrus = tuft or curling lock of hair. Composed of ice crystals, cirriform clouds are whitish and hair-like.
- **Cumuliform**: cumulus = heap or pile. Generally detached clouds, they look like white fluffy cotton balls.
- **Stratiform**: stratus = layer, these clouds are usually broad and fairly widespread appearing like a blanket.

Howard noticed that clouds often have features of two or more categories.
He also designated a special category for rainy clouds.

- **Nimbo-form**: nimbus = rain.

Clouds are vertically divided into three levels:

- **High-level, 5 to 13 km**:
  Cirrus, Cirrostratus, Cirrocumulus
- **Medium-level, 2 to 7 km**:
  Altostratus, Altocumulus, Nimbostratus
- **Low-level, 0 to 2 km**:
  Stratus, Stratocumulus
  - **Low-level with vertical development**: Cumulus (and Towering Cumulus), Cumulonimbus



Source: http://www.srh.weather.gov/jetstream/clouds/basicten.html

3. Cloud type: Cirrus (Ci)

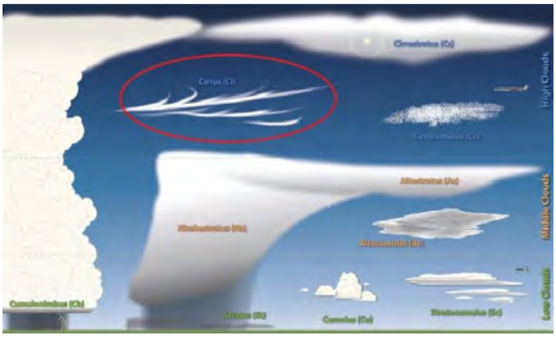
Cirrus (Ci) appears as detached clouds in the form of white, delicate filaments, patches or narrow bands. Composed of ice crystals, these clouds have a hair-like or silky sheen appearance.

Hazards

- Some turbulence
- Small chance of icing

Flying advice

Isolated patches rarely have any great significance, but an extensive deck, increasing from one direction, may indicate an approaching front. Cirrus is often associated with turbulence, but it will generally cause little discomfort to pilots or passengers.



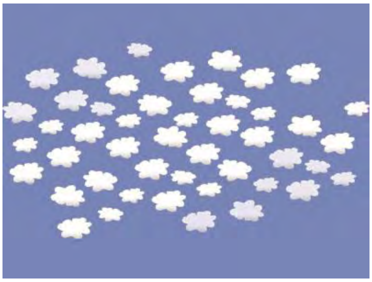
Main characteristics

- High-level cloud
- Isolated patches or a layer covering a wide area
- White streaks in many shapes and sizes
- Consist of ice crystals
- Generally occur in fair weather
- May produce fall streaks: falling ice crystals that evaporate before they touch the ground
- May produce optical phenomena such as halos and cloud iridescence

Photographs

Source: The Cloud Appreciation Society

4. Cloud type: Cirrocumulus (Cc)



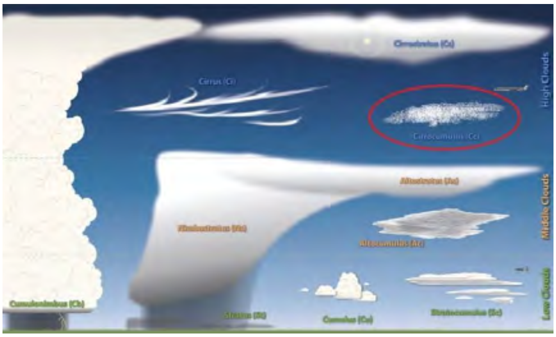
Cirrocumulus (Cc) clouds are thin, white patches or layers without shading. Comprised of super-cooled water, they consist of very small elements in the form of grains or ripples.

Hazards

- Chance of some turbulence
- Chance of icing

Flying advice

No special advice needed.



Main characteristics

- High-level cloud
- Brilliant white with a spotty appearance, no shadows
- Appears in wide, patchy sheets
- Consist of a combination of water droplets and ice crystals
- Do not produce precipitation and are normally associated with fine weather

Photographs



Source: The Cloud Appreciation Society

5. Cloud type: Cirrostratus (Cs)

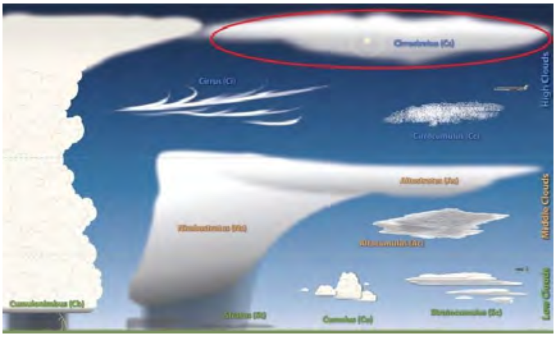
Cirrostratus (Cs) are transparent or semi-transparent, whitish clouds with a hair-like or smooth appearance that totally or partially cover the sky. Composed of ice crystals, they frequently produce a partial or complete halo around the sun or moon.

Hazards

- Small change of turbulence
- Very small chance of icing

Flying advice

Cirrostratus formations may cause slight turbulence at cloud level, but this is unlikely to affect aircraft operations or discomfort passengers.

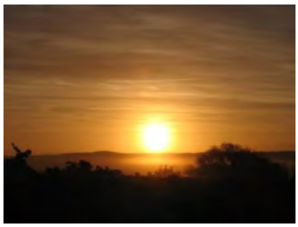


Main characteristics

- High-level cloud
- An even layer of Cirrus covering a wide area
- In a very thin layer of in strands
- Will often produce optical phenomena such as halos and iridescence

Photographs





Source: The Cloud Appreciation Society

6. Cloud type: Altocumulus (Ac)

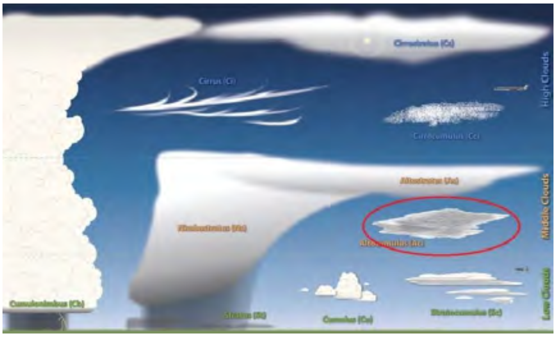
Altocumulus (Ac) clouds are composed of water and they appear as white or grey coloured roll-like elements, bands or individual puffs. They tend to occur in sheets or patches with wavy rolls and are the most common 'middle' cloud.

Hazards

- Some turbulence, and small chance of severe turbulence
- Very small chance of icing

Flying advice

No reason to fly around these clouds, unless a warning for turbulence has been issued. Do keep an eye on the thermometer as icing may occur at below freezing temperatures.



Main characteristics

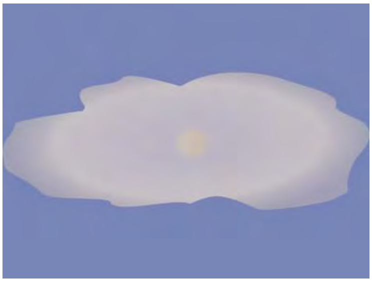
- Mid-level cloud
- Layer or patches of mostly separated clouds
- Parallel bands or rounded masses
- A portion of altocumulus is shaded
- Altocumulus clouds do not produce rain, but may indicate a forthcoming weather change
- May easily be confused with Cirrocumulus, which is a high-level cloud without any shading

Photographs



Source: The Cloud Appreciation Society

7. Cloud type: Altostratus (As)



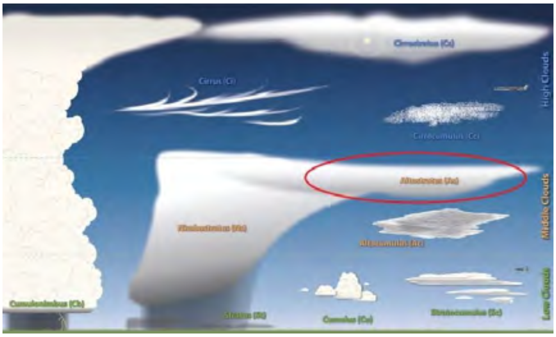
Altostratus (As) clouds are always translucent enough to reveal the sun or moon, but prevent objects on the ground from casting shadows. These clouds also appear to have grey or bluish hues and never produce halos.

Hazards

- Small chance of some turbulence
- Chance of serious icing

Flying advice

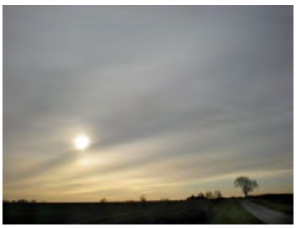
A thick deck of Altostratus may be a cause for concern if temperatures within the cloud are below freezing. So keep an eye on the thermometer.

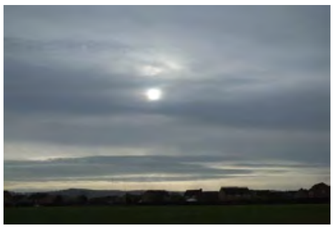


Main characteristics

- Mid-level cloud
- Usually covers the whole sky
- Grey or bluish-grey colour, never white
- The sun (or moon) may shine through, but will appear watery and will not cast shadows
- May easily be confused with Cirrostratus, but Altostratus does not show a halo around the sun or moon
- Altostratus clouds may produce some rain, and they usually form ahead of storms with continuous rain or snow

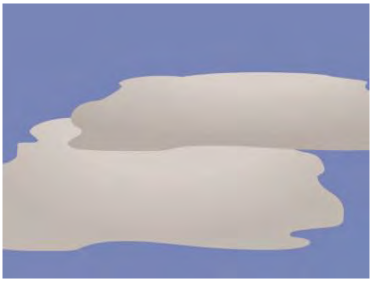
Photographs





Source: The Cloud Appreciation Society

8. Cloud type: Nimbostratus (Ns)



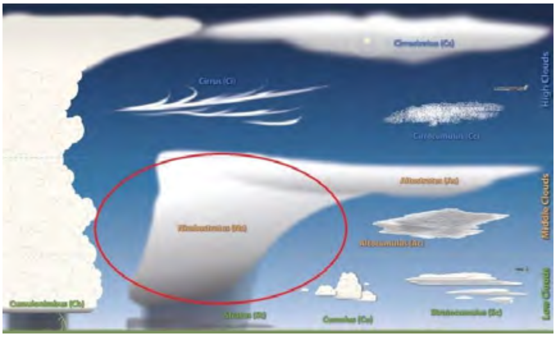
Nimbostratus (Ns) is a dark grey cloud that produces steady rain. Resulting from thickening Altostratus, the cloud base decreases into the 'low' cloud region as rain increases. It often becomes difficult to distinguish from Stratus clouds.

Hazards

- Some chance of turbulence
- Chance of icing
- Some chance of lightning

Flying advice

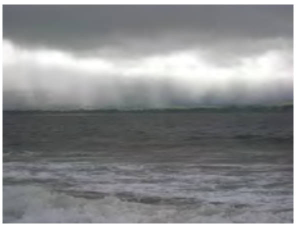
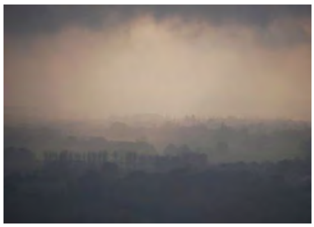
Keep an eye on the temperature to know of icing may occur. There may be some turbulence, but nothing too severe.



Main characteristics

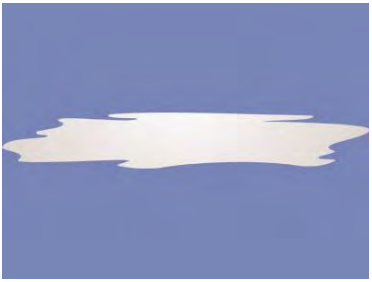
- Mid-level cloud, with a base height as low as 0.5 km
- Often called rain clouds
- Thick layer with uniform grey appearance
- May have some vertical development
- Bottoms can be blurred due to falling rain or snow
- Produces steady rain or snow

Photographs

Source: The Cloud Appreciation Society

9. Cloud type: Stratus (St)



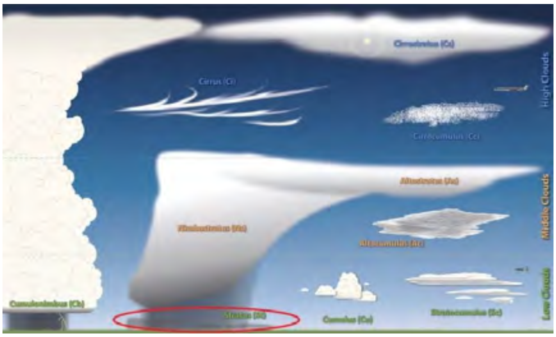
Stratus (St) is a flat, featureless cloud that is low to the ground. It varies in colour from grey to white and usually covers the entire sky. The cloud also appears fragmented during and after periods of rain.
Fog is a Stratus cloud on ground level.

Hazards

- No turbulence
- Some chance of serious icing

Flying advice

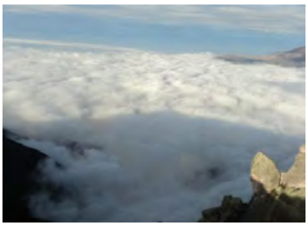
Low to the ground it can mask the surrounding terrain. Landing through fog should be avoided.



Main characteristics

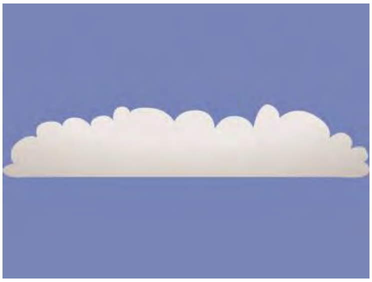
- Low-level cloud, with a base height as low as 0 km
- Combination of water droplets, super cooled water and ice crystals
- Wide sheets with ragged, grey appearance
- May produce light precipitation from a thick layer

Photographs


Source: The Cloud Appreciation Society

10. Stratocumulus (Sc)



Stratocumulus (Sc) is generally seen as a low grey or whitish layer showing little vertical development. Individual elements are often arranged in bands or rolls.

Hazards

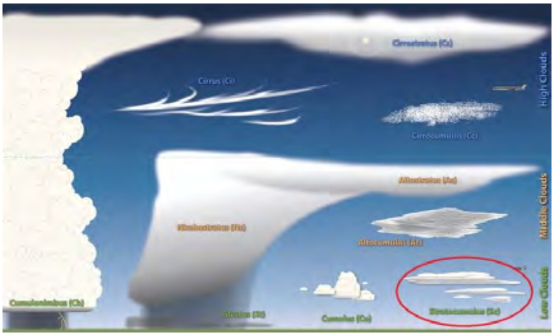
- Some turbulence
- Small chance of serious icing

Flying advice

No special advice needed.

Main characteristics

- Low-level cloud
- One of the two most common clouds
- Various colours, from white to dark grey
- Usually a flat base
- Ragged appearance along the upper surface
- Appears more lumpy than Stratus
- May produce a little bit of precipitation

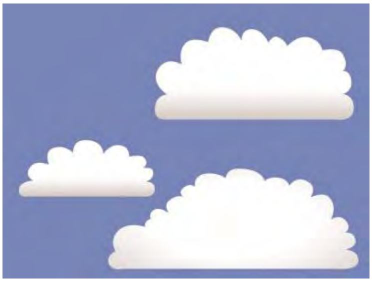


Photographs



Source: The Cloud Appreciation Society

11. Cloud type: Cumulus (Cu)



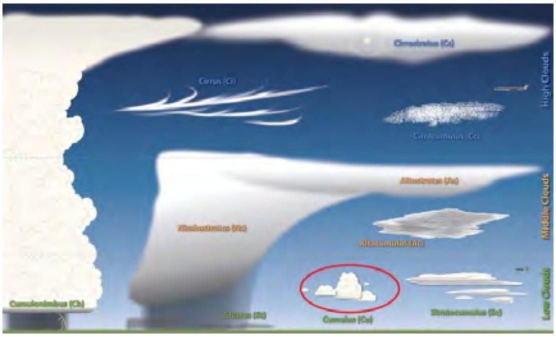
Cumulus (Cu) are detached, generally dense clouds and with sharp outlines that develop vertically in the form of rising mounds, domes or towers with bulging upper parts often resembling a cauliflower. The sunlit parts of these clouds are mostly brilliant white while their bases are relatively dark and horizontal.

Hazards

- Chance of turbulence
- Chance of icing
- Small chance of lightning

Flying advice

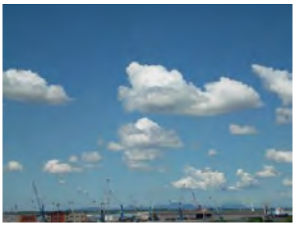
Regular Cumulus may give a little bit of a bumpy ride. Towering Cumulus are not Cumulonimbus yet, but they still may give some lightning and bad turbulence.

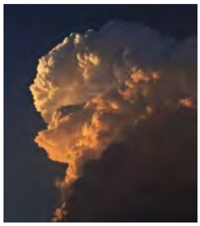


Main characteristics

- Low-level cloud with vertical development
  The top of a cumulus may reach into the mid and high levels.
- Puffy clouds with flat bases
- Can be white or light grey, with shading
- Appear by themselves or in clusters
- Come in various forms and sizes
- May show a high vertical development: Towering Cumulus
- Produce no precipitation, but can grow into Cumulonimbus

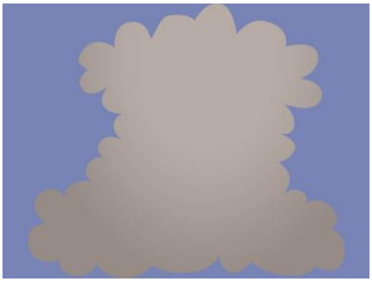
Photographs





Source: The Cloud Appreciation Society

12. Cloud type: Cumulonimbus (Cb)



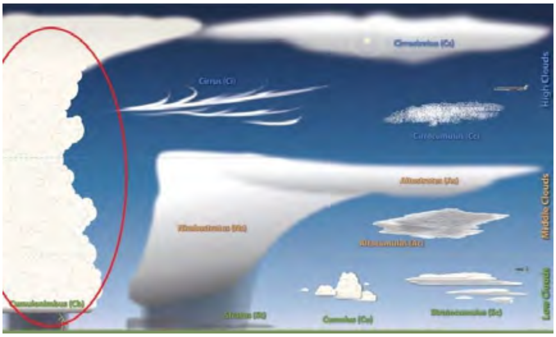
Cumulonimbus (Cb) is the thunderstorm cloud. It is a heavy and dense cloud in the form of a mountain or huge tower. The upper portion is usually smoothed, fibrous or striated and nearly always flattened in the shape of an anvil or vast plume. Under the base of this cloud which is often very dark, there are often low ragged clouds that may or may not merge with the base. They produce precipitation.

Hazards

- Chance of severe turbulence
- Chance of icing
- Big chance of lightning

Flying advice

Do not fly through or under a Cumulonimbus cloud, because there is a great risk of lightning within and under. Land your plane and wait for the storm to pass, or fly over it.



Main characteristics

- Low-level cloud with vertical development
  The top of a cumulonimbus may reach into the mid and high levels.
- Has a grey to almost black colour
- Top shaped like a mushroom or anvil
- Can reach a height of several kilometres
- Produces moderate to heavy showers

Photographs



Source: The Cloud Appreciation Society

13. Hazards

Pilots may encounter some hazards in and around clouds that influence aviation safety and passenger comfort.
The most common are:

1. Turbulence
2. Icing
3. Lightning

13.1. Turbulence

In almost all types of clouds turbulence may occur. Turbulence is any irregular or disturbed airflow in the atmosphere. Its origin may be thermal or mechanical and it may come about either within a cloud or in clear air. Occurrences of turbulence are local in extent and transient in character. Although general forecasts of turbulence are quite good, forecasting precise locations is difficult.

Turbulence hardly ever causes damage to the aircraft; therefore most pilots do not worry and just ride it out. Passengers, however, often experience turbulence as far more severe than it actually is.

13.2. Icing

The most hazardous aspect of structural icing is its aerodynamic effects. The presence of ice on an aircraft decreases lift, thrust, and range, and increases drag, weight, fuel consumption, and stall speed. For icing to form the atmosphere must have super-cooled visible water droplets and the temperature of the free air and the aircraft's surface need to be below freezing.

Clouds are the most common form of visible liquid water and super-cooled water is liquid water found at air temperatures below freezing. Water droplets in the free air do not freeze at 0°C, instead their freezing temperature varies from –10 to –40 °C, forming super-cooled droplets. When these strike an exposed object, such as a wing, the impact induces instant freezing and results in aircraft icing. When flying through a cloud at sub-zero temperatures, icing should be expected.

As a general rule, serious icing is rare in clouds with temperatures below –20°C since these clouds are almost completely composed of ice crystals. However, icing is possible in any cloud when the temperature is 0°C or below.

13.3. Lightning

Lightning is a sudden electrostatic discharge during an thunderstorm between electrically charged regions of a cloud, between two clouds, or between a cloud and the ground. Lightning occurs as a result of a build-up of static charges within a Cumulonimbus cloud. An aircraft passing close to an area of charge can initiate a discharge and this may occur even at some distance from a thunderstorm.

A lightning strike can damage electronic equipment and in rare events it can puncture the skin of an aircraft. Nearby lightning can blind the pilot leaving him momentarily unable to fly the aircraft. Lightning can also induce permanent errors in the magnetic compass when it is nearby or, even at a distance, it can disrupt radio communications.

A lightning strike can be very distressing to passengers and crew, but damage to an aircraft in flight which is sufficient to compromise the safety of the aircraft is rare. The safety of an aircraft in flight is usually not affected.

Appendix C

Creating Shuttle to Mars: a game to provide experience

In this appendix, belonging to Chapter 5, we present the materials used in the job analysis to identify the essential competencies in critical situations. Furthermore, we present the materials used in the *Shuttle to Mars* playtest.

Appendix C.1
Semi-structured interview scheme for job analysis

A. Interviewee background

1. What is your function/position?
2. How long have you been a pilot?
3. How many flight hours do you have?

B. Interviewee experience

1. Have you experienced situations in which the normal procedures did not suffice?
2. How many times?
3. Please describe a few of these situations briefly.
    1. What happened in this situation?
    2. What made this situation difficult (or easy)?
       Would you consider this an emergency?
        a. Was the safety of the aircraft and the passengers at risk?
    3. How did you solve this problem? What did you do?
    4. Was it a situation that was unknown to you? Or mostly unexpected?
       Did you have procedures available?
        a. Were they easy to find?
        b. Did the checklists suffice?
        c. Did you need to deviate from the checklist
    5. How did you feel during this situation? And after?
4. How did these situations differ from one another?
5. What made them non-normal?
    a. Have you been in situations in which it was hard to determine what was happening?
    b. And in situations for which no procedure or checklist was available?

C. Interviewee insight into/vision on competencies

1. Are you familiar with the ICAO list of competencies?
2. What do you think are the most important competencies or skills when everything goes as planned (normal situations)?
3. And when it doesn’t go as planned (non-normal situations)?
4. When is a pilot free to turn to creative solutions?

Based on ICAO competencies and other documents I have studied, I have come to this list of competencies which I believe are essential in unknown and unexpected situations:

- *Situation Awareness*
- *Application of procedures*
- *Aircraft Flight Path Management, manual control*
- *Workload management*

- *Problem Solving and Decision Making*
- *Communication*

5. Do you agree that these pilots need these competencies to act adequately in unknown and unexpected situations? Please elaborate.
6. Are any necessary competencies missing from the list, for the non-normal/critical situations?
7. Do you think the current training for airline pilots addresses these (missing?) competencies enough?
8. Do you think these competencies can be trained (to some extent) in a non-realistic setting (such as gaming) and may help develop these competencies?

Appendix C.2
ICAO core competencies and behavioural indicators

Competency	Behavioural Indicators
1. Application of Procedures (AP)	1a. Identifies the source of operating instructions 1b. Follows SOPs unless a higher degree of safety dictates an appropriate deviation 1c. Identifies and follows all operating instructions in a timely manner 1d. Correctly operates aircraft systems and associated equipment 1e. Complies with applicable regulations 1f. Applies relevant procedural knowledge
2. Communication (COM)	2a. Ensures the recipient is ready and able to receive the information 2b. Selects appropriately what, when, how and with whom to communicate 2c. Conveys messages clearly, accurately and concisely 2d. Confirms that the recipient correctly understands important information 2e. Listens actively and demonstrates understanding when receiving information 2f. Asks relevant and effective questions 2g. Adheres to standard radiotelephone phraseology and procedures 2h. Accurately reads and interprets required company and flight documentation 2i. Accurately reads, interprets, constructs and responds to datalink messages in English 2j. Completes accurate reports as required by operating procedures 2k. Correctly interprets non-verbal communication 2l. Uses eye contact, body movement and gestures that are consistent with and support verbal messages
3. Aircraft Flight Path Management, automation (AFPM-A)	3a. Controls the aircraft using automation with accuracy and smoothness as appropriate to the situation 3b. Detects deviations from the desired aircraft trajectory and takes appropriate action 3c. Contains the aircraft within the normal flight envelope 3d. Manages the flight path to achieve optimum operational performance 3e. Maintains the desired flight path during flight using automation whilst managing other tasks and distractions 3f. Selects appropriate level and mode of automation in a timely manner considering phase of flight and workload 3g. Effectively monitors automation, including engagement and automatic mode transitions

Table continued on next page

Table continued from previous page

Competency		Behavioural Indicators
4. Aircraft Flight Path Management, manual control (AFPM-M)		4a. Controls the aircraft manually with accuracy and smoothness as appropriate to the situation
		4b. Detects deviations from the desired aircraft trajectory and takes appropriate action
		4c. Contains the aircraft within the normal flight envelope
		4d. Controls the aircraft safely using only the relationship between aircraft attitude, speed and thrust
		4e. Manages the flight path to achieve optimum operational performance
		4f. Maintains the desired flight path during manual flight whilst managing other tasks and distractions
		4g. Selects appropriate level and mode of flight guidance systems in a timely manner considering phase of flight and workload
		4h. Effectively monitors flight guidance systems including engagement and automatic mode transitions
5. Leadership and Teamwork (L&T)		5a. Understands and agrees with the crew's roles and objectives
		5b. Creates an atmosphere of open communication and encourages team participation
		5c. Uses initiative and gives directions when required
		5d. Admits mistakes and takes responsibility
		5e. Anticipates and responds appropriately to other crew members' needs
		5f. Carries out instructions when directed
		5g. Communicates relevant concerns and intentions
		5h. Gives and receives feedback constructively
		5i. Confidently intervenes when important for safety
		5j. Demonstrates empathy and shows respect and tolerance for other people
		5k. Engages others in planning and allocates activities fairly and appropriately according to abilities
		5l. Addresses and resolves conflicts and disagreements in a constructive manner
		5m. Projects self-control in all situations
6. Problem Solving and Decision Making (PS&DM)		6a. Seeks accurate and adequate information from appropriate sources
		6b. Identifies and verifies what and why things have gone wrong
		6c. Employ(s) proper problem solving strategies
		6d. Perseveres in working through problems without reducing safety
		6e. Uses appropriate and timely decision making processes
	*	6f. Sets priorities appropriately
	*	6g. Identifies and considers options effectively
		6h. Monitors, reviews, and adapts decisions as required
	*	6i. Identifies and manages risks effectively
	*	6j. Improvises when faced with unforeseeable circumstances to achieve the safest outcome

Table continued on next page

Table continued from previous page

Competency		Behavioural Indicators
7. Situation Awareness (SA)	*	7a. Identifies and assesses accurately the state of the aircraft and its systems
		7b. Identifies and assesses accurately the aircraft's vertical and lateral position, and its anticipated flight path
	*	7c. Identifies and assesses accurately the general environment as it may affect the operation
	*	7d. Keeps track of time and fuel
	*	7e. Maintains awareness of the people involved in or affected by the operation and their capacity to perform as expected
	*	7f. Anticipates accurately what could happen, plans and stays ahead of the situation
		7g. Develops effective contingency plans based upon potential threats
	*	7h. Identifies and manages threats to the safety of the aircraft and people
		7i. Recognises and effectively responds to indications of reduced situation awareness
8. Workload Management (WM)		8a. Maintains self-control in all situations*
		8b. Plans, prioritises and schedules tasks effectively*
		8c. Manages time efficiently when carrying out tasks
	*	8d. Offers and accepts assistance, delegates when necessary and asks for help early
		8e. Reviews, monitors and cross-checks actions conscientiously
		8f. Verifies that tasks are completed to the expected outcome
	*	8g. Manages and recovers from interruptions, distractions, variations and failures effectively

Behavioural indicators marked with * are selected to be addressed in the *Shuttle to Mars* game.

Appendix C.3
Shuttle to Mars Playtest protocol (Dutch)

Welkom

Welkom. Fijn dat je ons wilt helpen met deze playtest. Het doel is om te bekijken of deze game speelbaar is. Met speelbaar bedoelen we of het duidelijk is hoe je de game bedient en wat je moet doen. Ook zijn we benieuwd of de game leuk en uitdagend is.

We testen vandaag de game, we testen niet hoe handig jij met de game bent. Eigenlijk kun je dus nooit iets fout doen. Het helpt ons heel erg als je hardop zegt wat je probeert te doen. Zeker als iets niet lukt.

Tijdens het testen nemen we het scherm en jouw gezicht op. Dit is om later goed te kunnen zien wat er allemaal gebeurd is in de test. De filmbeelden worden uitsluitend gebruikt voor deze test en alleen getoond aan mensen die betrokken zijn bij dit project als opdrachtgever of als maker.

We beginnen zo eerst met een korte vragenlijst. Daarna is het de bedoeling dat je de game gaat spelen. Deze staat op een iPad. Ik zal je aangeven hoe, wat en in welke volgorde. Ik wil je vragen hardop te vertellen wat je doet, waarom je het doet en wat je van die handeling verwacht.

Ik kijk met je mee wat je doet, en zal je soms vragen iets toe te lichten.

Ik heb deze app niet gemaakt, maar ben alleen gevraagd om het testen te begeleiden. In principe mag ik je niet helpen, tenzij er iets fout loopt in de applicatie. Je mag ook altijd zeggen wat je ergens van vindt tijdens het testen. Zowel positief als negatief. Wij kunnen hier tijdens de test niet op reageren omdat het mogelijk de resultaten beïnvloedt.

<vragenlijst, pagina 1>

Uitleg game

We beginnen met de game. Hier is de iPad. Ik zal je eerst iets over de game vertellen, daarna mag je een account aanmaken.

De game – Shuttle to Mars – speelt zich af in de ruimte. Jij bent een ruimtekoerier en het is jouw taak om je lading (cargo) naar de bestemming te brengen. Hoe minder cargo je verliest onderweg, en hoe beter de staat van je ruimteschip en crew is als je aankomt, des te beter heb je het gedaan.

Er zijn verschillende missies. Iedere missie begint met 1000 stuks cargo, een gezonde crew, een stevig ruimteschip, en een voorraad brandstof en ammunitie. Aan het begin van een missie moet je je route plannen en daarna ga je op pad. Je moet het ruimteschip op koers houden door te sturen. Je gaat vanzelf vooruit. Houd de status van alle systemen goed in de gaten en let ook op wat er buiten gebeurt. Heb je nog vragen?

Aan de slag

Dan gaan we beginnen. Je mag eerst een account aanmaken. Probeer het eerst zelf. Als het nodig is, help ik je. Vertel hardop wat je doet of probeert te doen.

<maak account>

De eerste missie

Nu mag je beginnen met The Long Haul. Dit is een heel eenvoudige missie waarin nog niet zoveel gebeurt. Je hebt dan even gelegenheid om aan de game te wennen.

Ga je gang. Denk hardop. *Wat zie je? Wat verwacht je? Wat doe je?* Als er iets echt niet lukt, zal ik je helpen.

<speel The Long Haul – ca. 10 minuten>

Hier laten we het bij.

Wat is je eerste indruk van de game?

Vond je het makkelijk of moeilijk om het ruimteschip te besturen?

Volgende missie

Dan mag je nu verder gaan met de Tutorial. Om daar te komen moeten we de app even sluiten en opnieuw openen (twee keer op de Home knop klikken en dan de Shuttle to Mars app omhoog swipen, vervolgens de app weer aantikken). Dan kun je de Tutorial kiezen uit het menu.

<speel Tutorial>

In de Tutorial worden de systemen van het ruimteschip uitgelegd. Lees de teksten goed door en denk eraan om weer hardop te denken.

[Nodig: spiekbriefje met de Engine-procedure voor het geval het echt niet lukt deze in te voeren]

Vond je de tutorial nuttig? Was hij duidelijk?

Derde missie

We gaan nu verder met een echte missie. Je mag de Omega missie starten. Bij deze missie moet je eerst je route plannen. Ga je gang.

<speel Omega missie>

[zo nodig helpen bij route plannen]

[belangrijk: pas starten als route helemaal gepland is en het einddoel van de eerste sectie is aangetikt]

Ik laat je nu zelf deze missie spelen. Zou je weer hardop willen denken over wat je ziet, wat je verwacht en wat je doet?

Afronding

Dit waren de missies in de game.

Je kunt nu het tweede deel van de vragenlijst invullen. Ook daarbij wil ik je vragen hardop te denken en je antwoorden toe te lichten.

<vragenlijst, vanaf pagina 2>

Dat was het. Bedankt voor je medewerking. Als kleine beloning mag je wat lekkers uitkiezen.

Mocht je achteraf nog wat te binnen schieten over de game, dan horen we dat graag nog. Je kunt dan mailen naar Esther (esther.kuindersma@nlr.nl).

Bedankt!

Appendix C.4
Shuttle to Mars Playtest questionnaire (Dutch)

Introductievragen Shuttle to Mars – playtest

Naam: ______________________________

De vragenlijst bestaat in totaal uit 4 pagina's. We vragen je hardop te zeggen wat je invult en eventueel een toelichting te geven aan de testbegeleider.

Kun je aangeven waarom je meedoet met deze test en wat je van de test verwacht?

____
____
____

Stelling	Oneens		Neutraal		Eens
Ik sta positief tegenover de inzet van **innovatieve trainingsmethoden** in de (recurrent) training voor verkeersvliegers.	○	○	○	○	○
Toelichting (optioneel):					
Ik sta positief tegenover de inzet van een **virtuele training/game** in de (recurrent) training voor verkeersvliegers.	○	○	○	○	○
Toelichting (optioneel):					
Ik ben iemand die **vaak als eerste** gebruik maakt van nieuwe programma's, technieken en mogelijkheden.	○	○	○	○	○
Toelichting (optioneel):					
Ik speel zelf geregeld **games en spellen**, in welke vorm dan ook (bordspel, kaartspel, computer- of smartphone game, etc).	○	○	○	○	○
Toelichting (optioneel):					

Wacht met het invullen van deel 2 van de vragenlijst tot je de game getest hebt!

Vragen na kennismaking met Shuttle to Mars

Het doel van deze vragenlijst is het krijgen van een volledig beeld van de sterke en zwakke punten van de game, om uiteindelijk een zo goed mogelijk product op te leveren.

We vragen je hardop te zeggen wat je invult en eventueel een toelichting te geven aan de testbegeleider.

Stelling	Oneens		Neutraal		Eens
Het was duidelijk **wat ik moest doen** in de game.	○	○	○	○	○
Toelichting (optioneel):					
De **besturing van de game** (knoppen, manual, etc) was duidelijk.	○	○	○	○	○
Toelichting (optioneel):					
Ik had **controle** over de game.	○	○	○	○	○
Toelichting (optioneel):					
Het **doel** van de game was duidelijk.	○	○	○	○	○
Toelichting (optioneel):					
De game was goed **speelbaar**.	○	○	○	○	○
Toelichting (optioneel):					
De **tutorial** gaf voldoende informatie om de game snel te kunnen spelen.	○	○	○	○	○
Toelichting (optioneel):					
Het kostte (ondanks de tutorial) nog **veel tijd** om het spel goed te kunnen spelen.	○	○	○	○	○
Toelichting (optioneel):					
Het spelen op de **iPad** werkt goed voor deze game.	○	○	○	○	○
Toelichting (optioneel):					
Ik zou deze game liever spelen op een **pc of laptop**.	○	○	○	○	○
Toelichting (optioneel):					

Stelling	Oneens		Neutraal		Eens
De **opdrachten** in de game waren interessant.	○	○	○	○	○
Toelichting (optioneel):					
Ik voelde soms een soort **stress of werkdruk** door de opdachten in de game.	○	○	○	○	○
Toelichting (optioneel):					
Het **verhaal** in de game was interessant.	○	○	○	○	○
Toelichting (optioneel):					
De vormgeving van de game is **aantrekkelijk**.	○	○	○	○	○
Toelichting (optioneel):					
Ik was **zeer betrokken** in de game / ik speelde **fanatiek** mee.	○	○	○	○	○
Toelichting (optioneel):					
Ik zou de game **vaker willen spelen**.	○	○	○	○	○
Toelichting (optioneel):					
Ik zou de game **aanbevelen** aan anderen.	○	○	○	○	○
Toelichting (optioneel):					
Ik zie **overeenkomsten** tussen deze game en het werk als verkeersvlieger.	○	○	○	○	○
Toelichting (optioneel):					

Welke woorden vind jij passen bij deze game?

☐ Leerzaam
☐ Voor volwassenen
☐ Kinderachtig
☐ Duidelijk
☐ Saai
☐ Uitdagend
☐ Voor thuis
☐ Ingewikkeld
☐ Handig
☐ Interessant
☐ Vrolijk
☐ Voor op het werk
☐ Spannend
☐ _______________

Wat vond jij het beste aan deze virtuele training/game?

Wat vond jij het minst goede aan deze virtuele training/game?

Hartelijk dank voor deelname aan deze test!

Appendix D

Measuring the Shuttle to Mars experience

In this appendix, belonging to Chapter 6, we present the materials used in the small-scale study to determine to acceptance of a serious game for competency development by airline pilots.

Appendix D.1
Questionnaire 1: StM Start

Welcome!
You have just played the Shuttle to Mars tutorial and your first mission.

Please answer the questions in this questionnaire. After the last question, you will receive a passcode to continue playing the game.

Please enter your personal information. *
Please write your answer(s) here:

- First name:
- Last name:
- Address:
- Postal code:
- City:
- E-mail address:
- Phone number (home):
- Phone number (mobile):

Please enter your birthday. *
Please enter a date:

What year did you graduate from flight academy? *
Please enter a date:

How many years have you worked for an airline since graduation? *
Please write your answer here:

How many flight hours do you have? *
Please write your answer here:

Please indicate to what extent the statement applies to you. *

	not at all true 1	**2**	**3**	**somewhat true 4**	**5**	**6**	**very true 7**
I feel positive about the use of innovative training methods in (recurrent) training for airline pilots.	○	○	○	○	○	○	○
I feel positive about the use of a virtual training or game in (recurrent) training for airline pilots.	○	○	○	○	○	○	○
I am often one of the pioneers in using new technology or software.	○	○	○	○	○	○	○

On a scale from 1 to 10, how motivated are you to participate in this experiment? *

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Motivation	○	○	○	○	○	○	○	○	○	○

1 = not motivated at all, 10 = extremely motivated

How often do you play games in everyday life? *

- ◯ Absolutely never
- ◯ Very rarely, only a few time per year
- ◯ A few times per month
- ◯ A few times per week
- ◯ Daily

Please include all kinds of games, but not sports. For example: boardgames, video games, mobile games, rpg, puzzles.

What type of games do you play? *

- ☐ Card games (non-computer)
- ☐ Board games (non-computer)
- ☐ Puzzles (non-computer)
- ☐ Action and adventure games (computer)
- ☐ Shooter games (computer)
- ☐ Role playing games (computer)
- ☐ Strategy and puzzle games (computer)
- ☐ Card and board games (computer)
- ☐ Other:

On average, how many minutes do you spend on games per week? *

Please write your answer here:

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
It is clear to me what I have to do in this game.	◯	◯	◯	◯	◯	◯	◯
It is clear to me how to control the game (buttons, switches, manual, etc.).	◯	◯	◯	◯	◯	◯	◯
I feel like I am in control of the game.	◯	◯	◯	◯	◯	◯	◯
The purpose of the game is clear to me.	◯	◯	◯	◯	◯	◯	◯
The tutorial provided sufficient information to play the game.	◯	◯	◯	◯	◯	◯	◯
I like the graphics of the game.	◯	◯	◯	◯	◯	◯	◯
I look forward to playing the game.	◯	◯	◯	◯	◯	◯	◯

When this gaming block was finished, how did you feel? *

- ◯ I wanted to continue playing.
- ◯ I felt neutral.
- ◯ I was relieved that I was done for now.

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I am more motivated to complete the experiment than to complete the game.	○	○	○	○	○	○	○
I look forward to playing the next mission in the game.	○	○	○	○	○	○	○
Playing the game frustrated me.	○	○	○	○	○	○	○
I believe the gameplay competes with that of commercial adventure games.	○	○	○	○	○	○	○

The Shuttle to Mars game relates to the eight ICAO core competencies for airline pilots. You have received a hand-out with these competencies and their corresponding behaviour.

The next questions focus on these competencies. Please look at the hand-out and then answer the questions.

Please indicate how important you believe each competency is in NORMAL SITUATIONS. *

	not at all important 1	2	3	somewhat important 4	5	6	very important 7
Application of Procedures	○	○	○	○	○	○	○
Communication	○	○	○	○	○	○	○
Aircraft Flight Path Management, automation	○	○	○	○	○	○	○
Aircraft Flight Path Management, manual control	○	○	○	○	○	○	○
Leadership and Teamwork	○	○	○	○	○	○	○
Problem Solving and Decision Making	○	○	○	○	○	○	○
Situation Awareness	○	○	○	○	○	○	○
Workload Management	○	○	○	○	○	○	○

Please indicate how important you believe each competency is in NON-NORMAL SITUATIONS . *

	not at all important 1	2	3	somewhat important 4	5	6	very important 7
Application of Procedures	○	○	○	○	○	○	○
Communication	○	○	○	○	○	○	○
Aircraft Flight Path Management, automation	○	○	○	○	○	○	○
Aircraft Flight Path Management, manual control	○	○	○	○	○	○	○
Leadership and Teamwork	○	○	○	○	○	○	○
Problem Solving and Decision Making	○	○	○	○	○	○	○
Situation Awareness	○	○	○	○	○	○	○
Workload Management	○	○	○	○	○	○	○

Please indicate how important you believe each competency is in EMERGENCIES. *

	not at all important 1	2	3	somewhat important 4	5	6	very important 7
Application of Procedures	○	○	○	○	○	○	○
Communication	○	○	○	○	○	○	○
Aircraft Flight Path Management, automation	○	○	○	○	○	○	○
Aircraft Flight Path Management, manual control	○	○	○	○	○	○	○
Leadership and Teamwork	○	○	○	○	○	○	○
Problem Solving and Decision Making	○	○	○	○	○	○	○
Situation Awareness	○	○	○	○	○	○	○
Workload Management	○	○	○	○	○	○	○

Please select which training method you believe best suitable to train each of the eight ICAO core competencies. *

	Book / syllabus	CBT	Full flight simulator	Lecture / presentation	PC based simulator	Serious game	Training with a coach
Application of Procedures	○	○	○	○	○	○	○
Communication	○	○	○	○	○	○	○
Aircraft Flight Path Management, automation	○	○	○	○	○	○	○
Aircraft Flight Path Management, manual control	○	○	○	○	○	○	○
Leadership and Teamwork	○	○	○	○	○	○	○
Problem Solving and Decision Making	○	○	○	○	○	○	○
Situation Awareness	○	○	○	○	○	○	○
Workload Management	○	○	○	○	○	○	○

With 'Training with a coach' we mean a group training session guided by a coach or mentor. We explicitly do not mean a flight training with an instructor.

Thank you:
Please use code 528624 to gain access to Block 1 of Shuttle to Mars.

Block 1 contains 5 missions. After the missions, there will be a questionnaire.
Please finish Block 1 and the questionnaire within one week from today.

Appendix D.2
Questionnaire 2: StM Block 1

Welcome back.
You have just played Block 1 of the Shuttle to Mars game. Please answer the questions in this questionnaire.

After completing the questionnaire, you will receive a passcode for the next block by e-mail when it is time to continue.

How many flight hours did you log during this gaming block? *
Please write your answer here:

How much time did you spend playing the Shuttle to Mars game, during this gaming block? Please estimate your StM game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour. *
Please write your answer here:

Did you play any other games (digital or analogue) during this gaming block? *
- ◯ Yes
- ◯ No

How much time did you spend playing other games (computer or analogue), during this gaming block? Please estimate your game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour. *
Please write your answer here:

What games did you play? Please name the games you have played. *
Please write your answer here:

When this gaming block was finished, how did you feel? *
- ◯ I wanted to continue playing.
- ◯ I felt neutral.
- ◯ I was relieved that I was done for now.

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	**2**	**3**	**somewhat true 4**	**5**	**6**	**very true 7**
I am more motivated to complete the experiment than to complete the game.	◯	◯	◯	◯	◯	◯	◯
I look forward to playing the next mission in the game.	◯	◯	◯	◯	◯	◯	◯
Playing the game frustrated me.	◯	◯	◯	◯	◯	◯	◯
I believe the gameplay competes with that of commercial adventure games.	◯	◯	◯	◯	◯	◯	◯

The list below consists of pairs of contrasting attributes that may apply to the Shuttle to Mars game. The circles between the attributes represent gradations between the opposites. For the assessment of the Shuttle to Mars game, please express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the game. Nevertheless, please tick a circle in every line.

Please provide your personal opinion. Do not make assumptions for the pilot community.

Please assess the Shuttle to Mars game by ticking one circle per line. *

	1	**2**	**3**	**4**	**5**	**6**	**7**	
Annoying	○	○	○	○	○	○	○	Enjoyable
Not understandable	○	○	○	○	○	○	○	Understandable
Creative	○	○	○	○	○	○	○	Dull
Easy to learn	○	○	○	○	○	○	○	Difficult to learn
Valuable	○	○	○	○	○	○	○	Inferior
Boring	○	○	○	○	○	○	○	Exciting
Not interesting	○	○	○	○	○	○	○	Interesting
Unpredictable	○	○	○	○	○	○	○	Predictable
Fast	○	○	○	○	○	○	○	Slow
Inventive	○	○	○	○	○	○	○	Conventional
Obstructive	○	○	○	○	○	○	○	Supportive
Good	○	○	○	○	○	○	○	Bad
Complicated	○	○	○	○	○	○	○	Easy
Unlikable	○	○	○	○	○	○	○	Pleasing
Usual	○	○	○	○	○	○	○	Leading edge
Unpleasant	○	○	○	○	○	○	○	Pleasant
Secure	○	○	○	○	○	○	○	Not secure
Motivating	○	○	○	○	○	○	○	Demotivating
Meets expectations	○	○	○	○	○	○	○	Does not meet expectations
Inefficient	○	○	○	○	○	○	○	Efficient
Clear	○	○	○	○	○	○	○	Confusing
Impractical	○	○	○	○	○	○	○	Practical
Organized	○	○	○	○	○	○	○	Cluttered
Attractive	○	○	○	○	○	○	○	Unattractive
Friendly	○	○	○	○	○	○	○	Unfriendly
Conservative	○	○	○	○	○	○	○	Innovative

What are your priorities in playing this game? *

- ☐ Arriving at the destination without damage
- ☐ Delivering the cargo to the destination
- ☐ Having fun playing
- ☐ Playing the game by the rules
- ☐ Reaching the destination quickly
- ☐ Other:

Please elaborate on your priorities in playing, and the reasons why you have those priorities. *
Please write your answer here:

Consider the priorities in your work, during the flight. How do they compare to your priorities in the game? *
Please write your answer here:

Thank you:

You will receive a passcode to continue to Block 2 by e-mail when it is time to continue.

Block 2 contains 4 missions. After the missions, there will be a questionnaire.
Please finish Block 2 and the questionnaire within one week from receiving the passcode.

Appendix D.3
Questionnaire 3: StM Block 2

Welcome back.
You have just finished Block 2 of the Shuttle to Mars game. Please answer the questions in this questionnaire.

After submitting the questionnaire, you will receive a passcode for the next block by e-mail when it is time to continue.

How many flight hours did you log during this gaming block? *
Please write your answer here:

How much time did you spend playing the Shuttle to Mars game, during this gaming block? Please estimate your StM game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour. *
Please write your answer here:

Did you play any other games (digital or analogue) during this gaming block? *
- ○ Yes
- ○ No

How much time did you spend playing other games (computer or analogue), during this gaming block? Please estimate your game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour. *
Please write your answer here:

What games did you play? *
Please write your answer here:

When this gaming block was finished, how did you feel? *
- ○ I wanted to continue playing.
- ○ I felt neutral.
- ○ I was relieved that I was done for now.

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I am more motivated to complete the experiment than to complete the game.	○	○	○	○	○	○	○
I look forward to playing the next mission in the game.	○	○	○	○	○	○	○
Playing the game frustrated me.	○	○	○	○	○	○	○
I believe the gameplay competes with that of commercial adventure games.	○	○	○	○	○	○	○

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I am anxious while working on this task.	○	○	○	○	○	○	○
I think that doing this task is useful for training airline pilots.	○	○	○	○	○	○	○
I think this is an important task.	○	○	○	○	○	○	○
I am satisfied with my performance at this task.	○	○	○	○	○	○	○
I would describe this task as very interesting.	○	○	○	○	○	○	○
I feel like I have to do this.	○	○	○	○	○	○	○
I feel pressured while doing this task.	○	○	○	○	○	○	○
I think this is a boring task.	○	○	○	○	○	○	○
I believe this task could be of some value to me.	○	○	○	○	○	○	○
I don't put much energy into this task.	○	○	○	○	○	○	○
I feel like it was not my own choice to do this task.	○	○	○	○	○	○	○
I put a lot of effort into this task.	○	○	○	○	○	○	○
It is important to me to do well at this task.	○	○	○	○	○	○	○
I try very hard on this task.	○	○	○	○	○	○	○
This task is fun to do.	○	○	○	○	○	○	○
This task does not hold my attention at all.	○	○	○	○	○	○	○
I am very relaxed in doing this task.	○	○	○	○	○	○	○
I think this task is quite enjoyable.	○	○	○	○	○	○	○
I do this task because I want to.	○	○	○	○	○	○	○
I don't try very hard to do well at this task.	○	○	○	○	○	○	○
As a professional I felt taken seriously.	○	○	○	○	○	○	○
I feel it is important to play this game seriously.	○	○	○	○	○	○	○
Making errors in this game should feel similar to making errors during a (simulator) training flight.	○	○	○	○	○	○	○

In the pirate encounters, what do you base your actions on?*

- ☐ My shuttle's hull integrity
- ☐ The fun I would have shooting at the pirate ship
- ☐ The amount of resources I have (cargo, fuel, ammo)
- ☐ The distance I still have to travel
- ☐ The other things that are happening
- ☐ Their demand for cargo or fuel
- ☐ Other:

Please elaborate on why you base your actions on these variables. *
Please write your answer here:

The game also has some less eventful moments. How do those moments make you feel?
For the following statements please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I got bored and did not pay as much attention anymore.	○	○	○	○	○	○	○
I got distracted and did not pay as much attention anymore.	○	○	○	○	○	○	○
I expected things to happen soon and became extra watchful.	○	○	○	○	○	○	○
It didn't change how I felt and how I played.	○	○	○	○	○	○	○

When you are flying an aircraft and not much is happening, what do you do to stay alert? *
Please write your answer here:

Thank you:

You will receive a passcode to continue to Block 3 by e-mail when it is time to continue.

Block 3 contains 4 missions. After the missions, there will be a questionnaire.
Please finish Block 3 and the questionnaire within one week from receiving the passcode.

Appendix D.4
Questionnaire 4: StM Block 3

Welcome back.
You have just finished Block 3 of the Shuttle to Mars game. This is the last gaming block of the NLR Serious Gaming experiment. Please answer the questions in this questionnaire.

After submitting the questionnaire, the researcher will contact you about the final interview.

How many flight hours did you log during this gaming block? *
Please write your answer here:

How much time did you spend playing the Shuttle to Mars game, during this gaming block? Please estimate your StM game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour.*
Please write your answer here:

Did you play any other games (digital or analogue) during this gaming block?*
- ◯ Yes
- ◯ No

How much time did you spend playing other games (computer or analogue), during this gaming block? Please estimate your game play time in hours and decimals. For example: 1.25 for 1 hour and 15 minutes. You can round up or down to quarters of an hour.*
Please write your answer here:

What games did you play?
Please write your answer here:

When this gaming block was finished, how did you feel? *
- ◯ I wanted to continue playing.
- ◯ I felt neutral.
- ◯ I was relieved that I was done for now.

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I am more motivated to complete the experiment than to complete the game.	◯	◯	◯	◯	◯	◯	◯
I look forward to playing the next mission in the game.	◯	◯	◯	◯	◯	◯	◯
Playing the game frustrated me.	◯	◯	◯	◯	◯	◯	◯
I believe the gameplay competes with that of commercial adventure games.	◯	◯	◯	◯	◯	◯	◯

Please read the following statements and answer by marking one of the numbers that best describes your experience.*

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I enjoyed playing the game.	○	○	○	○	○	○	○
I was frustrated at the end of the game.	○	○	○	○	○	○	○
I was frustrated whilst playing the game.	○	○	○	○	○	○	○
I liked the game.	○	○	○	○	○	○	○
I would play this game again.	○	○	○	○	○	○	○
I was in control of the game.	○	○	○	○	○	○	○
The controllers responded as I expected.	○	○	○	○	○	○	○
I remember the actions the controllers performed.	○	○	○	○	○	○	○
I was able to see on the screen everything I needed during the game.	○	○	○	○	○	○	○
The point of view of the game that I had spoiled my gaming.	○	○	○	○	○	○	○
I knew what I was supposed to do to win the game.	○	○	○	○	○	○	○
There was time when I was doing nothing in the game.	○	○	○	○	○	○	○
The game kept constantly motivating me to keep playing.	○	○	○	○	○	○	○
The graphics of the game were plain.	○	○	○	○	○	○	○
I do not like this type of game.	○	○	○	○	○	○	○
I like to spend a lot of time playing this game.	○	○	○	○	○	○	○
I got bored playing this time.	○	○	○	○	○	○	○
I usually do not choose this type of game.	○	○	○	○	○	○	○
I did not have a strategy to win the game.	○	○	○	○	○	○	○
I felt what was happening in the game was my own doing.	○	○	○	○	○	○	○
I challenged myself even if the game did not require it.	○	○	○	○	○	○	○
I played with my own rules.	○	○	○	○	○	○	○
I felt guilty for the actions in the game.	○	○	○	○	○	○	○
I knew how to manipulate the game to move forward.	○	○	○	○	○	○	○
The graphics were appropriate for the type of game.	○	○	○	○	○	○	○
The sound effects of the game were appropriate.	○	○	○	○	○	○	○
I did not like the music of the game.	○	○	○	○	○	○	○

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
The graphics of the game were related to the scenario.	○	○	○	○	○	○	○
The graphics and sound effects of the game were related.	○	○	○	○	○	○	○
The sound of the game affected the way I was playing.	○	○	○	○	○	○	○
The game was unfair.	○	○	○	○	○	○	○
I understood the rules of the game.	○	○	○	○	○	○	○
The game was challenging.	○	○	○	○	○	○	○
The game was difficult.	○	○	○	○	○	○	○
The scenario of the game was interesting.	○	○	○	○	○	○	○
I did not like the scenario of the game.	○	○	○	○	○	○	○
I knew all the actions that could be performed in the game.	○	○	○	○	○	○	○

For each of the following statements, please indicate how true it is for you. *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I felt like I was in control over the game.	○	○	○	○	○	○	○
The purpose of the game was clear to me.	○	○	○	○	○	○	○
I like the graphics of the game.	○	○	○	○	○	○	○
I enjoyed playing the game.	○	○	○	○	○	○	○
The assignments (missions) in the game were interesting.	○	○	○	○	○	○	○
I felt engaged in the game.	○	○	○	○	○	○	○
I would recommend the game to others.	○	○	○	○	○	○	○
I see resemblances between the game and my job as an airline pilot.	○	○	○	○	○	○	○

We have based the design of the Shuttle to Mars game on events and activities that an airline pilot may experience in their jobs.

For each of the game events in the list below, please describe what situation or task from your work you would match with it. If you are not sure, please say so and take a guess.*

Game event	Airline pilot task
Breaking down of engine and steering	____________________________
Breaking down of indicators for hull integrity, fuel and ammo	____________________________
Entering authentication calls	____________________________
Following the blue bubble line	____________________________
Hard reset procedures	____________________________
Pirate attack	____________________________
Pirate negotiation	____________________________
Red lights and pushing the button	____________________________
Space ships passing your shuttle	____________________________

Do you think you can learn something from playing the Shuttle to Mars game? *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
I can learn something from playing this game.	○	○	○	○	○	○	○

Please elaborate on your answer. For example:
- **What do you think you can learn from playing the game?**
- **How would you learn from it?**
- **Why do you think you may not be able to learn from it?***

Please write your answer here:

Do you think that playing the Shuttle to Mars game can help you do your job in the cockpit? *

	not at all true 1	2	3	somewhat true 4	5	6	very true 7
This game can help me do my job.	○	○	○	○	○	○	○

Please elaborate on your answer. For example:
- **What part of the game can help you?**
- **What can it help you with?**
- **Why do you think playing the game cannot help you do your job?***

Please write your answer here:

Thank you:
You will be contacted about the final interview.
The interview will take about 45 minutes to 1 hour.

Appendix D.5
StM semi-structured interview

Getting started

- *Thank you for participating in the experiment.*
- *Time limit for this interview is set to 1 hour*

1. Heb je bezwaar tegen een audio opname van dit interview? Als ik een letterlijk citaat uit het interview wil gebruiken, dan zal ik hiervoor nog expliciet contact met je opnemen.

A. Reaction

1. Wat vond je van de game?
2. Wat vond je van het spelen van de game?
3. Zou je het je kunnen voorstellen dat je deze game als onderdeel van je training zou spelen, met nog meer missies?
4. Denk je dat je in je werk iets aan deze game zou hebben?
5. Ben je tijdens het spelen van de game “handigheidjes” gaan gebruiken? Heb je manieren gevonden om de regels te omzeilen?

B. Learning

1. Wat heb je geleerd van het spelen van de game?
2. Denk je dat je een of meer van de ICAO core competencies hebt gebruikt om de game te kunnen spelen? Welke?
3. Denk je dat je deze competenties sterker zijn geworden door het spelen (of sterker zouden kunnen worden door meer spelen)?
4. In hoeverre zijn de competenties in de game vergelijkbaar met die in de werkelijkheid?
5. Denk je dat je daar ook buiten de game iets aan hebt?

C. Behaviour

1. Heb je gedurende je deelname aan het experiment op enig moment in de cockpit tijdens je gewone werk aan de game moeten denken?
2. Heeft het spelen van de game effect op hoe je handelt in de cockpit?
3. Denk je dat het (nog meer) effect kán hebben als je het vaker en langer zou spelen?

Conclusion

- *Summarize.*
- *Express gratitude for the cooperation.*
- *Have participants fill out form for reimbursement of (travel) expenses.*
- *If applicable, give prize.*

1. Heb jij nog vragen of opmerkingen?

Summary

Over the last decades, there has been a strong improvement in aviation safety. The downside of these improvements is that airline pilots do not gain as much experience in difficult situations anymore. In addition, pilots nowadays are often trained directly to fly commercial airliners and start working for an airline right after obtaining their licence. Pilots no longer have a career in which they successively have a number of different aviation jobs.

All in all, pilots do not have as many opportunities to develop through experience the competencies that they need in critical situations. However, competencies can also be developed through training.

This thesis investigates whether competencies can be developed through training with the use of serious games. We formulate the following problem statement.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

We address the problem statement from two different perspectives. On the one hand, we look at whether games are a suitable training method to develop competencies. On the other hand, we consider whether airline pilots will accept to be trained through games.

To answer the problem statement, we formulate three research questions. They focus on (1) the design of serious games for competency development, (2) the effect of voluntary gameplay in a serious game, and (3) airline pilots' acceptance of game-based learning as a training method.

In **Chapter 1**, we briefly describe the background of the problem, before we introduce the problem statement and the three research questions. Also, we discuss the research methods used, and give an overview of the following chapters.

Chapter 2 gives an overview of relevant literature as we discuss the five main elements of the problem statement, viz. (1) airline pilots, (2) airline pilot training, (3) critical situations, (4) competencies, and (5) game-based learning.

In **Chapter 3**, we address the first research question.

RQ 1: *How should a serious game be designed to support competency development effectively?*

To answer the research question, we first identify and discuss three requirements that a game needs to fulfil in order to support competency development. Next, we translate the four components of the Four Components for Instructional Design (4C/ID) model into six characteristics that games should have for competency development. We show that the characteristics can be supported by sixteen elements that are commonly present in games, or that can be added to the game or the environment.

We introduce the Serious Games for Competency Development (SG4CD) model, in which we connect the sixteen elements for gameplay and learning with the six characteristics for competency development. The SG4CD model shows which elements are needed to develop competencies with a serious game. Based on the model, games for competency development can be designed in a more structured way.

In **Chapter 4**, we address the second research question.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

Based on the two types of outcomes of serious games, we split RQ 2 into two subquestions.

RQ 2a: *To what extent does the voluntary play of a serious game affect the learning effect?*

RQ 2b: *To what extent does the voluntary play of a serious game affect the gameplay experience of the player?*

To answer the research question and its subquestions, we conduct an exploratory study consisting of three experiments, in which the participants voluntarily or mandatorily play the *CloudAtlas* game that was developed especially for this purpose. In the second and third experiments, the distinction between voluntary and mandatory participation in the experiment is also a factor.

The game we conduct the experiments with, does not result in a learning effect. Playing or not playing the game does not influence the test results of the participants. Consequently, RQ 2a cannot be answered conclusively.

For RQ 2b, we investigate the enjoyment of the players and how they experience the game. There are no indications that voluntary play, which is highly valued by several game-design experts, has an effect on the game experience. On the contrary, our findings show that participants with a stronger sense of obligation play the game as long, as well, and with as much fun. In all three experiments, participants who played the game mandatorily report an equal amount of enjoyment as the voluntary players. Furthermore, they do not have strong negative feelings about that obligation. They even play the game longer than the voluntary players.

In **Chapter 5**, we discuss the preparations that we have made to be able to answer the third research question.

We describe the design and development of the *Shuttle to Mars* game. The design of the game is based on the SG4CD model and supports the characteristics for competency development. We pay special attention to the design of "meaningful events" in order to be able to provide the player with authentic learning tasks.

We describe the playtest that we have performed with the first version of the *Shuttle to Mars* game. The playtest shows that the game is playable and that the players enjoy playing it. Furthermore, the players are able to see the parallels between game events and aviation situations. The outcomes of the playtest are positive and give confidence that the game can achieve a positive learning effect.

In **Chapter 6**, we answer research question 3.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

We discuss the small-scale study that we conduct with the *Shuttle to Mars* game. Five airline pilots and three instructors (who are also captains with an airline) play and assess the game. Based on the outcomes, we conclude that airline pilots are open to the innovative approach of using games as a training method for essential competencies. However, they do indicate that the version of the game that they have tested is not yet adequate. With improvements to the game and embedded in the airline pilot training, the game has the potential to provide a positive and effective learning experience.

In **Chapter 7**, we answer the research questions and the problem statement. Also, we discuss the limitations of the research and give recommendations.

The research in this thesis shows that using serious games as a training method for competency development has potential. In the first place, we have shown that a game can be used to develop competencies. A serious game can support all the characteristics needed for competency development. Secondly, we have found that airline pilots and instructors are open to using serious games as a training method. They were motivated to play the game. Finally, our research shows that playing a serious game mandatorily does not have negative effects. Therefore, a serious game may also be effective for airline pilots who are less willing to be trained through playing serious games.

Based on our findings and the estimated results of future research, we expect that game-based learning can become an effective and validated training method for aviation. Moreover, we expect it to become a standardised training method that will be part of initial and recurrent training for airline pilots. We consider game-based learning for aviation to be *cleared for take-off*.

Samenvatting

De afgelopen decennia is in de luchtvaart de veiligheid sterk toegenomen. De keerzijde hiervan is dat verkeersvliegers minder ervaring opdoen met lastige situaties. Daarbij komt dat zij tegenwoordig vaker rechtstreeks worden opgeleid tot piloot op een verkeersvliegtuig en voor een luchtvaartmaatschappij gaan werken. Piloten hebben niet langer een carrière waarin zij verschillende luchtvaartbanen hebben gehad.

Alles bij elkaar hebben piloten tegenwoordig minder gelegenheid om de competenties, die ze nodig hebben als ze toch een keer in een kritieke situatie ("critical situation") terecht komen, te ontwikkelen door het opdoen van ervaring. Echter, competenties kunnen ook worden ontwikkeld door middel van training.

Deze thesis onderzoekt of de competenties door training met behulp van serious games kunnen worden ontwikkeld. Daarbij is de volgende probleemstelling geformuleerd.

Probleemstelling: *In welke mate kan een serious game gebruikt worden om verkeersvliegers te trainen om in kritieke situaties adequaat te handelen?*

De probleemstelling kent twee verschillende invalshoeken. Enerzijds is het de vraag of serious games geschikt zijn om competenties mee te ontwikkelen. Anderzijds is het de vraag of piloten een serious game willen accepteren als leermiddel waarmee zij hun competenties kunnen ontwikkelen.

Om bovenstaande probleemstelling te beantwoorden zijn drie onderzoeksvragen geformuleerd. Deze hebben betrekking op (1) het ontwerp van een serious game voor competentie-ontwikkeling, (2) het effect van het vrijwillig spelen van een serious game, en (3) de acceptatie van een serious game als leermiddel door verkeersvliegers.

In **Hoofdstuk 1** schetsen we beknopt de achtergrond van het probleem, alvorens we de probleemstelling en de drie onderzoeksvragen introduceren. We bespreken bovendien de onderzoeksmethode en geven een kort overzicht van de volgende hoofdstukken.

In **Hoofdstuk 2** bieden we een overzicht van relevante literatuur. Voorts bespreken we de vijf elementen uit de probleemstelling, viz. (1) verkeersvliegers, (2) de vliegopleidingen, (3) kritieke situaties, (4) competenties en (5) game-based learning.

In **Hoofdstuk 3** wordt de eerste onderzoeksvraag besproken.

OV 1: *Op welke wijze moet een serious game ontworpen worden om competentie-ontwikkeling efficient te ondersteunen?*

In antwoord op de onderzoeksvraag identificeren en bespreken we allereerst drie vereisten waaraan een game moet voldoen om bij te dragen aan competentie-ontwikkeling. Vervolgens vertalen we de vier componenten van het Four Components for Instructional Design (4C/ID) model naar zes kenmerken die games dienen te bezitten voor competentie-ontwikkeling. We laten zien dat deze kenmerken kunnen worden verzorgd door zestien elementen die gewoonlijk aanwezig zijn in games of die kunnen worden toegevoegd aan de game of de omgeving.

We introduceren het Serious Games for Competency Development (SG4CD) model, waarin we de zestien game-elementen verbinden met de zes kenmerken voor competentie-ontwikkeling. Het SG4CD-model laat zien welke elementen nodig zijn om met een game competenties te ontwikkelen. Op basis van het model kunnen games voor competentie-ontwikkeling op een meer gestructureerde wijze ontworpen worden.

In **Hoofdstuk 4** wordt de tweede onderzoeksvraag besproken.

OV 2: *Wat is het effect van vrijwillig spelen op de uitkomsten van een serious game?*

Op basis van twee verschillende uitkomsten van serious games, splitsen we OV 2 in twee subvragen.

OV 2a: *In hoeverre heeft het vrijwillig spelen van een serious game effect op het leereffect?*

OV 2b: *In hoeverre heeft vrijwillig spelen van een serious game effect op de spelervaring van de speler?*

Ter beantwoording van de onderzoeksvraag worden drie experimenten besproken, waarin de deelnemers aan het experiment de speciaal voor dit doel ontwikkelde *CloudAtlas* game vrijwillig of verplicht spelen. In het tweede en derde experiment wordt ook het onderscheid tussen vrijwillig en verplicht deelnemen aan het experiment onderzocht.

De game waarmee de experimenten zijn uitgevoerd blijkt geen leereffect tot stand te brengen. Het wel of niet spelen van de game heeft geen invloed op het toetsresultaat van de deelnemers. Hierdoor is het niet mogelijk om OV 2a goed te beantwoorden.

Voor OV 2b hebben we het plezier en de beleving van de game onderzocht. We hebben geen aanwijzingen gevonden dat het vrijwillig spelen, dat door verschillende experts op het gebied van game-design zo belangrijk wordt geacht, een effect heeft op de spelbeleving. Integendeel, onze bevindingen laten zien dat deelnemers met een sterker gevoel van verplichting even lang, even goed en met evenveel plezier de game spelen. In alledrie de experimenten rapporteren deelnemers die de game verplicht moesten spelen een gelijke mate van plezier als de vrijwillige spelers. Zij hebben bovendien geen sterke negatieve gevoelens met betrekking tot die verplichting. Zij spelen de game zelfs langer dan de vrijwillige spelers.

In **Hoofdstuk 5** bespreken we de voorbereidingen die we hebben getroffen om de derde onderzoeksvraag te kunnen beantwoorden.

We beschrijven het ontwerp en de ontwikkeling van de *Shuttle to Mars* game. Het ontwerp van de game is gebaseerd op het SG5CD-model en ondersteunt de kenmerken voor competentie-ontwikkeling. We besteden speciale aandacht aan het ontwerpen van "meaningful events" om de speler authentieke leertaken aan te kunnen bieden.

We beschrijven de playtest die we uitvoeren met de eerste versie van de *Shuttle to Mars* game. De playtest laat zien dat de game speelbaar is en dat de spelers de game met plezier spelen. Bovendien zijn de spelers in staat om parallellen te trekken tussen gebeurtenissen in de game en luchtvaartsituaties. De uitkomsten van de playtest zijn positief en geven vertrouwen dat de game een positief leereffect kan bewerkstelligen.

In **Hoofdstuk 6** beantwoorden we OV 3.

OV 3: *In welke mate accepteren verkeersvliegers een spel (serious game) als leermiddel om essentiële competenties voor kritieke situaties te ontwikkelen?*

We bespreken de kleinschalige studie die we hebben uitgevoerd met de *Shuttle to Mars* game. Vijf verkeersvliegers en drie instructeurs (die tevens captain zijn bij een luchtvaartmaatschappij) hebben de game gespeeld en beoordeeld. Op basis van de resultaten mogen we concluderen dat verkeersvliegers openstaan voor de vernieuwende aanpak waarin een game als leermiddel wordt gebruikt om essentiële competenties te trainen. Zij geven echter aan dat de geteste versie van de game hier nog niet geschikt voor is. Met verbeteringen aan de game en als deze wordt ingebed in de opleidingen voor piloten heeft de game wel de potentie om een positieve en effectieve leerervaring te bieden.

In **Hoofdstuk 7** worden de onderzoeksvragen en de probleemstelling beantwoord. Daarnaast worden de beperkingen van het onderzoek besproken en aanbevelingen gedaan.

Het onderzoek dat in deze thesis wordt beschreven, laat zien dat het gebruik van serious games als leermiddel voor het trainen van competenties potentie heeft. In de eerste plaats hebben we laten zien dat een game gebruikt kan worden om competenties te ontwikkelen. Een serious game kan alle kenmerken bezitten die nodig zijn voor competentie-ontwikkeling. In de tweede plaats hebben we vastgesteld dat verkeersvliegers en instructeurs open staan voor het gebruik van serious games als leermiddel. Zij waren gemotiveerd om de game te spelen. Tenslotte laat ons onderzoek zien dat het verplicht spelen van een serious game geen nadelige gevolgen heeft. Een serious game kan dus ook effectief zijn voor piloten die minder bereidwillig zijn om te leren door middel van serious games.

Op basis van onze bevindingen en de uitkomsten van toekomstig onderzoek, verwachten wij dat game-based leren een effectieve en gevalideerde trainingsmethode kan worden voor de luchtvaart. Wij verwachten dat het op termijn een gecertificeerde trainingsmethode zal worden die deel uitmaakt van de opleiding en training van verkeersvliegers. Wat ons betreft is game-based leren voor de luchtvaart *cleared for take-off*.

Curriculum Vitae

Esther Kuindersma was born in Holten, the Netherlands, on 3 October 1977. She attended secondary school at CSG Liudger in Drachten and received her Atheneum diploma in 1995. She attended high school (senior year) in Highland, IL before starting her academic studies in 1996. In 2001, she obtained her MSc degree in Educational Science & Technology from Twente University in Enschede, the Netherlands.

With her specialisation in instructional technology, didactics and digital learning, she worked in several companies developing online training materials for almost ten years. She then became an educational project manager in non-profit organisation aiming to stimulate participation and self-development of all seniors in the digital society.

Looking for a new challenge, in 2014, Esther applied for a research position on serious gaming and didactics at the Training & Simulation department of the Netherlands Aerospace Centre (NLR) in Amsterdam, and at the Leiden Centre of Data Science (LCDS) that was hosted at the Leiden Institute for Advanced Computer Science (LIACS) of Leiden University. From 2015 to 2018, she conducted her PhD research that resulted in five publications and this thesis.

Esther lives in Almere, the Netherlands with her husband Sjoerd Huijg and their sons, Jasper (2010) and Thomas (2013). She is currently working at the Aviation Academy of the Amsterdam University of Applied Sciences, where she is project manager for the accreditation of a new professional master programme in Aviation Operations.

List of publications

The investigations performed during this PhD research resulted in the following publications.

Kuindersma, E. C., Field, J. & van der Pal, J. (2015). Game-based training for airline pilots. Paper presented at the Simulation-Based Training for the Digital Generation conference at the Royal Aeronautical Society. London, UK.

Kuindersma, E. C., van der Pal, J., van den Herik, H. J. & Plaat, A. (2015). Voluntary play in serious games. In A. De Gloria & R. C. Veltkamp (Eds.), *Games and Learning Alliance, 4th international conference* (pp. 131–140). Heidelberg, Germany: Springer.

Kuindersma, E. C., van der Pal, J., van den Herik, H.J., & Plaat, A. (2016a). Comparing voluntary and mandatory gameplay. *International Journal of Serious Games*, 3, 17.

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Kuindersma, E. C., van der Pal, J., van den Herik, H. J., & Plaat, A. (2017). Building a game to build competencies. In J. Dias, P. A. Santos & R. C. Veltkamp (Eds.), *Games and Learning Alliance, 6th international conference* (pp. 14-24). Heidelberg, Germany: Springer.

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39 Merijn Bruijnes (UT) *Believable Suspect Agents: Response and Interpersonal Style Selection for an Artificial Suspect*
40 Christian Detweiler (TUD) *Accounting for Values in Design*
41 Thomas King (TUD) *Governing Governance: A Formal Framework for Analysing Institutional Design and Enactment Governance*
42 Spyros Martzoukos (UvA) *Combinatorial and Compositional Aspects of Bilingual Aligned Corpora*
43 Saskia Koldijk (RUN) *Context-Aware Support for Stress Self-Management: From Theory to Practice*
44 Thibault Sellam (UvA) *Automatic Assistants for Database Exploration*
45 Bram van de Laar (UT) *Experiencing Brain-Computer Interface Control*
46 Jorge Gallego Perez (UT) *Robots to Make you Happy*
47 Christina Weber (UL) *Real-time foresight: Preparedness for dynamic innovation networks*
48 Tanja Buttler (TUD) *Collecting Lessons Learned*
49 Gleb Polevoy (TUD) *Participation and Interaction in Projects. A Game-Theoretic Analysis*

50 Yan Wang (UVT) *The Bridge of Dreams: Towards a Method for Operational Performance Alignment in IT-enabled Service Supply Chains*

2017

1 Jan-Jaap Oerlemans (UL) *Investigating Cybercrime*
2 Sjoerd Timmer (UU) *Designing and Understanding Forensic Bayesian Networks using Argumentation*
3 Daniël Harold Telgen (UU) *Grid Manufacturing: A Cyber-Physical Approach with Autonomous Products and Reconfigurable Manufacturing Machines*
4 Mrunal Gawade (CWI) *Multi-core Parallelism in a Column-store*
5 Mahdieh Shadi (UvA) *Collaboration Behavior*
6 Damir Vandic (EUR) *Intelligent Information Systems for Web Product Search*
7 Roel Bertens (UU) *Insight in Information: from Abstract to Anomaly*
8 Rob Konijn (VUA) *Detecting Interesting Differences: Data Mining in Health Insurance Data using Outlier Detection and Subgroup Discovery*
9 Dong Nguyen (UT) *Text as Social and Cultural Data: A Computational Perspective on Variation in Text*
10 Robby van Delden (UT) *(Steering) Interactive Play Behavior*
11 Florian Kunneman (RUN) *Modelling patterns of time and emotion in Twitter #anticipointment*
12 Sander Leemans (UT) *Robust Process Mining with Guarantees*
13 Gijs Huisman (UT) *Social Touch Technology: Extending the reach of social touch through haptic technology*
14 Shoshannah Tekofsky (UvT) *You Are Who You Play You Are: Modelling Player Traits from Video Game Behavior*
15 Peter Berck (RUN) *Memory-Based Text Correction*
16 Aleksandr Chuklin (UvA) *Understanding and Modeling Users of Modern Search Engines*
17 Daniel Dimov (UL) *Crowdsourced Online Dispute Resolution*
18 Ridho Reinanda (UVA) *Entity Associations for Search*
19 Jeroen Vuurens (TUD) *Proximity of Terms, Texts and Semantic Vectors in Information Retrieval*
20 Mohammadbashir Sedighi (TUD) *Fostering Engagement in Knowledge Sharing: The Role of Perceived Benefits, Costs and Visibility*
21 Jeroen Linssen (UT) *Meta Matters in Interactive Storytelling and Serious Gaming*A Play on Worlds
22 Sara Magliacane (VU) *Logics for causal inference under uncertainty*
23 David Graus (UVA) *Entities of Interest— Discovery in Digital Traces*
24 Chang Wang (TUD) *Use of Affordances for Efficient Robot Learning*
25 Veruska Zamborlini (VU) *Knowledge Representation for Clinical Guidelines, with applications to Multimorbidity Analysis and Literature Search*
26 Merel Jung (UT) *Socially intelligent robots that understand and respond to human touch*
27 Michiel Joosse (UT) *Investigating Positioning and Gaze Behaviors of Social Robots: People's Preferences, Perceptions and Behaviors*
28 John Klein (VU) *Architecture Practices for Complex Contexts*
29 Adel Alhuraibi (UVT) *From IT-Business Strategic Alignment to Performance: A Moderated Mediation Model of Social Innovation, and Enterprise Governance of IT*
30 Wilma Latuny (UVT) *The Power of Facial Expressions*
31 Ben Ruijl (UL) *Advances in computational methods for QFT calculations*
32 Thaer Samar (RUN) *Access to and Retrievability of Content in Web Archives*
33 Brigit van Loggem (OU) *Towards a Design Rationale for Software Documentation: A Model of Computer-Mediated Activity*
34 Maren Scheffel (OUN) *The Evaluation Framework for Learning Analytics*
35 Martine de Vos (VU) *Interpreting natural science spreadsheets*
36 Yuanhao Guo (UL) *Shape Analysis for Phenotype Characterisation from High-throughput Imaging*
37 Alejandro Montes Garcia (TUE) *WiBAF: A Within Browser Adaptation Framework that Enables Control over Privacy*
38 Alex Kayal (TUD) *Normative Social Applications*
39 Sara Ahmadi (RUN) *Exploiting properties of the human auditory system and compressive sensing methods to increase noise robustness in ASR*
40 Altaf Hussain Abro (VUA) *Steer your Mind: Computational Exploration of Human Control in Relation to Emotions, Desires and Social Support For applications in human-aware support systems"*
41 Adnan Manzoor (VUA) *Minding a Healthy Lifestyle: An Exploration of Mental Processes and a Smart Environment to Provide Support for a Healthy Lifestyle*
42 Elena Sokolova (RUN) *Causal discovery from mixed and missing data with applications on ADHD datasets*
43 Maaike de Boer (RUN) *Semantic Mapping in Video Retrieval*
44 Garm Lucassen (UU) *Understanding User Stories - Computational Linguistics in Agile Requirements Engineering*
45 Bas Testerink (UU) *Decentralized Runtime Norm Enforcement*
46 Jan Schneider (OU) *Sensor-based Learning Support*
47 Yie Yang (TUD) *Crowd Knowledge Creation Acceleration*
48 Angel Suarez (OU) *Collaborative inquiry-based learning*

2018

1 Han van der Aa (VUA) *Comparing and Aligning Process Representations*
2 Felix Mannhardt (TUE) *Multi-perspective Process Mining*
3 Steven Bosems (UT) *Causal Models For Well-Being: Knowledge Modeling, Model-Driven Development of Context-Aware Applications, and Behavior Prediction*
4 Jordan Janeiro (TUD) *Flexible Coordination Support for Diagnosis Teams in Data-Centric Engineering Tasks*
5 Hugo Huurdeman (UVA) *Supporting the Complex Dynamics of the Information Seeking Process*
6 Dan Ionita (UT) *Model-Driven Information Security Risk Assessment of Socio-Technical Systems*
7 Jieting Luo (UU) *A formal account of opportunism in multi-agent systems*
8 Rick Smetsers (RUN) *Advances in Model Learning for Software Systems*

9 Xu Xie (TUD) *Data Assimilation in Discrete Event Simulations*
10 Julienka Mollee (VUA) *Moving forward: supporting physical activity behavior change through intelligent technology*
11 Mahdi Sargolzaei (UVA) *Enabling Framework for Service-oriented Collaborative Networks*
12 Xixi Lu (TUE) *Using behavioral context in process mining*
13 Seyed Amin Tabatabaei (VUA) *Using behavioral context in process mining: Exploring the added value of computational models for increasing the use of renewable energy in the residential sector*
14 Bart Joosten (UVT) *Detecting Social Signals with Spatiotemporal Gabor Filters*
15 Naser Davarzani (UM) *Biomarker discovery in heart failure*
16 Jaebok Kim (UT) *Automatic recognition of engagement and emotion in a group of children*
17 Jianpeng Zhang (TUE) *On Graph Sample Clustering*
18 Henriette Nakad (UL) *De Notaris en Private Rechtspraak*
19 Minh Duc Pham (VUA) *Emergent relational schemas for RDF*
20 Manxia Liu (RUN) *Time and Bayesian Networks*
21 Aad Slootmaker (OUN) *EMERGO: a generic platform for authoring and playing scenario-based serious games*
22 Eric Fernandes de Mello Araujo (VUA)) *Contagious: Modeling the Spread of Behaviours, Perceptions and Emotions in Social Networks*
23 Kim Schouten (EUR) *Semantics-driven Aspect-Based Sentiment Analysis*
24 Jered Vroon (UT) *Responsive Social Positioning Behaviour for Semi-Autonomous Telepresence Robots*
25 Riste Gligorov (VUA) *Serious Games in Audio-Visual Collections*
26 Roelof Anne Jelle de Vries (UT) *Theory-Based and Tailor-Made: Motivational Messages for Behavior Change Technology*
27 Maikel Leemans (TUE) *Hierarchical Process Mining for Scalable Software Analysis*
28 Christian Willemse (UT) *Social Touch Technologies: How they feel and how they make you feel*
29 Yu Gu (UVT) *Emotion Recognition from Mandarin Speech*
30 Wouter Beek (VU) *The "K" in "semantic web" stands for "knowledge": scaling semantics to the web*

2019

1 Rob van Eijk (UL) *Comparing and Aligning Process Representations*
2 Emmanuelle Beauxis Aussalet (CWI, UU) *Statistics and Visualizations for Assessing Class Size Uncertainty*
3 Eduardo Gonzalez Lopez de Murillas (TUE) *Process Mining on Databases: Extracting Event Data from Real Life Data Sources*
4 Ridho Rahmadi (RUN) *Finding stable causal structures from clinical data*
5 Sebastiaan van Zelst (TUE) *Process Mining with Streaming Data*
6 Chris Dijkshoorn (VU) *Nichesourcing for Improving Access to Linked Cultural Heritage Datasets*
7 Soude Fazeli (TUD)
8 Frits de Nijs (TUD) *Resource-constrained Multi-agent Markov Decision Processes*
9 Fahimeh Alizadeh Moghaddam (UVA) *Self-adaptation for energy efficiency in software systems*
10 Qing Chuan Ye (EUR) *Multi-objective Optimization Methods for Allocation and Prediction*
11 Yue Zhao (TUD) *Learning Analytics Technology to Understand Learner Behavioral Engagement in MOOCs*
12 Jacqueline Heinerman (VU) *Better Together*
13 Guanliang Chen (TUD) *MOOC Analytics: Learner Modeling and Content Generation*
14 Daniel Davis (TUD) *Large-Scale Learning Analytics: Modeling Learner Behavior & Improving Learning Outcomes in Massive Open Online Courses*
15 Erwin Walraven (TUD) *Planning under Uncertainty in Constrained and Partially Observable Environments*
16 Guangming Li (TUE) *Process Mining based on Object-Centric Behavioral Constraint (OCBC) Models*
17 Ali Hurriyetoglu (RUN) *Extracting actionable information from microtexts*
18 Gerard Wagenaar (UU) *Artefacts in Agile Team Communication*
19 Vincent Koeman (TUD) *Tools for Developing Cognitive Agents*
20 Chide Groenouwe (UU) *Fostering technically augmented human collective intelligence*
21 Cong Liu (TUE) *Software Data Analytics: Architectural Model Discovery and Design Pattern Detection*
22 Martin van den Berg (VU) *Improving IT Decisions with Enterprise Architecture*
23 Qin Liu (TUD) *Intelligent Control Systems: Learning, Interpreting, Verification*
24 Anca Dimitrache (VU) *Truth in Disagreement - Crowdsourcing Labeled Data for Natural Language Processing*
25 Emiel van Miltenburg (VU) *Pragmatic factors in (automatic) image description*
26 Prince Mayurank Singh (UT) *An Integration Platform for Synchromodal Transport*
27 Alessandra Antonaci (OUNL) *The Gamification Design Process applied to (Massive) Open Online Courses*
28 Esther Kuindersma (UL) *Cleared for take-off: Game-based learning to prepare airline pilots for critical situations*