The Effects of a Customisable Pedagogical Agent in a Serious Game Teaching Art Concepts to Middle School Students

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Abstract

During this project a serious game was created, which included a pedagogical agent to teach middle schoolers about art concepts. The game is used to test if the option to customise the agent would have an effect on fun, knowledge gain, and how the player rated the agent. This game consists of five mini games and a character creator. The mini games each focused on teaching a specific art concept; perspective, image cropping, composition, genre, and colour blending. The player can customise the agent in the character creator.

The game was tested on 36 students (4th, 5th, and 6th grade - ages 10 to 13) at a Danish public school. They played the game in groups of two or three students, half the groups could customise their agent, while the other half could not. A prior and post questionnaire, the Fun Toolkit, a Godspeed Questionnaire, and video data were used for evaluation.

The result of the data showed that the 4th grade isolated had the most promising results, but with a sample size of only 12 students in the 4th grade, nothing can be finally concluded. The result did indicate increased fun, knowledge gain, and higher rating of the agent, when the players were able to customise the agent.

Preface

The full datasets are included on the accompanying DVD.

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Introduction

Serious games are a large industry, valued at 1.5 billion $ in 2010 [13]. The term was popularised by Sawyer and Rejeski in their white paper "Serious games: Improving public policy through game-based learning and simulation" [13], shortly before the release of the video game America's Army in 2002 [1]. Serious Games are defined by Zyda in 2005 as "A mental contest, played with a computer in accordance with specific rules, that uses entertainment, to further government or corporate training, education, health, public policy, and strategic communication objectives" [47]. According to Giessen there is hardly any evidence that serious games improve learning more than traditional teaching methods. However there is evidence that serious games are effective when combined with a dedicated teacher [16].

Pedagogical agents can embody different roles depending on their intended use. They have been used as guides, helpers, tutors etc. in many different contexts, a well-known example being the Microsoft Word office assistant "Clippit" [22]. These agents have to be tailor made for their role to be effective; however there is disagreement of how the agents should look, to be appealing in specific contexts. Some studies show an increase in student learning [3] and reward a more rich experience [28].

It seems there is a lack of research investigating the effects of pedagogical agents in serious games, and games in general. However there is much research into using agents in museum exhibits, primarily what can be referred to as "kiosk" agents [8, 14, 44, 25] in addition to other learning environments rather than games [3, 31, 23, 35].

Parts of the problem of serious games needing a dedicated teacher could possibly be circumvented by using pedagogical agents to supplement parts of the teacher's role, which could potentially make the use of serious games in the classroom easier.

This study aims to find out whether combining serious games and agents is feasible, from the aspect of learning and fun, and is inspired by the work of Rehm & Jensen [37].

Background

Agents

Agents are used in different ways depending on the intended use of a specific agent. They are used in a variety of different fields such as Human Computer Interaction (HCI) and Human Robot Interaction (HRI). Agents can have different roles which cater to the specific goals that the agent needs to fulfil. These roles could be; teacher, co-student, guide, or conversational partner.

In HCI most agents are made to be graphical characters that the user can interact with. These agents are usually made to look stereotypical, so that users can easily identify their role [7].

This is also the case in HRI where robots with human features, gestures, and voices, as these are getting closer to mimic human expressions. There is however the problem of the uncanny valley, were the familiarity of something artificial degrades when the human likeness lies within a specific threshold. For stationary agents/objects; a corpse or a prosthetic hand would lie within this threshold, whereas with moving objects this could be the case for robots if they are too human like. The problem with the uncanny valley is that an agent falling within the valley will be appalling to the people using it [7].

Haake et al. also mention that “even with an ingeniously designed embodied pedagogical agent from a computational perspective, an inadequate visual appearance can decrease the pedagogical benefits considerably”. Several studies have shown that a well and carefully chosen graphical appearance of an embodied pedagogical agent can increase the student's self-esteem in a specific subject as well as their knowledge level [20].

“Embodied pedagogical agents are used to add or strengthen social and communicative features in a pedagogical system” [20]. This serves by Haake et al. to inform that as a minimum an embodied pedagogical agent needs features resembling eyes and a mouth. An embodied pedagogical agent can be made from the basic constituents of: a human, an animal, a creature, an inanimate-object, a fantasy object, or a combination of these. The main idea is that the agent relies heavily on the anthropomorphic capabilities (that the agent has some form of human characteristics), and that the static and dynamic visual qualities serve to enforce the power of the anthropomorphism by mimicking human behaviour.

Physical properties

Kann et al. name a second design consideration they denote as *physical properties*, these properties include: Body type, face shape, skin colour, haircut and hair colour, and clothes and accessories. Representation of gender, age, and ethnicity can be drawn through a combination of these properties [20].

Kann et al. also state that the knowledge of different effects of these physical properties are based on studies from different fields such as psychology and behavioural science and there is a large body of experience-based knowledge from areas such as film, theatre, graphic design, and advertising. It should however be noted that every choice made regarding the physical properties of the agent will have social, cultural, psychological and affective influence. This means that it is impossible to create a “neutral” embodied pedagogical agent [20].

It would be a flaw to, in a study comparing gender, making the male agent thin and the female agent obese, or where there are any other large divide in how the agents are portrayed, as this will have a dividing effect in how these agents are perceived by the users in relation to how they are cognitively thinking about the agent's social, cultural, psychological and affective influence. Krämer et al. likewise state that every person has a specific preference, meaning that it is difficult to create an agent which fits all users [26].

Graphical style

The graphical style of an agent may have significant but unintentional and unpredictable effects on the user's experience. Therefore it is important to look into both degree of detail and degree of naturalism.

Degree of detail

Degree of detail pertains to the concepts of taking something that in real life has a high degree of detail, like the human face, and reduce this detail by e.g. changing the shades of the face to lines, so that it resembles a drawing more than a photograph. Another way is to use posterization, were the image is converted into a binary image containing only black or white pixels. In both these cases the level of detail is decreased, this “*reduction of detail promotes increased distinctiveness of the agent’s facial expressions which may support a more rapid and accurate processing interpretation.*“ [20]

Naturalism - stylization

The term naturalism covers realism but it is not necessarily photorealism, a character can be naturalistic but still be a 3d model, or a binary 2d drawing. What separates naturalistic agents from stylistic agents is that the stylised agent is usually made from a specific drawing style, and has a reduced level of detail. Both Haake et al.

and Girard & Johnson [20, 17] found indication that children prefer stylised agents over more naturalistic looking agents.

Realism

When talking about realism in embodied pedagogical agents, a realistic looking agent is not necessarily the one following the naturalistic style mentioned before; this all depends on the design of the agent. A well designed agent made in stylised 2d drawing might be thought as to look more realistic than a 3d naturalistic model that falls within the uncanny valley. An example of this is put forth by Haake et al., where another research team, Gustavson &Czarniawska [19], made an embodied conversational agent named Olga. In this case there was a disagreement between the design team and the linguistic team. Haake et al. mentioned that at the conference, were the research was presented, there was a broad consensus amongst the conference audience that this was indeed the case; that the stylised version would then be the best choice of style to use for the agent [20]. There is however no consensus amongst the field of study concerning agents that a visual realism is better. Some propose that a high degree of realism increase the involvement and sense of virtual presence of a user, while others propose that a high degree of realism help the user to get more curious about the personality of the character, which evolves the relationship between the user and the agent. On the other side it is proposed that users will easily be involved with, and project themselves easier onto, agents that are more visually simplified than an agent who is highly detailed and naturalistic [20].

Roles

Within embodied pedagogical agents Haake et al. [20] has elaborated on a list made by [10] that describes the pedagogical roles that an embodied pedagogical agent can have. These roles are divided into two categories; either being “more authoritative roles” or “less authoritative roles”. The list is as follows:

More authoritative roles:

- The tutor
- The coach
- The guide
- The instructor
- The mentor
- The expert

Less authoritative roles

- The competing co-learner
- The collaborating learning companion
- The tutee
- The peer tutor that can alternate in the role of being a tutor and tutee
- The troublemaker
- The critic
- The clone

These roles are however often diffuse and ill defined, the total authoritative presence of the roles is dependent on the culture or subculture in which it is used. Therefore it is a good idea to define the role and personality of the agent so that it fits within the context, in which it is being used. In a study by Baylor & Kim [6] they used 3 different embodied pedagogical agents with three different roles and visual appearances. The different roles where expert, mentor, and motivator, the graphical appearance of these three agents was that of a human, with clothes matching their role. The expert was made to look older and formally dressed, the motivator was young, smiling, and casually dressed, while the mentor was a middle way between the two. Their results showed that the expert led to increased information acquisition, the motivator lead to increased self-efficacy (one's own belief in one's abilities) and the mentor led to improved learning and motivation.

Visual stereotypes

Visual stereotypes and prototypes (typical exemplar) refer to the concept of trying to determine a character's personality and lifestyle from their looks, hair, clothes, gender etc. This is very prominent in video games, comics, movies, and theatre where a character has to be dispositioned quickly to the viewer/player. When discussing visual prototypes and visual stereotypes the latter is often referred to as something negative while visual prototypes are seen as something neutral.

An issue when using embodied pedagogical agents with a visual stereotype is that the users will have a prejudice to the personality of the agents before “knowing” it. This would not be an issue in a project such as [6] who found that these stereotypes can help reinforce the intended use of an agent, but this could lead to issues if used without thorough thought. As an example one could use a young teenager (dressed in street fashion) as an agent in a serious game teaching math or similar, if the agent has the role of mentor, and is teaching users of a similar age. In this case the users might feel that the agent's visual authority is too low to work as a mentor and therefore not listen or follow instruction. This however all depends on the social culture, environment, and context to what is being taught. This scenario might be entirely different if the agent taught about drawing street art (graffiti) or similar [20].

The design of a visual agent is dependent on the learning context, learning goals, and the group of learners using the agent.

Agents in museums

Agents have been widely used in museums as static museum guides. The following section will cover some examples of research of these types of agents.

Examples are Tinker [8], The COHIBIT Museum Experience [14], Ada & Grace [44], and Max [25].

Tinker [8] is an embodied virtual agent that is used at the Boston museum of science and it uses several form of relational behaviour to establish social bonds with the visitors. These behaviours are nonverbal conversational behaviour, empathy, social dialogue, reciprocal self-disclosure Tinker uses these to try and establish bonds with the visitors. Tinkers task is to draw in the visitors to the guide area, provide them with help, and give them an experience relevant to the Boston museum of science. This experience could be for “her” to explain to the visitors how “she” is made, what technologies have been used, and how they affect Tinker’s personality.

Tinker is an excellent example of an embodied virtual agent, both in the gestures that she uses as well as her ability to meaningfully interact, both verbally and by gestures, with the visitors and offer an illusion of intelligence.

At the museum tinker is visualised on a 6 foot screen, she is able to recognise different visitors using a “hand recognition unit” the visitors hand is then classified using computer vision techniques which then is used as biometric identification, this is used as identification if the visitor returns to Tinker. When Tinker asks a question the visitor is presented with several answers on a user response screen, the user can then choose between several different answers or questions.

The research conducted using Tinker examines different aspect, one being the effect of user identification. In this test the research team found no significant difference in attitude measures, “actual learning, or perceived learning, between the users who Tinker was able to identify, and the ones she could not.

They also performed a test to look at the perceived and actual learning facilitated by a relational and non-relational Tinker. Relational properties are empathy, humour, form of address etc. The relation version of Tinker had a significant increase in both perceived learning and actual learning.

Gebhard & Karsten [14] created a museum exhibit concerning cars, using two life-sized virtual characters (VC - Agents) and measured user impression and rating.

Cameras were used to detect users, while the orientation of car parts used in the exhibit were detected using RFID. The virtual characters were used as guides in relation to the task the user was performing.

The users were tasked with constructing a car model using 10 different parts, and were evaluated, looking for two different aspects of the VCs, task-oriented aspects and non-task oriented aspects.

Gebhard & Karsten were looking into 4 different categories: believability, sociability, application domain/role, and general operative system features/handling.

From their testing, they concluded that there was a need for non-task oriented aspects such as joy-of-use and entertainment for the participants to have a positive experience from the exhibit. Participants were overall satisfied with the help the exhibit gave them, while finding the lifelikeness of the VCs in general to be of average importance.

Traum et al. [44] have created a virtual guide for the Boston Museum of Science focusing on STEM and direct contact with the visitors.

The virtual guide consists of a pair of twins, Ada and Grace, which use speech recognition to understand questions and statistics to give the participants the most likely answer. It is located in a kiosk at the museum and able to answer 150 questions about the exhibits or the science behind them.

Their speech recognition had a response accuracy of 53 %. They tested interaction with the Ada and Grace and collected 225 observations, 180 interviews, and 61 questionnaires.

The median time of use was 3 minutes and 7 seconds, and on a 4 scale Likert, looking at interest, it scored a 3. It scored the same in the context of attitude towards conversation with the exhibit. 90% of participants described the exhibit as acting like a human.

Kopp et al. [25] have created an embodied conversational agent (ECA), Max, for which the aim is to be used as an educator, removing the focus from being a teacher to being a cooperative interaction partner. It used speech recognition to pick up keywords, and answered based on 608 different rules.

They wanted to test it to figure out whether it could lead a coherent conversation and found that it was able to classify the questions into one of the 608 possible 63 % of the time, which includes misclassifications.

They state that people were likely to use human like dialogue when engaging with the agent instead of viewing it as a technology.

A different type of use of an agent in a museum setting is Rehm & Jensen's paper which investigates the use of a companion agent in a museum exploration game made to be like a treasure hunt [37]. The companion agent was embodied and used verbal and nonverbal behaviours to convey information about the different artworks found at the museum. They found that using a companion agent gave better engagement and retention of detail, than a paper based treasure hunt type game. This is different from the other examples as this agent is not situated in a specific place within the museum, but instead Rehm and Jensen uses tablets so the users bring the agent with them, when they travel around the museum.

Serious Games and Game based learning

Serious games and game based learning (which are essentially the same thing in all but name, and hereby referred to only as serious games) serve many functions in entertainment, learning, health, advertising, and social change. Serious games can be used as an explicit learning device, but it can also be used in stealth learning were the players are focusing on playing the game and not the learning elements [46].

Several design guidelines and methods have been used to help design serious games and game based learning experiences, but it is difficult to create a unifying framework that brings the diverse and cross disciplinary competences, needed to develop serious games, together [46].

Brian Winn in his paper 'The Design, Play, and Experience Framework' lists evidence from 10 different research papers that show that the amount of games which have a perceptual, cognitive and social benefit is growing. Some believe that games are enjoyable because of learning; this doesn't have to be in an educational context, but could also be because of learning the mechanics, lore, etc. of a game. Well-made games are also thought to be enjoyable due to them presenting the player with challenge, support, and feedback. These experiences are similar to other "optimal" states of mind such as flow [11]. Games often follow the same structure as what can be described as "good pedagogy" which is "progressive problem solving and scaffolded learning" [46].

Serious games are best when engaging the students, and allowing them to become an active participant in their own learning/educational process. This active learning is built on the assumption that the learner is an active participant in the construction of his or her knowledge, which is what Dewey in 1916 coined as "learning by doing" [12]. This form of active learning has shown to improve student ability to recall past knowledge, improve enjoyment, and is essential for collaborative- and problem based learning [46].

Deborah Liebermann in her paper describes what can be learnt from playing interactive games [27]. Winn has then taken these and described them in a list format, it is as follows [46].

- Games provide the player with an active experience.
- Games encourage the player to learn by doing.
- Games are a social medium providing the player with human-to-human like interactions and emotional responses.
- Games are participatory by providing the player with customized feedback.

- Games are engaging. Participation makes the player pay close attention. It demands thoughtful planning and decision making. It demands learning in order to succeed (if you don't learn you can't succeed).
- Games promote behavioural learning. The game gives the player rewards for behaviour (points, power, rank, and so forth). This positive feedback in the game can encourage desired behaviours in real life.
- Game offer consequences. These are not abstract or hypothetical; they are represented in the game directly. The player plays a character and identifies with him or her. Success and failure map directly to the player's actions; one's ego and self-image are invested in the experience.
- Games provide role models for the player. The player can learn from the game characters and understand their behavioural experiences.

"*Making good games is hard, making good serious games is even harder*" [46]. Winn's reasoning behind this statement is that instead of with pure entertainment games, which mainly has to focus on the fun factor of the game, the designers of serious games have to take into account the optimal set of 'serious outcomes'. In the development of a serious game from 2005 made by Winn and colleagues (Life Preservers) they found that to make a serious game, three types of actors/developers has to be taken into account, namely academic, content experts, and game developers. The academics are interested in pedagogical-, communicational, cultural theory etc. The content expert is interested in the given subject, and its learning goals, while the game designer is focused on creating engaging and fun gameplay. In the development of Life Preservers it was found that these three fields needed to be included in a way where they were compatible and complementary [46].

Winn separates serious games into two categories these being exogenous educational games and endogenous educational games

Exogenous educational games:

Exogenous educational games often reuse successful game mechanics proven by other digital games, board games, or playground games, and then insert the learning content into the pre exiting game structure and rules found in the original games. Examples are:

Typing of the Dead [45] which based on the original House of the Dead [21] where the shooting mechanics were replaced with typing out words to shoot zombies.

Mathris [29] which is based on Tetris [42], combining Tetris with simple math.

Geography Quiz Game 3D [15], a quiz game, where the player travels around the world, answering geography questions choosing between A, B, C, and D answers.

Endogenous educational games

Endogenous educational games contain more complex learning goals, and are about teaching something different than memorisation. This is done by integrating learning content into the structure of the game. Like exogenous educational games, endogenous educational games often adopt familiar game genres, like role playing games or adventure games, the key difference between the two being that endogenous educational games is that "the game play itself informs the pedagogical theory and embodies the learning content".

Endogenous games require the players to explore the game space and use the knowledge that they have

gained to meet the challenges of the game. Endogenous games promote active problem solving and help reinforce context specific goals. This is the form of game that Winn wants to promote by using "The Heart of Serious Game Design", he states himself that endogenous games seek an idealised convergence of content, theory, and game design and that the main problem is that this is an ill specified design problem that has infinite possible solutions [46].

The Effects of Serious Games

Giessen in his review paper of serious games called "Serious Games Effects: an Overview" [16] where he critically examines research pertaining to serious games and the different possible positive and negative factors related to them. He describes that the evidence of the positive effects on learning and teaching using serious games "*remains somewhat fuzzy".* He also states that many learners seem to avoid the "learning mode" in serious games. The learners go through the learning bit fast, so that they can return to the "gaming mode".

Giessen states that it is seems to still be uncertain whether serious games has a positive improvement on learning results, based on his review he makes two assumptions [16].

1. The luditive aspect of a game might be too intense to a point that it hinders learning.
2. Serious games activate the hippocampus, and enforce successful teaching and learning.

Giessen states that all the meta-analysis research he has investigated shows that there is only meagre findings to the teaching and learning effects of serious games, some of them even state that "there is no proof whatsoever that serious games enhance teaching and learning" and others make the point "no significant advantage was found". Giessen however elaborates that this could be due to the multitude of different genres and game types. This makes it hard to compare them with each other, and because of this "every game has specific possibilities of how its effect would be" [16].

As mentioned by Winn [46], Giessen also states that the success of a serious game is very dependent on the context and the content [16]. Giessen further states that it is also dependant on the pedagogical competences of the teachers using a specific serious game in a lesson. Serious Games should not stand alone but should be included in a context with other learning assets. The activation of the learner is crucial, games which puts the learner in a passive role generally has a low effective learning.
Giessen states that most research shows that there is no difference in the learning outcomes between a serious game, and a classroom lecture [46].

Meluso et al. [32] looks at the difference in learning between single player and collaborative play using a STEM based serious game teaching about landforms and ecosystems. They found that there was no significant difference between single player and collaborative play, in relation to learning.

Thompson et al. [43] used a serious game to try and teach children (4th graders) to eat more fruit and vegetables; they found that the game increased the numbers of fruits and vegetables that the children consumed.

Muehrer et al. [33] tested a series of serious games involving plant biology, on 161 participants from the 8-10th grade. They found a statistically significant increase in knowledge, when giving the participants quizzes after one hour sessions.

Frameworks for Serious Game Design

The MDA framework

The Mechanics, Dynamics, and Aesthetics (MDA) framework depicts the design bond between the player and the designer. The designer makes the mechanics or rules of the game, which influence the player's action called dynamics, while the aesthetics are the player's emotional responses to the game.

This framework only allows the designer to have direct control over the mechanics and rules, and due to this he or she must think about what the intended emotional response should be and work out how to implement it in way, which can trigger this desired emotion. This is often reached through playtesting and balancing so the desired aesthetic is reached through an iterative process.

The MDA framework has proven to be useful but there are many things that it doesn't take into account and it has primarily been made for entertainment games.
An issue with the MDA framework is that it does not encompass the unique design challenges needed to make a serious game [46].

The DPE framework

The Design, Play, and Experience (DPE) framework is built upon the MDA framework to address the need for a framework to help in serious game design for learning. This also displays the relationship between the designer and player and it follows the same basic structure as the MDA. Instead here the designer has direct control of the design, and the first thing should be to come up with the intended learning goals. These goals can then help guide the rest of the design through an iterative process.

Due to the fact that play is a mediated experience, it is heavily influenced by the design but also greatly by the player's social, cultural, and experiential background. This means that the experience of one player can be very different from other players. To try and avoid this, as this could mean that the intended goal of the game is unachievable, the target group of the game has to be taken strongly into account throughout the whole design process [46].

The Extended DPE

The Extended DPE framework adds extra layers to the DPE framework, which elaborates on the design elements of serious games; it adds four layers to the three upper categories. These layers are labelled as follows: learning, storytelling, gameplay, and user experience [46].

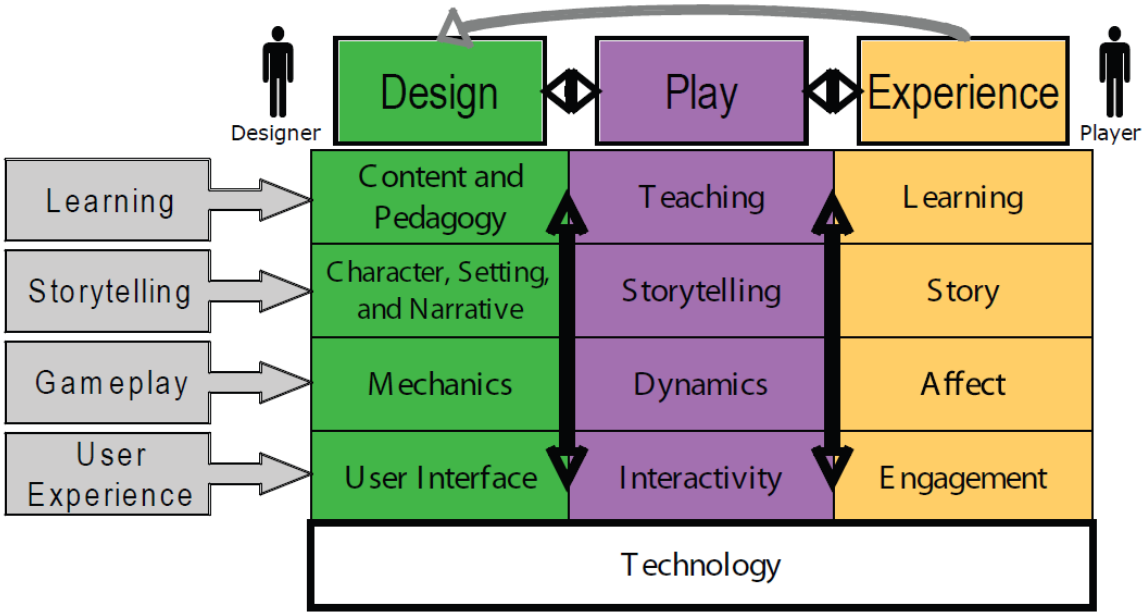

Figure 1 – The Extended DPE Framework [46], shows the layers needed for Serious Game development and corresponding layers for Design, Play, and Experience.

Experiential Learning

Experiential learning is a theory on how people learn through 4 stages; getting experiences through Concrete Experience, reflecting upon the experiences, called Reflective Observation. Those reflections are then combined into abstract concepts through a phase called Abstract Conceptualization, before lastly being testable through the phase, Active Experimentation [24]. At the same time Kolb et al. have also developed a theory of learning styles, which include a combination of these concepts, while neglecting others, these come in a simple form with two personalities types and an advanced form with 4 types. This study will only focus on the simple version, as the advanced one would require a whole other study to be taken into consideration.

The simple personality types include the watchers who prefer reflection observation, while the doers prefer active experimentation, which is closely related to the principles of “learning by doing” [12].

The Evolution of the Concept

Originally the game was intended for mediating street art in a playful manner with a pedagogical agent around the city of Aalborg. The focus shifted to mediating art at Kunsten in Aalborg, due to the estimate that it would be an easier controllable environment to test in. The means of mediating the art would still be playful interactions with a pedagogical agent as guide. The art is located closer together compared to the street art, which will make it easier for the test participants to get around, and easier for the research team to monitor and help them if there are problems.

When contacting Kunsten, they gave a positive reply to a collaboration but needed some time to make it fit in their schedule. A range of mini games were made as a proof of concept to show examples of how playful interaction could work in a museum context (see section Early Prototypes).

After a while they responded that they sadly did not have the time for a collaboration after all. Therefore the focus of the project had to change again. Going back to street art was one option, but again the distance between art works and uncontrollable environment spoke against street art. An alternative, which had been loosely discussed at an early point in the project, was testing at a school.

A small rural Danish primary school was contacted and a meeting was set up to discuss the project and matching of expectations. The focus now shifted from mediating art to teaching about art concepts. The means for mediation were kept to be playful interaction with a pedagogical agent as guide. This shift in focus meant that some of the first prototypes had to be altered to fit better for traditional teaching, while some prototypes were scrapped because they were not relevant anymore.

The teacher provided a book [30] with a list of subjects that are taught from 4th to 6th grade. This included colours, composition, genre, image cropping, and perspective. The book was the teacher's choice of teaching material, and we chose to base our mini games on the subjects of this book.

Project Proposal

As Giessen [16] stated serious games are dependable on the pedagogical competences of the teachers using serious games in lessons. In the ideal circumstances the agents should act as a teacher, removing the need and the problem for some serious games, which is that the teacher has to be very involved for them to be successful. (which some could be imagined to be reluctant to be due to more preparation work). However, how this agent should be implemented according to pedagogical agent [20] and serious game [46] guidelines needs to be investigated. Due to the various aspects needed in agent creation, and their potential effect on the agent's effect on the users, we propose that having the users be able to customize their own agent, will cause them to make an agent that fits their needs.

Problem statement: There is a lack of research looking into the effects of both customizable agents and the benefits of agents in serious games.

We aim to clarify the following:

- Would there be a difference in learning between a game which utilises a customisable agent, in comparison to one which only has a premade agent?
- Will children find the game with the customisable agent more fun?
- Will children playing a game with a customizable agent have a more positive view of the agent?

Based on our problem statement and questions we analysed learning goals, target group, and game considerations.

Concept

The concept of the game is to teach students in 4th, 5th, and 6th grade about art analysis in a playful way, by using a pedagogical agent in a serious game. The curriculum for the three grades is the same.

Learning goals

The learning goals are made up from conversation with teacher, EMU, and the book [30] which a 4th grade teacher told us she used extensively in class and as a curriculum.

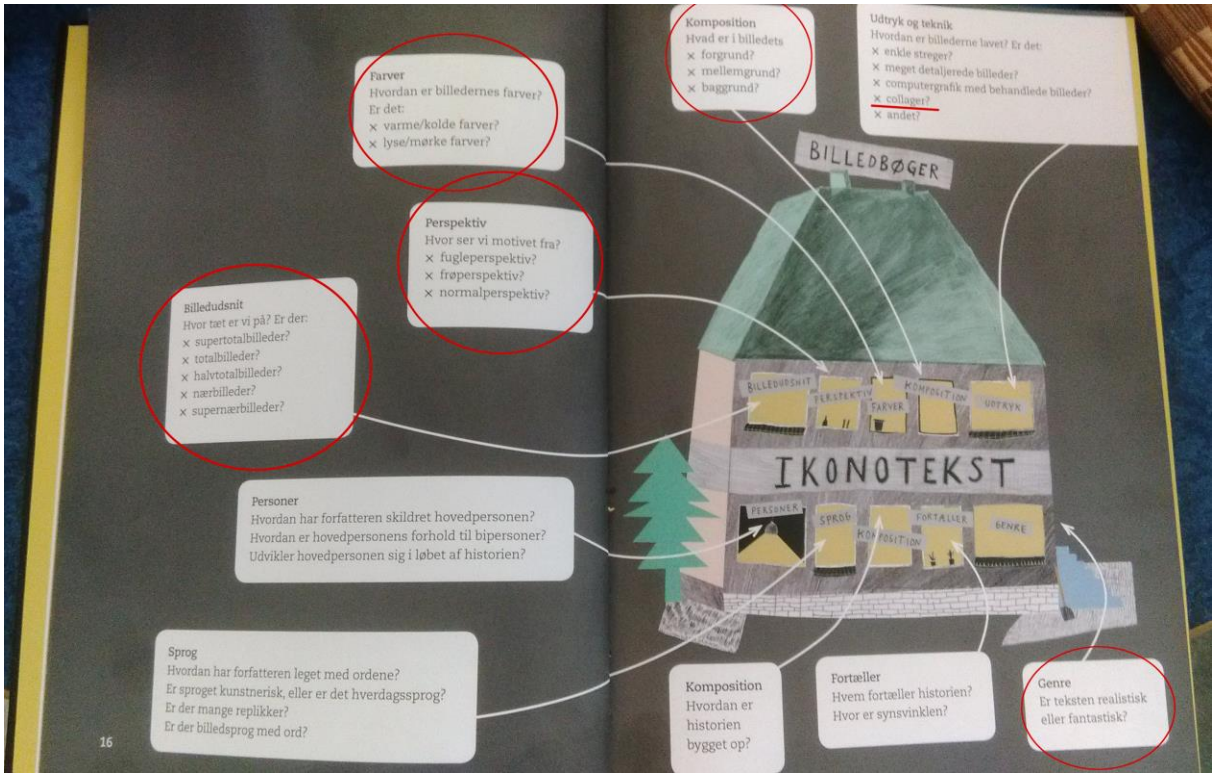

Figure 2 - The book specified by the teacher, circled in red are: Image Cropping(Billedudsnit), Perspective(Perspektiv), Colours (Farver), Komposition (Composition), and Genre. Underlined is Collage.

Colours

The learning goals for colour include; the mix of the three primary colours, Red, Yellow, and Blue (the RYB colour model), warm and cold colours, as well as the symbolical use of colour. These are separated on EMU into different tiers and levels.

We have chosen to focus on the mix of the RYB colours, as the 4th grade teacher implied that students had trouble doing this.

Composition

Composition involves the principle of depth, such as foreground, middle ground, and background. This is based on the principles stated by the book [30] and the fact that the teacher would like to have the children able to distinguish between them. The book refers to these terms as composition, which it will be called from here and forward along with depth for emphasis.

Genre

The book by Trine May [30] talks about natural vs. fantastical, which involves story genres, while EMU.dk mentions image genres. These were combined, so that the children should be able to determine whether a painting is natural, meaning featuring a realistic scenario, or fantastical involving non-realistic portrayals. These were kept simple as the 4th grade had not learned to distinguish between different period paintings yet.

Image cropping
The Danish term (billedudsnit) covers the 6 cinematographic shot sizes of extreme long shot, long shot, medium shot, medium close-up, close-up, and extreme close-up. The term image cropping is hereafter used as meaning these shot sizes, and not cropping an image.

Perspective
Perspective involves: worm (frog) perspective, normal perspective, and bird's eye view. In film and photography these terms are often used, as a way to portray a character in a specific way, elicit a specific emotion, or atmosphere.

The different learning goals chosen have a varying degree of complexity, where colour mixing and image cropping are seen as the most complex, while composition, genre, and perspective are seen as less complex and easier to understand and identify.

Target group
Due to the 4th graders being the youngest of the possible evaluation groups, it was chosen to base the learning level on the educational level of them. The gender distribution in the different classes are mostly 50-50, therefore the game and agent should be made to be as neutral as possible. While Haake et al. states that creating a neutral agent is impossible [20], we will still try not to include anything that can be seen as overly boyish or girlish in the game. At the same time the students will be able to customise the agent to fit their imagination and preference.

Game Concept
The game should consist of a character creator where the player can customise their pedagogical agent. This agent will then guide the player through mini games, where they learn about image cropping, perspective, colour blending, composition, and genre. The agent will instruct the player in the tasks and options in the different mini games and character creator.

The art used in the game will, where appropriate be from Kunsten's collection. [2]

Since the agent can be created by the students themselves, to avoid hitting the uncanny valley and inspiration from Rehm & Jensen [37], we settled on an agent representing a monster in the shape of a slime seen from many RPGs [38].

Design & Implementation
The design and implementation is split into two sections. The first covering the early prototypes and process, while the second shows the final prototypes used in the game and for evaluation.

Early Prototypes

Narrative
In the beginning it was intended that a narrative should be the driving force behind the game. At this point the game was intended for street art and Kunsten. As the project changed from street art and Kunsten to be more focused at a school, the narrative part was prioritized lower than the learning goals. The reasoning behind this decision was that at Kunsten or the street art we would have to recruit volunteers to play the game. In that scenario a narrative would be a way to keep the participants interested and ensure that they would play the

game till the end. When testing students at a school they are volunteered by their teacher, and playing the game is done as a substitute to normal school work. Therefore a deeper narrative was not prioritized highly.

The narrative would have made it a treasure hunt style game. There had been a break-in in the agent's apartment and another monster had stolen all the monster parts from the wardrobe. The thief would however have dropped the parts all around different artworks on his way home. It would then be the player's mission to help the agent find all these parts again. This would give the player a reason to seek out the next artwork to find additional parts. These new parts could then be used in the wardrobe to continually customize the agent.

Interacting with the art (Vuforia)

The mini games were designed to be played in connection to certain artworks. Therefore a way was needed to check that the player was at the artwork when the game began. When the project was aimed at street art, GPS coordinates were discussed. But it was decided to use the virtual environment platform Vuforia. The Vuforia platform has an extension for Unity3d and therefore fit well with our needs. The narrative is then, that the only way the monster can look at the outside world is through the camera of the platform. So the player has to point the camera at the specific artwork to start the game.

Early in the project it was discussed if the games should be played as a layer on top of the artwork as an augmented reality game, but it was decided not to. One of the main reasons is that this would require the player to point the camera at the artwork while playing while the art is usually located at vertical surfaces. A player would have to hold the tablet up in front of them, which would be fatiguing. Therefore it was decided to use the artworks as triggers instead. When the camera saw a certain image, it would launch the corresponding mini game. After the launch the player could hold the tablet the way they found comfortable.

Colour Blending (version 1)

The gameplay of the first iteration of the colour blending game differ quite a bit from the final state of the game. In version one the player had to figure out what colour they would get, as was it an equation. So the task could be Blue + Red = ?. The player then had to turn a wheel to find the correct colour and click 'select' (Vælg).

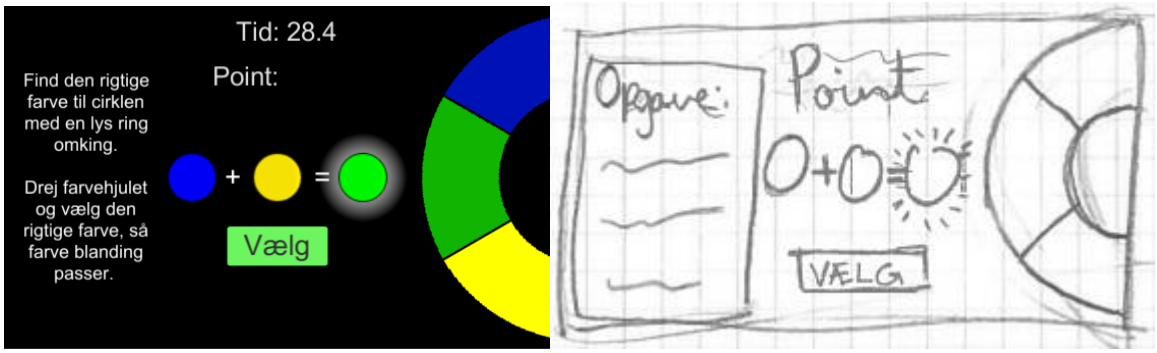

Figure 3 – The early prototype for Colour Blending and a concept drawing.

The wheel is turned by swiping your finger over it vertically. The goal in the game is to solve as many tasks as possible in 30 seconds. Each task gives one point, so the idea was to create a bit of friendly competition amongst the players.

The plan to further expand the gameplay was to make tasks where the player had to subtract colours e.g. Orange - Red = ?. This would have given another layer to the game, where players first had to check what kind of task it was, before they should start to solve it.

The game was designed so the player would not get a new task before the one at hand had been completed. This also meant that there was no penalty for selecting the wrong colour.

In the state which the prototype reached, the feedback for selecting the right colour was getting a point and a new task. There was no feedback for choosing the wrong colour. This should have been implemented if the game had been further developed.

The reason this prototype was not developed further was, that we wanted the players to have a more playful interaction with colour blending, instead of the mathematical manner of this prototype.

Snake Clone

In this early prototype the player controlled a squid around the painting. The idea was that the player plays as a squid with the camera close to the painting. This way the player only sees the details of the painting. Then you should navigate the painting to find flashing stars to eat. When eating the squid grows a little and the camera would zoom out a bit. The more it eats, the more it grows, and the more the camera will zoom out, and in the end the player would be able to see the full painting on the tablet. The idea was to make the player look at all the small details of the painting while they played as a small squid, with the possibility to look at the real painting as kind of roadmap.

The prototype was intended to promote curiosity of the details of the painting by using playful interaction.

Figure 4 – The snake clone prototype.

Looking Glass

Similar to Snake Clone, the idea was to direct the player's focus to specific objects in the painting. As a way of doing this an idea was to restrict what a player could see of a painting on the tablet, while giving them an object to look for. The restriction would be through monocular vision which is accompanied by them being able to see the actual painting in front of them on a wall and then having to compare their location on the tablet with one in real space.

Figure 5 - To the left is what the player sees in game, with the task of finding a shoe, to the right is the actual image with the shoes marked in the bottom right corner.

In the game the player is able to move the monocular view port using touch to find the object; the object could be a pair of shoes, a spider, etc. The prototype is set-up to use the above image [Figure 5] as the reference and contains 5 tasks, which switch at random. When they have located the object in the image, they are given one of the other 5 tasks.

Depth Platformer

Another way of interacting with art was to have the player experience the painting by walking around in it, using the foreground, middle ground, and background as the layers.

Figure 6 - The platformer prototype. Upper part of the image is the foreground, the bottom two are the middle ground, and the fourth is the background.

The idea was to use traditional platforming, such as jumping over obstacles and enemies, while gradually getting towards a goal at the end of the level in the upper part of the image. When walking all the way to the

left in the foreground, the character would start in the right side in the middle ground, and when walking all the way to the left in the middle ground, they would start again at the right side in the background. There was not a goal implemented, instead the player went back to the beginning in the foreground if they went all the way to the left in the background.

Jigsaw Puzzle

Another idea for interacting with art was the Jigsaw Puzzle. In [Figure 7] below, is an image of the prototype next to the actual painting. The idea was that the image was deconstructed and turned into a jigsaw, which the player was then tasked with putting together again. When one piece was placed very close to the correct position it snaps into place and another piece spawns on the right hand side. With this example they are supposed to have the original painting in front of them as a reference, as the task is otherwise close to impossible, if they haven't seen the painting before.

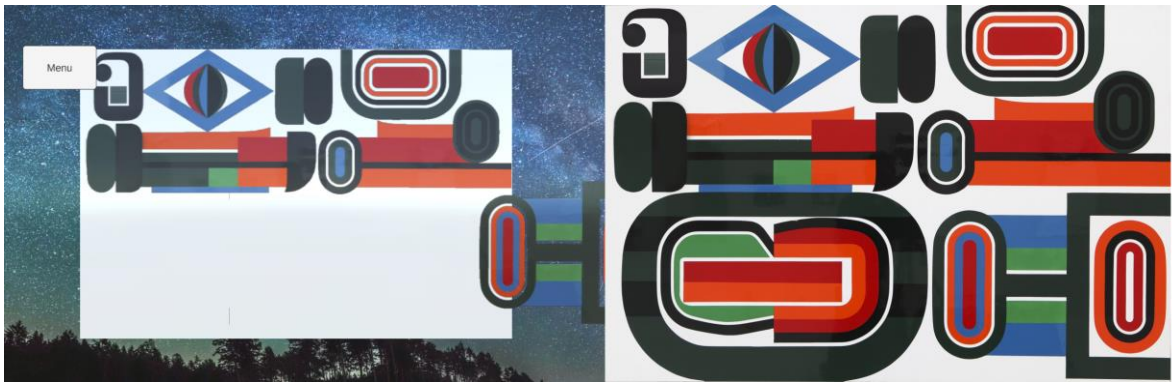

Figure 7 - To the left is an in game image of the jigsaw prototype, the new puzzle piece spawns on the right hand side. To the right is the painting it is based on.

Rollerball

The Rollerball game was created as a prototype for Kunsten. They have a painting made by Preben Hornung in 1949 called 'Fabriksbillede'. This is an abstract painting of heavy industry mostly in black and white.

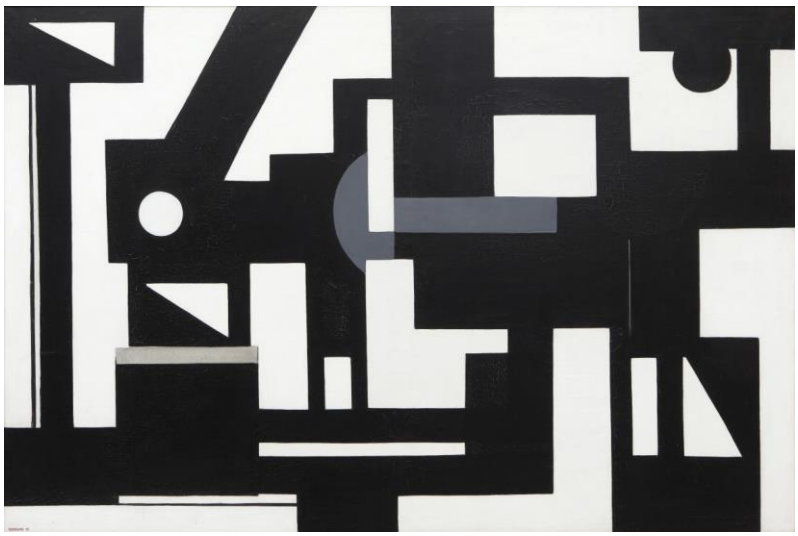

Figure 8 – The level for the Rollerball prototype.

The idea was to make the player roll a ball around the picture, but only on the black part. The painting would become a maze where the player had to navigate from one point to another. The full painting was not available on the tablet, so the player had to use the real painting as a roadmap to easier find their way.

Figure 9 – The Rollerball Prototype.

Early Character Creator

As a proof of concept, a simple version of a character creator was made, which featured different limbs, appendages, and clothes, which could be attached to the slime character (hereafter called appendages). When placed at the right position, eye in the eye region etc., they would snap in place, and when in place they could be removed and repositioned. It featured the ability to place hair, a hat, antlers, eyes, nose, mouth and shoes [see figure 10 below].

The eyes, antlers, and shoes had the ability to flip if they were placed in the opposite position so the corner of the eye would face inward, the antlers point outward and the shoes look natural.

The different appendages are cut out of images of paintings used for educational purposes from the website of KUNSTEN Museum of Modern Art [2].

Figure 10 – The early character creator. The black circles are attachment points which snap the appendages into place if they hover over the correct attachment points on the slime.

When some appendages have been placed, the lock button can be pressed, which parent the appendages to the slime and hides the attachment points. A button can then be pressed, which plays a simple animation on the slime.

A 3D version of the slime was also attempted; however as soon as limbs were attached it reached the uncanny valley. This did not happen for a 2D version as easily, and therefore a 2D version was chosen.

Final Prototype

Vuforia

The Vuforia implementation uses the back camera on the tablet to recognise 5 different images, to which each has a game attached. When the Unity3d level with the Vuforia implementation is launched, the regular viewfinder from the tablet camera is shown. The player then has to locate one of the images [Figure 11 below], point the camera at it, which then launches the game.

Figure 11 - : The 5 images used for launching games through Vuforia.

Character Creator

For the character creator, it was important to create a simple interaction. The player was given the option of 36 different appendages to customise their character with, so it was important that they were represented in an, if not intuitive, then relatable way. Therefore the design was inspired by the Sims 3 (Maxis Software, 2009), which uses a system of scroll menus, which appear to the right of a number of category buttons, which switch the scroll menu to a different category.

Figure 12 - The Sims 3. Notice the category buttons to the left and the scroll menu to the right.

Character, Narrative & Setting

The setting for the character creator is in the character's dressing room accessed by pressing the door on the right side of the living room.

The living room consists of a rectangular room seen at an angle, in which some elements of paintings have been inserted to fit with the collage art style.

When the game is started, and the CC (character creator) option is selected, the character tells the player that they should head into the dressing room, so it can be dressed for the occasion. If the NCC (no character creator) version is chosen, the character tells the player that they should get going by pressing the left door, which leads to the Vuforia camera.

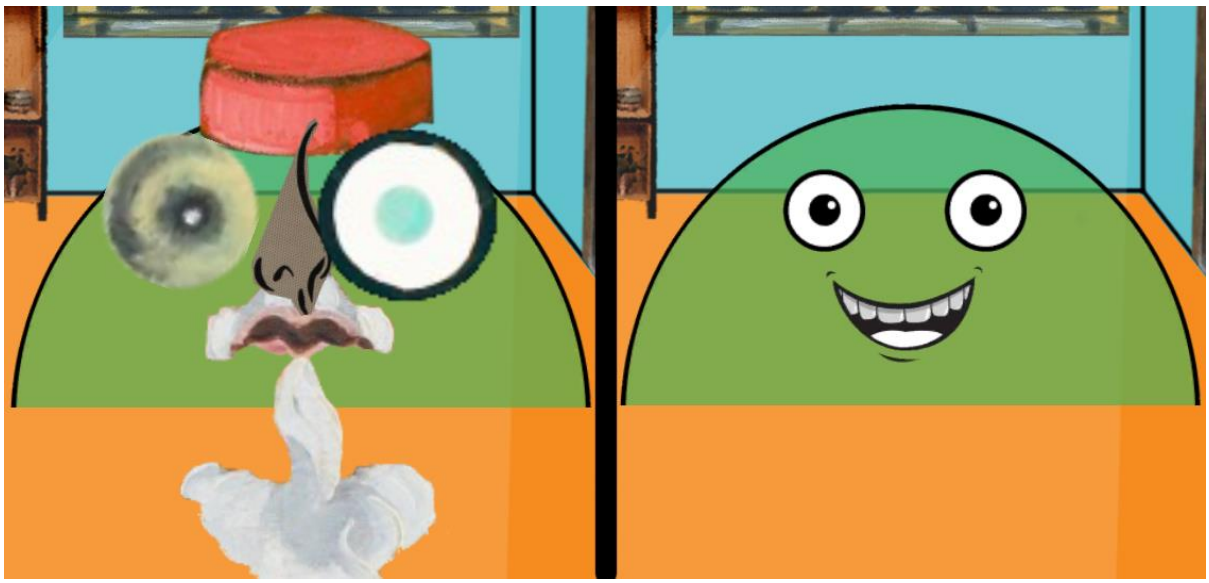

Figure 13 – The characters. The customised agent on the left, the premade agent on the right.

The appearance of the premade agent was made from the principle of looking genderless and happy. Therefore it was given a large smiling mouth and some gender neutral eyes.

The voice of both agents is male which shouldn't make much of a difference, as the gender of the agent does not affect learning according to [23].

However, [34] states that students, when given the option, will pick an agent matching their age and gender, for which having an additional female voice would have been useful for both the premade genderless agent and the customisable agent.

User Interface

For the improved character creator, appendages have been added in menus, which allow many more options for the different types of appendage. Below is a table showing the amounts of each appendage type [Table 1].

These cover the categories of face shape, haircut and hair colour, and accessories from the list of physical properties [20]. Skin colour was briefly introduced, created from sections of different paintings, but they resulted in a loss of detail, when adding other elements from similar paintings on top.

Table of Appendages

Hair	Eyes	Noses	Mouths	Shoes
10	10	7	7	2

Table 1 - Character creator appendages. The different amounts of appendages for each category.

To access the appendages, a menu consisting of six buttons was added, which in turn open a scroll menu with the different appendages [see Figure 14 below]. When one of the buttons in the scroll menu is pressed, the appendage spawns to the right of the menu and can then be dragged into place. To give the player more freedom the attachment system was changed, to enable each appendage to be placed in any of the available positions without restrictions, so if they wanted a mouth for an eye, they were able to.

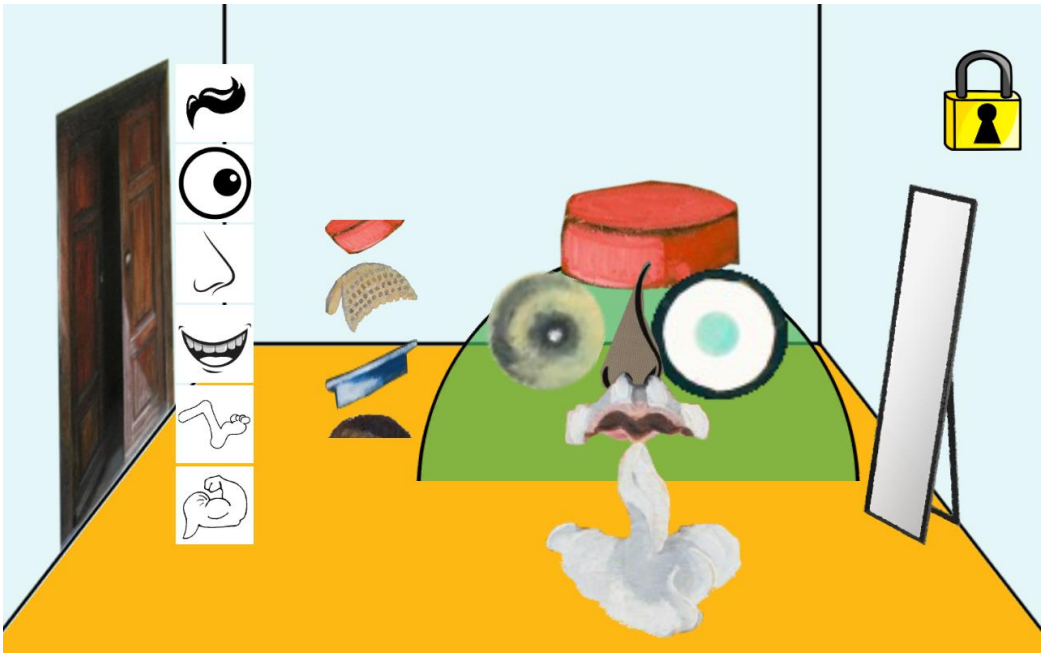

Figure 14 - The character creator. On the left is a button for each appendage type, which opens a scroll menu. To the right is a dressed up slime. The arms were not implemented.

Colour Blending (version 2)

Content & Pedagogy

The final version of the colour blending game was intended to have a playful manner of colour blending. Players have three tubes with the colours red, yellow, and blue. The player can blend the colours as they please and play around with different combinations.

The goal with the game is to make the players engage in a rich conversation about colour combinations and thereby learn from this experience. This serves the purpose of trying to cater to both learning styles, letting the doers perform active experimentation to learn about the colours, while the watchers can discuss and reflect upon it with each other.

Character, Narrative & Setting

Originally it was the idea that a monster dressed as a stereotypical French painter with a French accent and a beret would help you blend colours and apply them to a colourless painting. In the initial sketches of the game [Figure 15] the agent, the palette and the painting were of equal size.

Figure 15 – The sketches for Colour Blending Version 2.

This was changed during the implementation to make the interaction with palette and painting easier. The French painter was not implemented since the player's own agent should be in focus.

Mechanics

The initial idea was that players had to interact with the palette to blend the colours, but during the implementation it was decided that using the paint tubes as sliders would serve as a good analogy to pressing paint out of real paint tubes.

The palette has a drop of paint in the middle of it. This is white to begin with, but will change depending on what colour you blend. Around the middle are three additional drops of paint; red, yellow, and blue. The drops change in size dependent of how much of the given colour is in the blend. Is there e.g. no blue in the blend, then the blue drop will be completely gone.

User Interface

The three tubes with paint work as sliders that control how much the player wants of each colour. The blended colour will be applied to a segment of the painting by tapping the desired segment.

Implementation

The colourless painting was extracted from the very colourful piece of street art by Okudo and Antonyo in Aalborg figure (Okudo og Antonyo - WEAART 2015). The face in the painting was segmented into fewer segments than that on the original to make it easier to tap the intended segment.

The Unity3d game engine used for the development uses the RGB colour scale. The RGB scale is an additive colour scale that uses red, green and blue to make up every colour there is. Adding none of the three to the

blend will give black, and adding 100% of each will yield white. The scale is based on the human perception of light. No light will give a black colour, while light with every colour in it will be perceived as white.

That is not how colour blending is taught in the field of art however. Here the colour scale is RYB as in red, yellow, and blue. None of the colours gives you a white, while all the colours together make it black. This is a subtractive colour scale, and Unity3d does not support it. Therefore a method had to the found for converting RYB to RGB.

Gossett & Chen has found a way to convert from RYB to RGB by making a trilinear interpolation [18]. This was implemented with the help of [22]. The idea is to make a RYB interpolation cube.

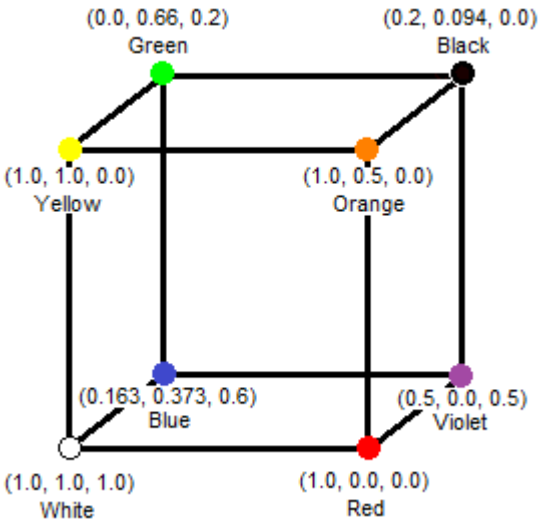

Figure 16 – RYB colour cube, based on [18].

Each corner has a colour and the RGB coordinates for that colour. When blending a new RYB colour, you get a set of RYB coordinates. From these, and with the interpolation cube, it is possible to find the RGB coordinates of the colour, so it can be represented in Unity3d.

Image Cropping

Content & Pedagogy

The image cropping game is based around taking images at different zoom levels: extreme longshot, longshot, medium shot, close-up, and extreme close-up. The aim is that after trying it, the player will have a better understanding of what the difference is between the shot types.

The game starts with a tutorial going through each zoom level from extreme longshot to extreme close-up, telling the player what they are often used for and showing an example image. They are then provided audio feedback if they are not close enough to the right shot.

This serves the purpose of giving lengthy tutorial for the watchers to reflect upon, while the doers are given feedback, when they are experimenting.

Character, Narrative & Setting

The backdrop for the game is the painting Maria Salver Kristi Fødder (Maria Salves the Feet of Christ), and the Slime wants the player to help it take pictures of the some of the different characters in the painting at different zoom levels. The player is put into the shoes of a photographer taking pictures of the scene.

Mechanics

The player is given a task, such as take a picture of Jesus in a close-up. The player then moves and zooms to where they think it is and press the shutter button. If they are not in the correct position, they are told whether to zoom closer, zoom further away, up, down, left, and right in that order.

User Interface

The user interface consists of the back of a DSLR camera, where they see through the back LCD display [see Figure 17 below]. To make sure that there was no confusion, all buttons were removed except the record button, which in this case serves as the button for taking pictures.

There is of course the concern that some children have never seen a DSLR camera before and are confused with the task. However, creating an interface similar to a tablet camera could be equally confusing as they already had the actual camera on the tablet working while using the Vuforia camera. Therefore it was thought that it would be simpler if the interface stood out.

To move the image around one simply moves the image with a finger, and zooming uses a pinch zoom system. This was felt to be the type of interaction children would be familiar with when working with images.

Figure 17 - The Image Cropping Game. The red button in the corner takes a picture, while the display allows moving the image around and zooming using pinch.

Perspective Game

Content & Pedagogy

The goal of this mini game was to tell the players about the different perspectives that can be used in pictures. The agent tells the player about perspective, and the goal is making the players engage in conversation about the subject.

The perspective game relates more to the watcher personality, showing the different types of perspective, while telling the player what they mean.

Character, Narrative & Setting

When the game starts the agent tells the player that the game is about perspective and that he/she can click the bird, the person, and the frog.

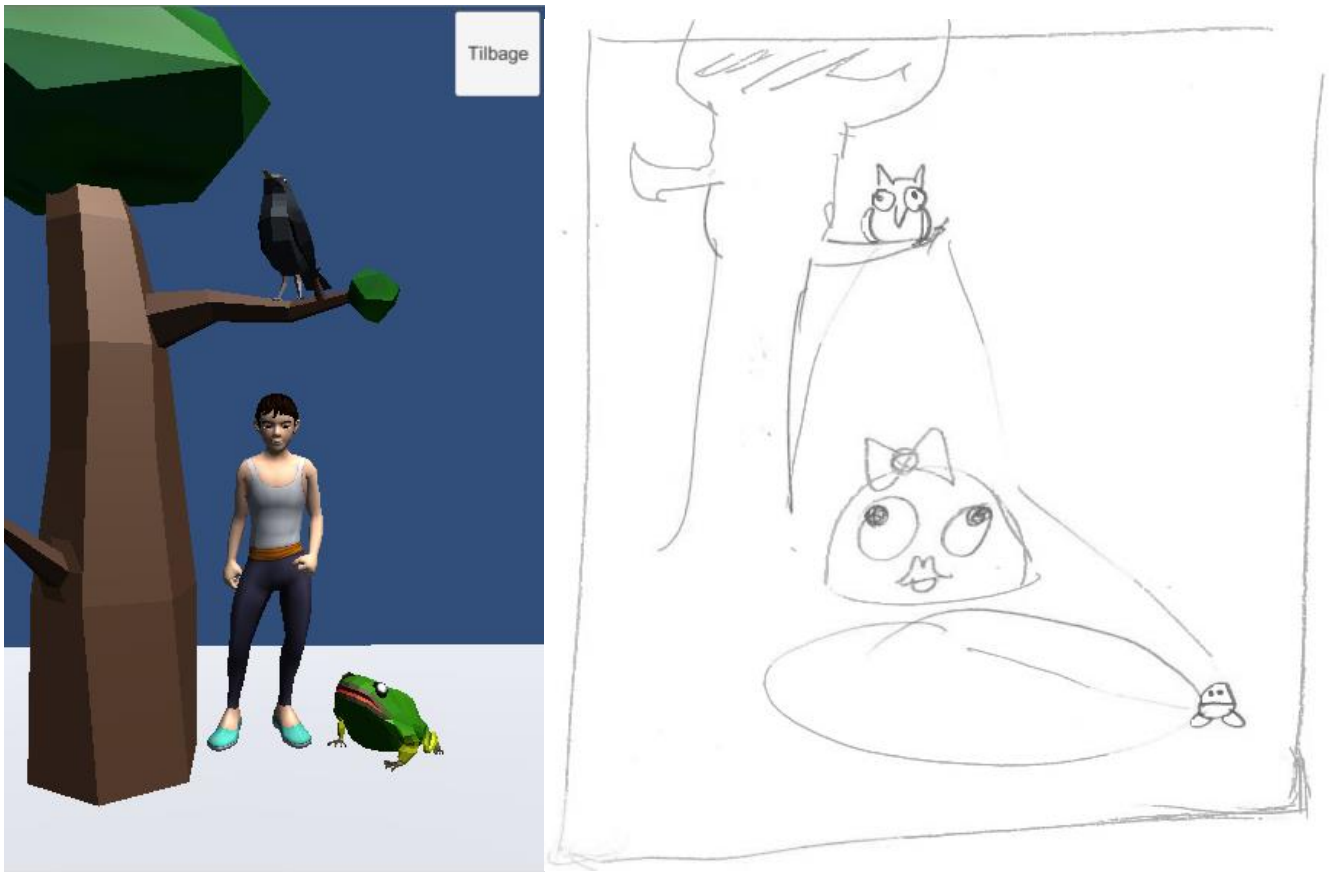

Figure 18 – The starting scene for the perspective game, and a concept drawing of the original idea.

In the Danish school system worm's eye view is called frog perspective, and therefore frog will be used throughout this project.

The perspective game was sketched out as a simple 3d environment where the player could switch between bird view, normal view, and frog view [Figure 18]. Initially it was intended to use a female monster for the normal perspective, but during implementation it was decided to use a human character instead. This was done because of the fear that the monster would confuse the players in this context. Since the monsters are fictive characters it could be hard to relate to their height. The players would perhaps be able to judge its height when it was next to the frog and bird. But at the same time the frog and the bird were enlarged, so they were easier to see and click. Therefore the monster was replaced with a human.

Mechanics

When the player clicks either the frog or the bird, the camera moves to their position and looks up or down at the human. When the human is clicked the camera moves up in front of him and looks him in the eyes to show normal perspective. At each of the three perspectives the agents tells a bit about the specific perspective. There is a back button in the top right corner at all times so the player can back out from any of the perspectives and see the full scene again. When the player has seen all three perspectives the game is over.

Implementation

All 3d models are made especially for the game except for the human model, which were downloaded from Unity3d's asset store. The scene was kept simple to avoid confusion about which objects were clickable.

Composition

Content

Composition is related to the concept of depth in a 2d image. The depth in an image is made up of foreground, middle ground, and background. The learning goal for the children is to be able to differentiate between these three. They do not need to be able to attribute them to any symbolic meaning.

The content learning is rooted in a painting which has a good representation of perspective and horizontal points.

This image was chosen as it is relatively easy to define the fore-, middle-, and background and it was thought that it was a much better representation than the image used in the earlier prototype[see Early Prototypes: Depth Platformer].

Pedagogy

In this game the pedagogical agent has the role of a collaborating learning companion. He and the animals appearing in this mini game are the ones who reinstate the concept of fore-, middle, and background. The idea is that the students will get a better understanding of depth when they have to move the agent between the three; this approach is grounded in experiential learning.

Character

The character is made up of the slime agent, who is also the one that the player controls, the character is friendly and inquisitive.

Narrative & setting

The narrative of this scene plays out on Svend Svinebugs farm. Svend is a pig who runs a farm. Living with him, is a Cow, Bull, and a Dog. The player and the agent is exploring the farm, and conversing with the animals.

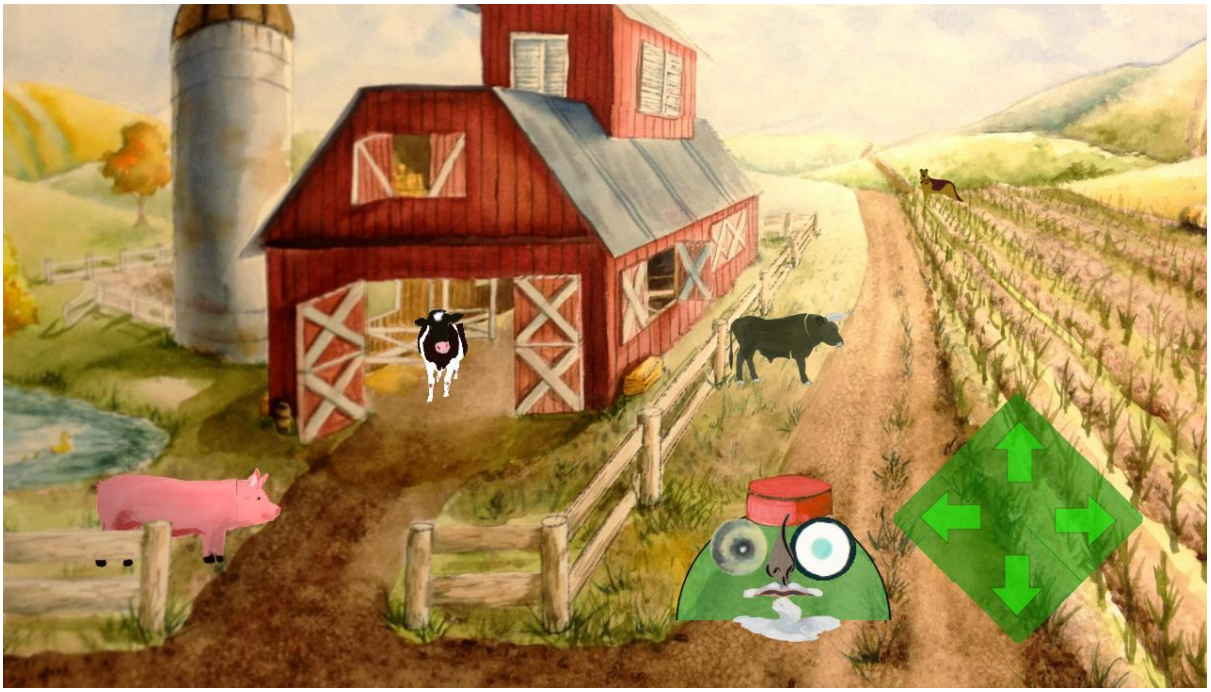

Figure 19 – A screenshot showing the composition game, the animals are standing at different depths

The animals' personalities are based on their names and species.

Svend the Swine: He is a bit of a braggart, who likes to boss around with the other animals on the farm. He sees himself as an exemplary animal and thinks he is the funniest pig in the world.

Maren the Cow: She is a friendly individual who is always helpful; she dislikes the way Svend is bossing all the other animals around.

Torben the Bull: Torben is angry, he runs back and between the barn and the edge of the field.

Henning the Dog: He is stuck at the end of the road, and all he really wants is to run back and forth, but alas, Torben is in the way.

Mechanics

The mechanics follows that of an exploration/adventure game, where the player has to go to and "investigate" different locations in the level. When the player enters one of the proximity of the animals they will instigate a conversation. The conversations pertains to the area of the image the animal is standing in, be it the foreground, middle ground, or background.

User interface

The user interface consists of 4 buttons that allows for movement in the left, right, up, and down directions. These buttons have the same colour to portray that these are the ones used to move him.

Implementation

The world is made by combining an orthographic camera (2D) with a 3D world. This is done to achieve the effect of being able to travel in all three directions.

The 3D world consists of colliders that inhibits the movement of the agent, and is made to fit the positions of the structures and animals in the scene seen from the perspective of the orthographic camera.

Figure 20 – A look into how the mini game was implemented in unity3d.

This gave the scene the feel of the things being further apart the father in the background they were.

The animals are drawn by hand and are in the scene to help guide the player, serve as pointers to where to go. The speech of the animals is written to be humorous and informative.

Natural vs. Fantastical

Content

Natural vs. Fantastical is related to the learning goals of knowing about different genres. The goal is that the students learns to differentiate between naturalistic (images that could be found in the real world, it is not dependent on painting style), and paintings made in a fantastical style containing imaginary images.

Pedagogy

The natural vs. fantastical game caters to the doer types, giving a short introduction and letting them quickly sort between the two genres.

Mechanics

The game is based on a shooting gallery, where the player has to “shoot” the images that have a different “genre” than the background. If the background is fantastical they have to shoot the images that are natural.

Implementation

In the game the images the players have to “shoot” appear out from the background. After the images appear they are stationary for a few seconds, the player will need to use this time to classify the images in relation to the background images.

Figure 21 - an example of a scene from the natural vs fantastical mini game, the goal is to shoot the images that don’t fit the background.

For each background there are four target images that have to be shot, and when these are either shot, or they have disappeared if the player was too slow, the game will go to the next background image.

Experiment

Design

The test is designed to answer the three different hypotheses in addition to providing ample information to identify faults and needed improvements for the prototype for further development. The main part of the test follows a quasi-experimental pre-test/post-test / control group design with the participants being assigned into groups depending on gender and social relations. This was done due to some students who were not willing to be grouped with some of the other students. These groups were then randomly assigned to either the treatment group or control group. The groups were made so the participants were either given a version of the game with the ability to create their own pedagogical agent or a version with a default agent, which is used as the control group.

Hypotheses

H1.1 The participants' knowledge about the learning objectives will increase after using the serious game.

H1.2 The participants in the CC group will have a higher post knowledge score increase than the NCC group.

H2.1 The participants will find the serious game more fun than a standard treasure hunt.

H2.2 The participants in the CC group will give the serious game a higher rating than the NCC group.

H3 The participants in the CC group will rate the agent higher on the Godspeed questionnaire, than the NCC group.

For H1, the knowledge is assessed as a pre-test post-test, where the participants have to fill out a pre and post-test knowledge questionnaire pertaining to the learning goals.

The H2 is assessed using the Smileyometer and Again Again table from the Fun Toolkit, these measurements will be given to the participants post activity.

H3 will be assessed through a post activity Godspeed questionnaire.

Participants

36 participants participated in the experiment, all of whom were from the same primary school but 3 different grades. The participants from each grade were as follows: 12 students (7 male, 5 female) from the 4th grade, 13 students (5 male, 8 female) from the 5th grade, and 11 students (5 male, 6 female) from the 6th grade. They were all given a consent form before testing, stating that they could be recorded during the test with the restriction of blurring faces if any part of recording was used in scientific publications and that the participants would remain anonymous. The age rage of the participants was 10 - 13 with the mean being 11.72 with a standard deviation of 0.91.

The students were separated into groups of 2 to 3 people. 3 people per group were preferred, but given the amount of students in the different grades this was not possible in 5th and 6th grade. For each grade the group compositions were as follows: 4th grade had four groups with three participants each. 5th grade had three groups with three participants and two groups with two participants. 6th had three groups with three participants and one group with two participants.

Apparatus

The prototype versions, which are described in section [Final Prototype] were played on Lenovo TAB 2 A10-30, 1280*800 resolution tablets of which five were available.

The Pre and Post Knowledge Questionnaire

The knowledge questionnaire consisted of multiple choice tasks for each of the five kinds of assignments. This section will go through one assignment from each category, and the full questionnaire can be found in the appendix.

Forgrund ☐ Mellemgrund ☐
Baggrund ☐

Figure 22

In the composition tasks a red line marks an area of the image. The student then has to tick either fore-, middle-, or background as the right answer. There are four tasks of this kind in the questionnaire.

Figure 23

The next category is image cropping. There are six of this type of task and each has six options. extreme longshot, longshot, medium shot, medium close-up, close-up, and extreme close-up. Since the nature is this task is a bit more a matter of judgement than the others, it was chosen that half a point would be awarded for choosing the answer next to the correct answer.

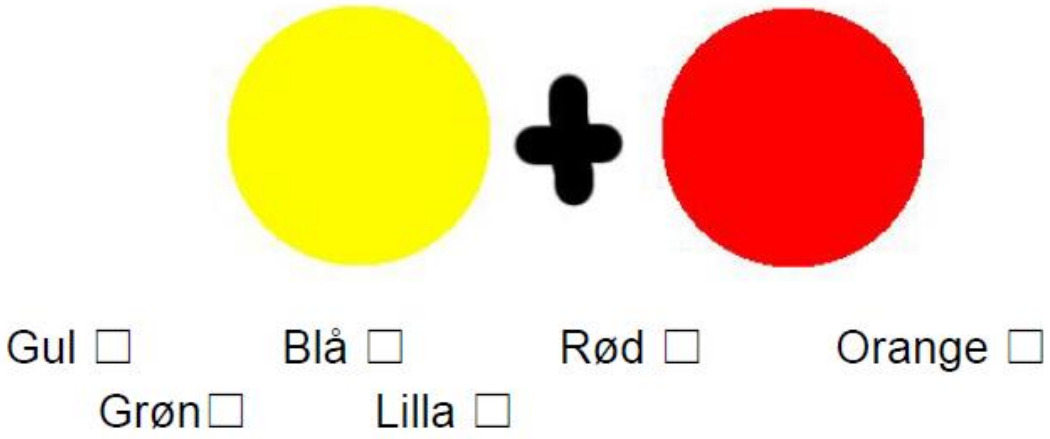

Figure 24

In the colour blending tasks the students had to add two colours together or subtract them. There were five blending tasks, three of which were addition tasks, and the remaining two were subtraction tasks.

Fugleperspektiv ☐ Frøperspektiv ☐
Normalperspektiv ☐

Figure 25

For the perspective tasks the students had to state if an image was in bird-, normal-, or frog perspective. There were six tasks of this type in the questionnaire.

Fantasifuldt ☐ Naturligt ☐

Figure 26

The final type of task was genre. Here the students had to state if the given image was natural or fantasy. Six tasks of this type were included in the questionnaire.

Fun Toolkit

Traditional evaluation methods that are used to evaluate on adults, can be ineffective when used as a means to evaluate on children. When children are used as a means of evaluation on an experiment or a usability test, adaptations have to be made to traditional methods, because of parameters, which adults are able to look through or disregard. The parameters could, due to the cognitive difference between children and adults, mean that the gathered data is biased and showing wrong correlations etc. As an example the behaviour of the evaluator may have a significant impact on the children's performance [40]. However research shows that verbalisation techniques such as think aloud and observational methods have validity in providing reliable unbiased data when used on children. An issue with verbalisation techniques, at least when children have to articulate their opinions in use, relies heavily on their ability to concentrate on both things. On the other hand, observational methods rely on the children's ability to express their opinions both orally and through body language [36]. These observational methods also place great demands on the researcher/data analyst who is interpreting the signs and comments and makes some effort at formalising the data in a meaningful way.

A method that is different from the before mentioned verbalisation- and observational methods is a method where the researchers ask the children about their opinion on different relevant subjects concerning the technology or similar, which is called questioning. Questioning can take different forms but the two most common forms of surveys are questionnaires and interviews. These forms are proved to be applicable on adults, but research that examines the validity and reliability, on this form of data gathered from children, is rare [36, 40].

Evaluation methods for children

Methods used for evaluating user experience on children include Problem Identification Picture Cards, Fun Toolkit, Laddering, and This and That. All these methods have been tested and validated on children [40].

The fun toolkit is comprised of a number of techniques aimed at gathering information from the participants. These techniques are named, the Smileyometer, the Fun Sorter, and the Again Again Table [36].

Smileyometer

The Smileyometer is a visual analogue scale with smiley faces representing a five point Likert scale which goes from awful - brilliant. It is usually given before and after the children interact with the technology being tested, the reason for this is to use the test before the activity to measure expectation, and use that as a reference point. The Smileyometer has been widely applied in research to measure satisfaction and fun and it is easy for the children to understand and complete, plus it does not require the children to express themselves in sentences.

The key attribute of the Smileyometer is that it is easy and quick to complete, requires limited reading ability, and requires no writing.

Similar techniques have been used in different settings, an example is in the medicinal industry where a meter with pain faces is used to evaluate on postoperative pain [36, 40].

Fun Sorter

The fun sorter is used to help the children rate a technology using two categories; one in which they select the most fun technology, and one in which they select the easiest to play. This is a good way to test usability of different inputs, the efficiency of output, graphical look etc. The fun sorter has to be interpreted by the children and they have to write a description of the technology. This can be difficult for younger children. Read

describes this tool as the most cognitively challenging of the three, as the ranking and positioning according to categories can quite difficult [36, 40].

Again Again Table

The Again Again table requires the children to mark for each activity the answer to the question: would you like to play it again? Here the children have three choices to either mark, yes, maybe, or no. The Again Again table is based on the psychological assumption that we want to return to the task that we liked the most. Read states that it should be used on at least three different technologies, whereas Sim and Horton use only two to get satisfying results. Read states that the Again Again table cannot be used to provide a yes/no answer to whether, or why, the children liked the product, instead further measurement and different measures have to be used to understand this [36, 40].

The Tools Used

From the Fun Toolkit the Smileyometer and the Again Again table were used. For the purpose of having something to compare the game with, a classic treasure hunt was made. In this treasure hunt the students had to answer two questions about each of the five images that were also used as reference images for the tablet game. The questions revolved around finding objects and colours in the images. One of the problems with the Fun Toolkit is students getting over enthusiastic because they get to do something other than normal schoolwork [40]. By using the treasure hunt for comparison, it should be possible to get an indication about whether the students are over enthusiastic or not.

Spørgeskema

Køn: Pige□ eller Dreng□
Alder:_____
Gruppe nummer:_____

Hvor sjovt var det at spille tablet spillet?

Forfærdeligt | Ikke godt | Godt | Rigtig godt | Brilliant

Hvor sjov var papir skattejagten?

Forfærdeligt | Ikke godt | Godt | Rigtig godt | Brilliant

Kunne du tænke dig at prøve det igen?

	Ja	Måske	Nej
Tabletspil			
Skattejagt			

Figure 27 – The Smileyometer and the Again Again Table.

[Figure 27] shows a scaled down version of the questionnaire. The Smileyometer part asked the student if it was fun playing the game, and playing the treasure hunt. In the Again and Again table the students were asked if they wanted to play the tablet game and the treasure hunt again, with the answers yes, no, or maybe.

Evaluation of the fun toolkit

Sim and Horton [40] look into the differences into the fun toolkit and a method called This and That. Here they found that the This and That method gave more ambiguous result than the fun toolkit. They also state that the fun toolkit offers the advantage of greater flexibility for the children in their responses, as they are able to show no preference. The Smileyometer does however seem to show what Sim & Horton describe as "over enthusiasm"[40]. Their conclusion is that both methods are able to be used on children, but that there are limitations. Sim and Horton would like to have had a better method that allows the decision makers to understand the attributes associated with fun in software for children, instead of just showing a preference between one thing and another.

Godspeed

The Godspeed questionnaire is a series of questions made to evaluate robots. There are five categories with three to six questions within each and the questionnaire uses semantic differential scales. The five categories are anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety. The questionnaire was made to equip robot developers with a toolbox of measuring tools, so the human-robot interaction research would be easily comparable in the future. The questionnaire can be used as a whole or in parts. It can also be used along with other measuring methods e.g. physiological data or observing the behaviour of users.

A shortcoming of questionnaires is that they are given to participants post activity, which gives them the option of moderating their answer to a more socially acceptable one; the answer they think the research team wants to hear.

The words used as anchors in the semantic differential scale can also prove to be a problem, since a word might not mean the same to everyone [5]. The questionnaire was originally in English, but has been translated into a series of languages including Chinese, Japanese, Dutch, and Spanish, but has not yet been translated into Danish.

We estimated the words in the Godspeed questionnaires were to be too complex for the students to understand. Therefore we translated the questionnaire to Danish. This was no simple task because some of the words represent some complex concepts and had no direct translation. Even the Danish translation could still be too complex for 10 to 13 year old children to understand, and the translation had to be simplified.

Anthropomorphism		
Fake - Natural	→	Falsk - Naturlig
Machinelike - Humanlike	→	Maskineagtig - Menneskeagtig
Unconscious - Conscious	→	Ubevidst - Bevidst
Artificial - Lifelike	→	Kunstig - Levende
Moving rigidly - Moving elegantly	→	Stive bevægelser - Elegante bevægelser
Animacy		
Dead - Alive	→	Død - levende
Stagnant - Lively	→	Stillestående - Livlig
Mechanical - Organic	→	Mekanisk - Organisk
Artificial - Lifelike	→	Kunstig - Levende
Inert - Interactive	→	Inaktiv - Interaktiv
Apathetic - Responsive	→	Ligeglad - Interesseret
Likeability		
Dislike - Like	→	Synes ikke godt om - Synes godt om
Unfriendly - Friendly	→	Ikke venlig - venlig
Unkind - Kind	→	Ikke flink - flink
Unpleasant - Pleasant	→	Ubehagelig - Behagelig
Awful - Nice	→	Nederen - Nice
Perceived Intelligence		
Incompetent - Competent	→	Dårlig til ting - god til ting
Ignorant - Knowledgeable	→	Ved ikke så meget - ved meget
Irresponsible - Responsible	→	Uansvarlig - ansvarlig
Unintelligent - Intelligent	→	Ikke så klog - meget klog
Foolish - Sensible	→	Fjollet - Fornuftig
Perceived Safety		
Anxious - Relaxed	→	Nervøs - Afslappet
Calm - Agitated	→	Rolig vs Ophidset
Quiescent - Surprised	→	Fredfyldt - Overrasket

Figure 28 – The translated Godspeed questionnaire.

A good example of this simplification of the anchors is ignorant - knowledgeable. Ignorant is the same word in both English and Danish, but would be too hard for the age group to understand, and therefore it has been simplified to “Ved ikke så meget” (Does not know much). There is a risk of losing meaning in the translation and simplification, but we found it necessary in our context.

The Godspeed questionnaire was the first questionnaire given to the students after playing the game. The reason for this was that it was found to be the hardest and longest of the questionnaires, so it would be best to have the students answer it before they lost concentration.

Godspeed questionnaire was chosen to evaluate the agent although it is originally intended for robots. The main difference between robots and digital agents is embodiment. Bartneck showed in 2002 that there is no difference in the enjoyment of interactions with robots compared to digital agents. There is however, a difference in social facilitation effect, which showed itself by participants putting more effort into negotiation with the robot than they did with the digital agent. [4] But since our agent could not negotiate, the Godspeed questionnaire was found to be an acceptable test.

The full Godspeed questionnaire can be found in the appendix.

Video Recording

The participants' self-recorded video was obtained using different means, the following cameras were used:

1x GoPro Hero 3, 1x GoPro Hero 3+, 1x Jobo JIB200 HD Sports Camera, 1x ZTE Blade Vec 4g smartphone, and 1x Huawei Honor U8860 smartphone.

Every group was equipped with a camera, using prebuilt harnesses for the GoPros and the Jobo camera, while the smartphone cameras were held in place with custom made harnesses.

Treasure Hunt

The paper treasure hunt is based on the five images used as the triggers for the game. Each image is represented on the paper treasure hunt but has a red square on it obstructing a detail and the participants are questioned about what the square is hiding. The task of the participants was to find the real world painting and circle the correct answer.

Procedure

The test was conducted in four stages. The participants are given a knowledge questionnaire prior to using the game to ascertain their prior knowledge in regards to the five art and image related topics covered in the prototype. These images were placed at strategic locations around the school to ensure that participants using one mini game would not disturb participants using another mini game.

They were then split into two groups; one (if odd-numbered) assigned the version without a character creator and the others (even-numbered) given the version containing the character creator. In addition each group was equipped with a camera for recording interaction and impressions when using the serious game.

To measure fun they also went on a treasure hunt using the same images as with the serious game. This was intended to serve as a way of giving them a reference point when answering the questionnaire for the Fun Toolkit and Again Again.

After using both the prototype and undergoing the treasure hunt, the participants are given a Godspeed questionnaire related to the virtual agent in the game followed by the Fun Toolkit questionnaire combined with Again Again, and lastly a questionnaire identical to the one they were given at the start.

The 4th and 5th grade started with the treasure hunt followed by the game, while the 6th grade started with the game. This made it possible to test both the 5th and 6th grade at the same time which was necessary because of the school's limited time schedule.

Results

H1.1 The participants' knowledge about the learning objectives will increase after using the serious game.

Examining the combined responses from both the prior and post knowledge questionnaires [Figure 29 - below] show that the distribution of correct answers from all participants in the post are mostly between 20-28, while the distribution of correct answers in the prior knowledge test are more evenly distributed in comparison to the post.

For the prior knowledge, the mean correct answers went from 19.94 to 20.86, while the standard deviation increased from 3.98 to 4.05.

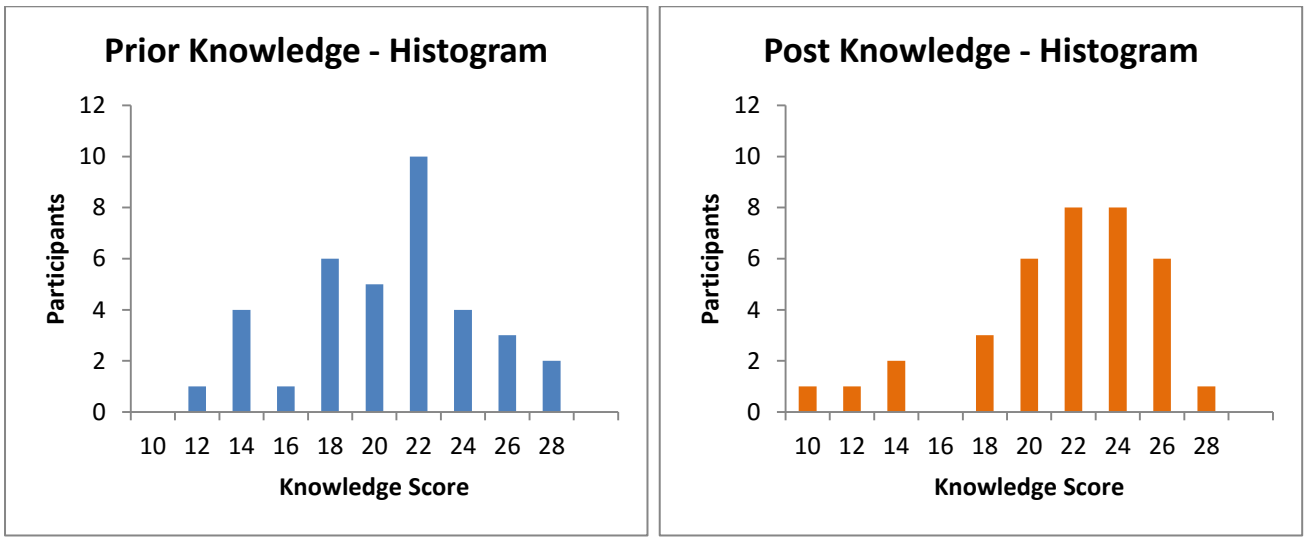

Figure 29 – The distribution for prior (blue) and post (orange) knowledge.

A t-test was conducted comparing prior against post knowledge for all participants.

Knowledge – Prior vs. Post, All Participants

Paired Student's t-test					Confidence Interval	
	Critical Value	t-value	df	p-value	Mean of Differences	Lower	Upper
	2.03	2.38	35	0.01	1.44	0.42	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 2

The paired t-test shows that there is a statistically significantly positive difference between the prior and post knowledge.

To see if there was a difference in knowledge, gain was found for the different grades grades. Gain is calculated as post minus prior knowledge. The gain for the different grades can be seen in [Table 3], which shows a noticeable difference in knowledge gained in the 4th grade compared to the 5th and 6th.

Gain Overview

Gain Between Grades				
	Count	Sum	Mean	SD
4th Gain	12	41.5	3.46	4.50
5th Gain	13	3.5	0.27	1.81
6th Gain	11	7	0.64	3.53

Table 3

The grades consisted of 12, 13, and 11 participants respectively. The sum is the total gain for the grade.

To verify that this is the case, an ANOVA is performed on the gain of all the grades.

Learning Gain – All Grades

ANOVA – Single Factor					
Source	SS	df	MS	F	p-value
Between	73.81	2	36.90	3.15	0.056
Within	387.08	33	11.73		
Total	460.89	35	13.17		

Note: SS: Sum of Squares, df: Degrees of Freedom, MS: Mean Square, F: f- statistic

Table 4

The ANOVA yielded a statistically significant difference in knowledge gained between the three grades at p< 0.06.

Learning Gain – All Grades

	Tukey Post Hoc - Groups		
	4^{th} Gain	5^{th} Gain	6^{th} Gain
Mean	3.46	0.27	0.64
n	12	13	11

Table 5

A Tukey Post Hoc shows that there is a statistically significant difference in knowledge gain in the 4^{th} grade compared to the 5^{th} and 6^{th} at $p < 0.06$.

H1.2 The participants in the CC group will have a higher post knowledge score increase than the NCC group.

Due to the statistically significant difference ($p<0.06$) in knowledge comparing the 4^{th} grade against the 5^{th} and 6^{th} grade and the very high mean for the knowledge gain of the 4^{th} grade, the 5^{th} and 6^{th} grade are removed from the CC and NCC knowledge comparison.

Therefore a t-test on the 4^{th} Grade CC and NCC groups was performed.

Knowledge – CC vs. NCC, 4th Grade

Student's t-test						**Confidence Interval**	
Critical Value	t-value	df	p-value	Mean of CC	Mean of NCC	Lower	Upper
2.35	-2.19	7.17	0.97	1.00	5.92	-9.15	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 6

The t-test shows that there is no statistical significant difference, for confirming whether CC is greater than NCC. However, reversing it shows that NCC is statistically significantly greater than CC.

H2.1 The participants will find the serious game more fun than a standard treasure hunt.

Again Again and Smileyometer mean

Game vs. Treasure Hunt, All Participants					
	No	Maybe	Yes	Smiley Mean	SD
Game	5	17	14	3.36	0.90
Treasure	7	16	13	3.47	0.84

Table 7

For all participants the Again Again table gives almost the same amount of; noes, maybes, and yesses in both the game and the treasure hunt, with the game receiving one more yes, and one more maybe.

Smileyometer - Game vs Treasure Hunt

Paired Student's t-test					Confidence Interval	
	Critical Value	t-value	df	p-value	Mean of Differences	Lower	Upper
	2.03	-0.54	35	0.7033	-0.11	-0.459	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 8

For the Smileyometer score applied to the game in comparison to the treasure hunt, a t-test shows that there is no statistically significant difference ($p > 0.05$).

Again Again - Game vs Treasure Hunt

Paired Student's t-test					Confidence Interval	
	Critical Value	t-value	df	p-value	Mean of Differences	Lower	Upper
	2.03	0.83	35	0.207	0.0833	-0.0866	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 9

The Again Again ratings were translated into numerical data, by giving a no rating 0, a maybe rating 1, and a yes rating 2.

For the numerical Again Again rating for the game in comparison to the treasure hunt, there is no statistically significant difference ($p > 0.05$).

H2.2 The participants in the CC group will give the serious game a higher rating than the NCC group.

Again Again and Smileyometer Overview

Game vs. Treasure	No	Maybe	Yes	Smiley Mean	SD
NCC Game	4	10	6	3.15	0.93
NCC Treasure	5	11	4	3.25	0.85
CC Game	1	7	8	3.63	0.80
CC Treasure	2	5	9	3.75	0.77

Table 10

The CC group gave more yesses in the Again Again questionnaire for both the game and treasure hunt; 8 and 9 vs 6 and 4. The Smileyometer means were also higher for the CC group.

Smileyometer to Game– CC vs. NCC

Student's t-test					Confidence Interval		
Critical Value	t-value	df	p-value	Mean of CC	Mean of NCC	Lower	Upper
2.033	1.64	33.765	0.055	3.625	3.150	-0.017	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 11

The t-test on the Smileyometer scores for CC vs. NCC in relation to the game shows a statistically significant difference (p> 0.06).

Numerical Again Again to Game– CC vs. NCC

Student's t-test					Confidence Interval		
Critical Value	t-value	df	p-value	Mean of CC	Mean of NCC	Lower	Upper
2.033	1.50	33.68	0.071	1.438	1.100	-0.043	Inf

Note: df: Degrees of Freedom; Inf: Infinite.

Table 12

The t-test on the numerical Again Again rating for CC vs. NCC shows statistically significant difference (p> 0.05).

H3 The participants in the CC group will rate the agent higher on the Godspeed questionnaire, than the NCC group.

Cronbach's Alpha for Godspeed Questionnaire

Cronbach's Alpha				
Anthropomorphism	Animacy	Likeability	Perceived Intelligence	Perceived Safety
0.04	0.66	0.82	0.76	0.69

Table 13

The Cronbach's Alpha for each category of the Godspeed questionnaire shows that the value for Anthropomorphism is too low for the questions to be considered reliable in accordance with the rates stated by [5] of either 0.7 or 0.6. The remaining categories have a Cronbach's alpha of 0.66 and above.

Godspeed Overview

NCC vs. CC				
	Count	Sum	Mean	SD
4th NCC	119	390	3.28	1.26
4th CC	114	458	4.02	1.42
5th NCC	120	418	3.48	1.32
5th CC	95	293	3.08	1.15
6th NCC	114	383	3.36	1.15
6th CC	95	347	3.65	1.08

Table 14

The counts for the Godspeed Overview are the total answers for the four categories excluding Anthropomorphism. The sum are the all the individual semantic differential scale scores added together.

Godspeed ANOVA - NCC vs. CC

ANOVA – Single Factor					
Source	SS	df	MS	F	p-value
Between	57.18	5	11.44	7.41	$9.02*10^{-7}$
Within	1004.90	651	1.54		
Total	1062.08	656	1.62		

Note: SS: Sum of Squares, df: Degrees of Freedom, MS: Mean Square, F: f- statistic

Table 15

The ANOVA for Godspeed, NCC vs. CC across all grades, shows a statistically significant difference.

Godspeed – CC vs NCC, All Grades

	Tukey Post Hoc - Groups						
	4th NCC	4th CC	5th NCC	5th CC	6th NCC	6th CC	Total n
Mean	3.28	4.02	3.48	3.08	3.36	3.65	
n	119	114	120	95	114	95	657

Table 16

A Tukey Post Hoc shows that the 4th grade CC is the only grade, where there is a statistical significant difference to the corresponding NCC group ($p< 0.05$). Therefore another ANOVA looking into which specific categories have a difference between CC and NCC for the 4th Grade.

Godspeed Categories ANOVA - NCC vs. CC, 4th Grade

ANOVA – Single Factor					
Source	SS	df	MS	F	p-value
Between	140.35	7	20.05	14.66	$1.26*10^{-15}$
Within	299.54	219	1.37		
Total	439.89	226	1.95		

Note: SS: Sum of Squares, df: Degrees of Freedom, MS: Mean Square, F: f- statistic

Table 17

The ANOVA shows that there is a statistical significant difference between at least one of the categories ($p<0.05$).

Godspeed – CC vs NCC, All Grades

	Tukey Post Hoc - Groups								
	CC Animacy	NCC Animacy	CC Likeability	NCC Likeability	CC PI	NCC PI	CC PS	NCC PS	Total n
Mean	3.36	2.31	4.83	3.77	3.73	3.07	4.44	4.35	
n	36	36	30	30	30	30	18	17	657

Note: PI: Perceived Intelligence, PS: Perceived Safety

Table 18

A Post Hoc Tukey shows that there is a significant difference within two of the categories. Animacy CC is statistically significantly higher than Animacy NCC, and Likeability CC is statistically significantly higher than Likeability NCC.

Within the other two categories no statistical significant differences are found.

Video Analysis

Overall Video Evaluation

Due to problems with one of the cameras on one of the test days only 12 videos were recovered of the 13 possible. The video quality was 720p for all five cameras, but the sound recording differed. Because of this poor quality it was hard to extract information from some of the recordings. Furthermore the environment made it worse. Other students roamed the halls of the school adding to unwanted noise or speech. The camera did not always point at the student speaking, making it hard to decide the source when an utterance was made.

The student with the camera was not always the tablet holder either, sometimes making it impossible to observe the interactions with the tablet. Despite these complications the video was analysed and annotated to our best ability.

Usability Evaluation

In this following chapter we will evaluate the usability of the different mini games. The video data has been annotated with instances of utterances about the interaction, and instances of observable interactions with the games.

Character Creator

Most groups seemed to have no trouble with the character creator, while some skipped it for different reasons. One group encountered a bug where they could not move the hair they wanted to up on the agent. They game was reset but the bug appeared again. Therefore, they gave up and continued without customising the agent. Two groups were very excited to get started, so they skipped the character creator to get playing. One of these groups had to restart the game after a bug in another game. After the restart they customised their agent as indented.

One group did not figure out, that it was possible to scroll in the dropdown menus and therefore, only had limited parts for the agent.

Perspective Game

It was observed that one group did not understand how to change between the different perspectives. They miss the instructions given by the agent because they are trying to find a place to sit, and therefore do not realise that the models act as buttons. Instead they try to swipe their fingers up and down the tablet. By chance they press the buttons and progress in the game.

Another problem that was observed was that if the player e.g. tapped the normal perspective button while the speak for normal perspective was running, it would start over.

Composition Game

Multiple bugs were experienced during the composition game. The agent was turned sideways then the game loaded, the agent got stuck on a fence, and the agent's size increased unintended. These were all more or less game-breaking bugs.

One group was observed trying to tap and pinch-zoom the screen before they became aware of the arrows in the corner. Hereafter they used that for moving around.

Utterances from many different players showed dissatisfaction with the game. They wanted clearer overview of the goals of the game, faster gameplay, and did not like the voices of the different animals.

Image Cropping Game

A few groups were confused about the interaction in the game. One tried to use the tablet as the camera and moved it around in front of the reference image. They followed instructions given by the agent, and lined up the image on the wall correctly in accordance with the tablet in what they thought was the correct distance, the tablet needed to have from the wall to manage the given task.

This did not solve the tasks in the game asked by the agent, but we had implemented a secret function to move on, in case the game got stuck. By clicking the 'take picture' button four times in a row, or getting four wrong shots in a row, the game would automatically continue. One group did this without figuring out, that it was a mistake. They got the instructions about image cropping, but they did not get to play around with it.

One group uttered amazement about how it worked, but a few groups also encountered bugs where the camera would not zoom out far enough in the last task.

It was clear that the continuous feedback in the game helped the players a lot. They knew what they had to do next all the time.

Colour Blending Game

Most groups had an easy time interacting with the colour blending game, but there were also problems. It was observed that some groups tried to interact with the palette before they realised, that they could only adjust the colour on the tubes. Two groups did not understand how to blend colours, and one group had trouble using the sliders to adjust the colour.

The face consisted of twenty segments and the game was programmed to finish the game when twenty segments had been painted. It did not take into account that some segments were painted multiple times. This resulted in frustrations for the players, when the agent told them "Good job", and the game was over. Some did not realise it was the end of the game, so they restarted it, with the belief it had crashed.

This was clearly a design flaw, as the groups should have been allowed to play for as long as they liked, without getting stopped by the game.

Some groups found it boring and just wanted to get it done; while one player uttered that (s)he loved it.

Fantasy vs Natural

The only observed problem with the Fantasy vs Natural game was that the players did not hear the instructions in the beginning. So when the tasks came, they did not know what to do. A button to repeat the instruction, some visual guidance, or a ready button would help this game.

Discussion

H1.1 The participants' knowledge about the learning objectives will increase after using the serious game.

Based on the t-test performed on prior and post knowledge for all participants, it can be concluded that the hypothesis is confirmed. However it is apparent that the 4th grade has the highest increase in knowledge of all the grades.

4th Grade Knowledge Category Averages

4th Grade	Depth	Image Cropping	Colour	Perspective	Fantasy / Natural	Mi	TI
Prior	0.65	0.46	0.47	0.72	0.85		
Post	0.92	0.67	0.52	0.92	0.84		
Increase	0.27	0.22	0.05	0.19	-0.01	0.14	0.72

Note: MI: Mean Increase. TI: Total Increase.

Table 19 - The numbers are based on the average amount of correct answers divided by the 27 possible. The average shows the increased learning from prior to post by category.

Digging deeper into the results seen in table 2 [above], for the 4th grade there is a large increase in three of the learning subjects, these being: Depth, Image Cropping, and Perspective. The increases are found by dividing the mean amount of correct answers for each learning subject divided by the total amount of questions, which are 27.

The increase for the 5th and 6th grade was however quite small with a mean increase of 0.01 and 0.02 respectively and a total increase of 0.03 and 0.08, while the large mean and total increase for the 4th grade was 0.14 and 0.72.

The post results for the 4th grade have such a large increase that they manage to equal or surpass the 5th grade in all learning subjects except colour.

The reasons behind the large increase in knowledge for the 4th grade could be attributed to their comparatively low prior knowledge levels (0.63), while the 5th grade started at 0.72 and the 6th grade at 0.81, which gave the 5th and 6th grade a much smaller window for improvement.

Another reason behind the large difference could be that the 4th graders were the intended target group and therefore the content of the game aside from the learning goals was aimed at that specific age group.

An example of the 5th and 6th graders' opinion of the game can be found in the video data, specifically the outburst of one male participant from the 6th grade, group 2, who said "This is some baby stuff. Waeh!" [26:15] ("Det er noget baby-noget det her. Waeh!"). The general opinion of the 5th and 6th grade was that of disinterest, while the opposite can be said for the 4th grade, which showed a greater focus as a whole.

Meluso et al. [32] found that for students (5th grade) who played a STEM based serious game had an increase in knowledge after playing, but found no significant difference between collaborative play and single player.

They do however state that the results may have been different if the collaborative players were given roles such as, driver of the controls etc. It can be assumed that this could be the case for our experiment as well.

H1.2 The participants in the CC group will have a higher post knowledge score increase than the NCC group.

The participants in the CC group did not have a higher post knowledge score compared to the NCC group, which means that the hypothesis is disproven.

If the means of the two groups are examined, 1.00 vs. 5.92, there is a great difference this is due to one participant in the NCC group who had a remarkable increase in score, going from 11.5 in the prior knowledge questionnaire to 26 correct in the post knowledge questionnaire as seen with participant NCC 6 in [Figure 30].

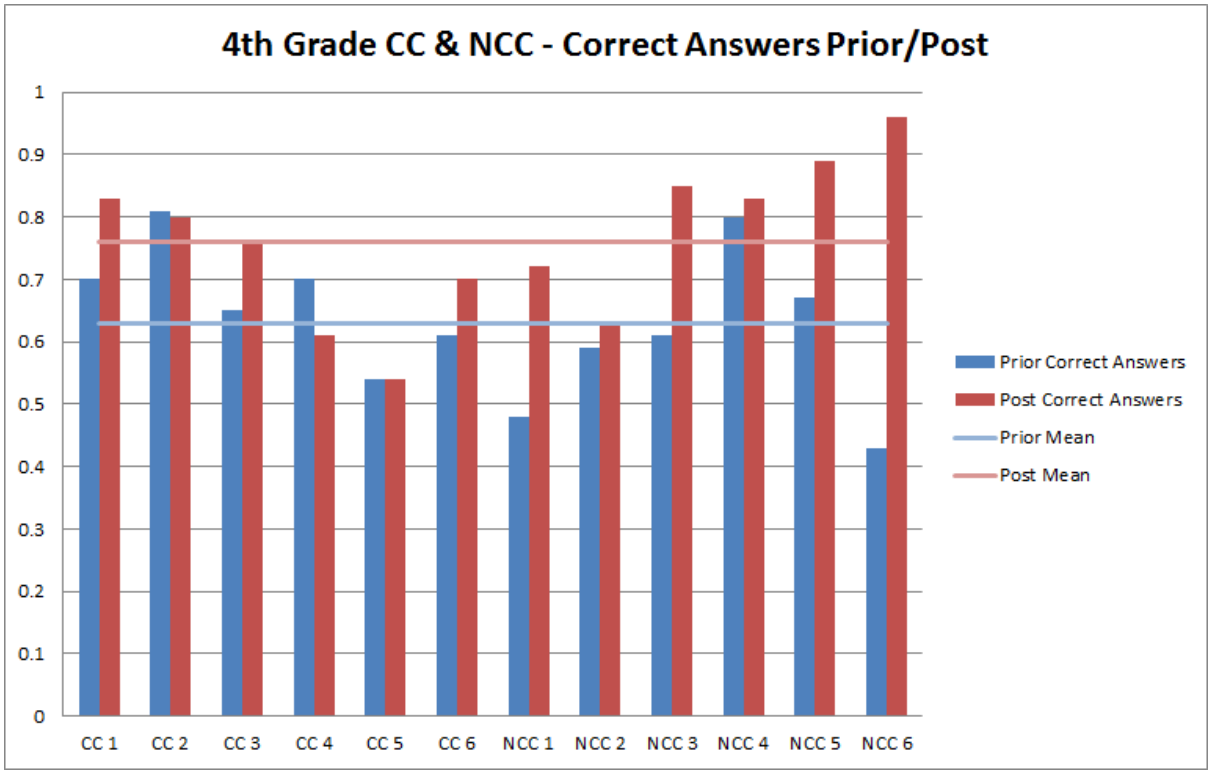

Figure 30 - 4th Grade CC participants on the left, NCC participants on the right, Overall prior and post mean. Numbers on the y-axis are number of correct answers divided by total questions.

We interpret this as the ability for the participants to create their own agent does not necessarily help in learning, however given the small sample size of six participants per group, more would have to be tested to be completely sure.

H2.1 The participants will find the serious game more fun than a standard treasure hunt.

The results of t-tests for measuring the difference in 'fun' using the Smileyometer and the Again Again table show that the participants did not find the game more fun than the treasure hunt. The mean of difference for the Smileyometer of -0.11 shows that there is hardly any difference in the mean participant rating of either. The Again Again table has a mean of differences of 0.08 which is also a negligible difference. Combined it can be said that the users have no clear preference when it comes to fun, which in other terms means that the participants find the game and treasure hunt to be equally fun. This was to some extent expected as this is also the case in Rehm & Jensen [37], where two different versions of a treasure hunt, one digital and one paper based, are tested. Their results show that both are given the same rating even though the digital one was more

intricate than the paper based one. The reason that Rehm & Jensen give is that engaging with playful elements is more fun than what they would traditionally be doing.

In our case this could apply in the same way, as one could imagine that playing, which is a break from the standard teaching method, would be more fun.

H2.2 The participants in the CC group will give the serious game a higher rating than the NCC group.

The results for the t-tests measuring fun for CC compared to NCC show that for the Smileyometer the difference is significant ($p < 0.06$) while for the Again Again table, the p-value is 0.071, just slightly higher than what we deem acceptable. Nonetheless there seems to be an indication that the participants in the CC group who were able create their own agent found the game more fun.

When looking at the Smileyometer mean in [Table 10], there seems to be a tendency for the CC group to rate both the game and the treasure hunt higher, compared to the NCC group. Whether this is due to both activities being better because one of them is or another cause is unknown, however based solely on those means it appears to be the case.

H3 The participants in the CC group will rate the agent higher on the Godspeed questionnaire, than the NCC group.

Comparing the CC group against the NCC group including all participants yielded a statistically significant difference for the 4th grade when comparing the two groups in the Tukey Post Hoc, which means that the hypothesis is partly confirmed but only in relation to the 4th grade.

Another ANOVA revealed that there was a statistically significant difference between the two groups in Animacy and Likeability. This means that the 4th graders found the agent to be more animated, lifelike, and likeable than the NCC group using the premade agent.

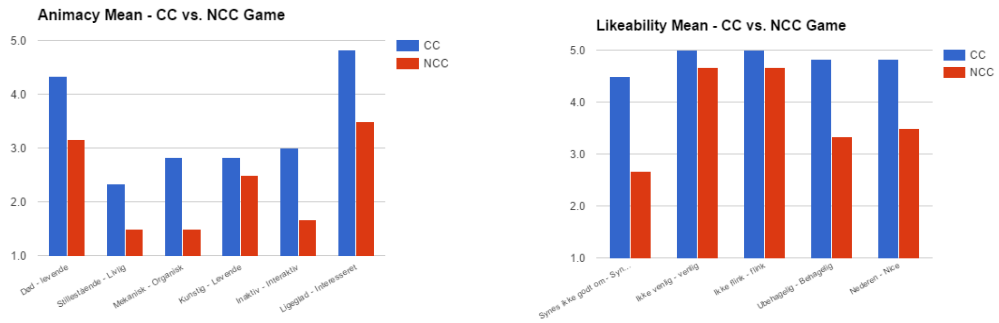

Figure 31 – Means for the two Godspeed categories and their individual semantic scales.

For Animacy, the CC group found the agent to be more: Alive, Lively, Organic, Lifelike, Interactive, and Responsive in comparison to the NCC group.

Godspeed 4th Grade Animacy

Animacy	Dead /Alive	Stagnant/ Lively	Mechanical /Organic	Artificial / Lifelike	Inert/ Interactive	Apathetic/ Responsive
CC Mean	4.3	2.3	2.8	2.8	3.0	4.8
NCC Mean	3.2	1.5	1.5	2.5	1.7	3.5
Mean Difference	1.2	0.8	1.3	0.3	1.3	1.3

Table 20

It can be seen that there is a large difference in mean (above 1.0) between the groups for 4 of the semantic differential scales. This means that even though there is no difference in speech or animations between the agents for the two groups, the fact that the CC group was able to customise their own agent, meant that they perceived it to be much more Alive, Organic, Interactive, and Responsive.

Godspeed 4th Grade Likeability

Likeability	Dislike/ Like	Unfriendly/ Friendly	Unkind/ Kind	Unpleasant/ Pleasant	Awful/ Nice
CC Mean	4.5	5.0	5.0	4.8	4.8
NCC Mean	2.7	4.7	4.7	3.3	3.5
Mean Difference	1.8	0.3	0.3	1.5	1.3

Table 21

Likewise for Likeability, there are large differences in means for 3 of the semantic differential scales, meaning that the CC group found the created agent to be more Likeable, more Pleasant, and Nicer compared to the default agent.

Usability Discussion

In general there were many bugs and unclear instructions throughout the whole game. These were partly because of time pressure due to the changing focus of the project, and partly because some parts simply were not designed well enough. In the following the shortcomings of the game will be discussed.

Character Creator

Most groups handled the character creator fine, but others had trouble using it. With the exception of one group it was due to an unclear interface. The exception was a group where the agent parts froze and could not

be applied. They navigated the well enough, but this unfortunate bug stopped them from using the character creator as intended.

It was observed that one group did not realise that it was possible to scroll down in the dropdown menu. This should have been clear through the design. It could have been done with a scrollbar, or perhaps showing half an object in the bottom of the drop-down menu to invite the player to scroll down to see the rest.

A few groups chose not to customise their agent, and just moved on to the mini games. This was not an ideal scenario, and there are two options to solve this. Either the player is forced to make changes to the agent before they can continue, or we accept that players are satisfied with the standard agent. Forcing them to make changes to it might annoy the players, which could give them a negative opinion about the agent. However they might not get the desired feeling of ownership of their agent, if they just use the standard. The middle ground would be to let them play with the standard agent, but make it possible to return to the wardrobe at any time to customise it. One group was observed to skip the customisation in the beginning of the game, but later, after a game restart, they took the time and customised the agent. This observation could indicate that the option of coming back to the wardrobe is a needed feature. It was planned earlier in the project, but as the focus shifted to testing at a school, it was not found to be as important, this should be reconsidered.

Furthermore, all the parts were not implemented in the character creator. There was a menu button for arms, but no arms were implemented, so nothing was in the dropdown menu. There were also only two feet in the game. More appendages were planned but did not reach the game due to time pressure.

Perspective Game

Only one group was observed to have problems with the interaction of this mini game. They tried to swipe to change view instead of tapping the objects as buttons. It should be clearer that the models are buttons e.g. with a glow around them, or alternatively there should be a button to get the instructions again.

It was also observed that the audio playback did not work as intended. When the player pressed a button while audio was being played, the clip would stop and the new clip would begin, even if it was the same clip. It was in hands of the player, so they decided if they wanted to restart the clip, but perhaps it should be made so they had to hear the full clip before being able to change or replay it. This would be done to ensure they hear all the instructions.

4th grade played this game on a computer instead of a tablet, due to a bug in Unity3d and Android. When animation contained rotation the object would disappear when it was built for Android. So there were no problems when it was tested on the computer, but the game broke when it was exported to the tablet. The bug was fixed by removing the animation and programming the transition instead. So the game worked as intended for 5th and 6th grade.

Composition Game

All groups quickly found the joystick and understood the interaction and how to control the agent. Only one group was observed to try different gestures before they found the joystick. There were complains about the game being too slow and that along with game breaking bugs seemed to give the players a negative attitude towards the game. The negative utterances towards the voices of the different animals could be a product of this negativity.

For the test of 4th grade the animation bug, as explained in the discussion of the perspective game, made the heads of the animals disappear. This made the game look weird, but it had no effect on the playability. The bug was fixed for the test of 5th and 6th grade.

This game should have been tested better prior to the test, unfortunately this was not possible with the given time schedule.

Image Cropping Game

The image cropping game did a good job of continually explaining what the player had to do next. However, one group missed the instruction of the interaction method. Had the instructions been given with both audio and visual effects, this could perhaps have been avoided. Further testing would also be needed to avoid game breaking bugs.

Colour Blending Game

The interaction was not clear enough in the colour blending game. The players figured it out, but it should be made clear, that they cannot interact with the palette. This uncertainty can make the players lose interest, which is not desirable. A worse design flaw however, was how abruptly the game ended. There was no reason for not letting the players continue to experiment with blending colours.

Fantasy vs Natural

The main problem with this game is its instructions were only given via audio. The players did not always hear them, and did not understand what to do in the game. There should also be visual guidance to make the goal clear to the player. To fully cater to the doer personality type, it should also give the player clear visual and audio cues, informing them whether they pressed the wrong or correct image. This is especially important if the instructions were not heard, so they could intuitively through active experimentation figure out the how the images should be sorted.

Conclusion

Experiment

The goal of this investigation was to combine a virtual agent with serious games, game based learning, while using principles from experiential learning to find out whether the ability to create your own agent, had an effect on learning, fun, and perception of the agent itself.

The aim of our serious game was to facilitate practical aspects of art in a school setting to 4th graders. The testing was performed on 4th, 5th, and 6th graders, which were split into two groups, one with the ability to customise their own agent and those who were given a premade agent. We then compared knowledge, fun, and the perception of the agent between the two groups for each grade.

We found that the knowledge of the students had improved especially for the 4th grade that had a knowledge gain of approximately 6 times that of the 6th grade. This was in all probability caused by the 5th and 6th grade having a higher knowledge of the subjects to begin with. In the end, the 4th grade had a similar knowledge level compared to the 6th grade.

To give the students a better frame of reference, when rating their amount of fun, they were also given a treasure hunt. In general their rating of fun was the same for both the game and treasure hunt; however students who made their own agent found the game more fun than those who were not able to.

The perception of the two versions of the agent measured using Godspeed only showed a difference for the 4th grade. In particular these were in the aspects of Animacy and Likeability, meaning that the 4th graders found the customised agent to be more lifelike and likeable.

The Game

There are three general things, which the mini games and character controller were lacking in. These were clear goals, feedback, and sufficient testing. The lack of clear goal and feedback left the players unsure and frustrated, when they were supposed to have fun while learning. The insufficient testing meant that the mini games contained bugs, which in some cases were game breaking.

All in all the game as a whole is a decent first iteration. It worked as intended in most cases but unfortunately not every time. More iterations to test both the concepts and the usability would be needed in order to make the game work better. However, time pressure did not allow for prior testing on the target group, and therefore the game seems more like a prototype in some aspects.

Future Work

One point of uncertainty was the small sample size for each grade. To make sure that the results are reliable, a further study could benefit from a larger sample size possibly focussing solely on one specific grade. Based on the results, if our game was to be used again it should be used solely on 4th graders, to make sure that the answers are as reliable as possible.

Another interesting study would be to test a version using an agent against one not using an agent and just pure speak. While Rehm & Jensen [37] found that for their treasure hunt, an agent improved memory retention, it would be interesting to see whether this also applies to a serious game.

It is still unclear whether the Godspeed questionnaire can actually be applied to children while the Cronbach's Alpha does show that it should be reliable in our case (except Anthropomorphism), to be entirely certain that it is viable further studies have to be performed. These studies could be into age, culture, and different translations from the one we have translated, could also be interesting to investigate.

In relation to agents and Godspeed, it would be interesting to see what parts of the agent's embodiment; appearance, behaviour and animation have an effect on the different scales of the Godspeed questionnaire.

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Appendix:

Prior and Post Questionnaire

NAVN_____

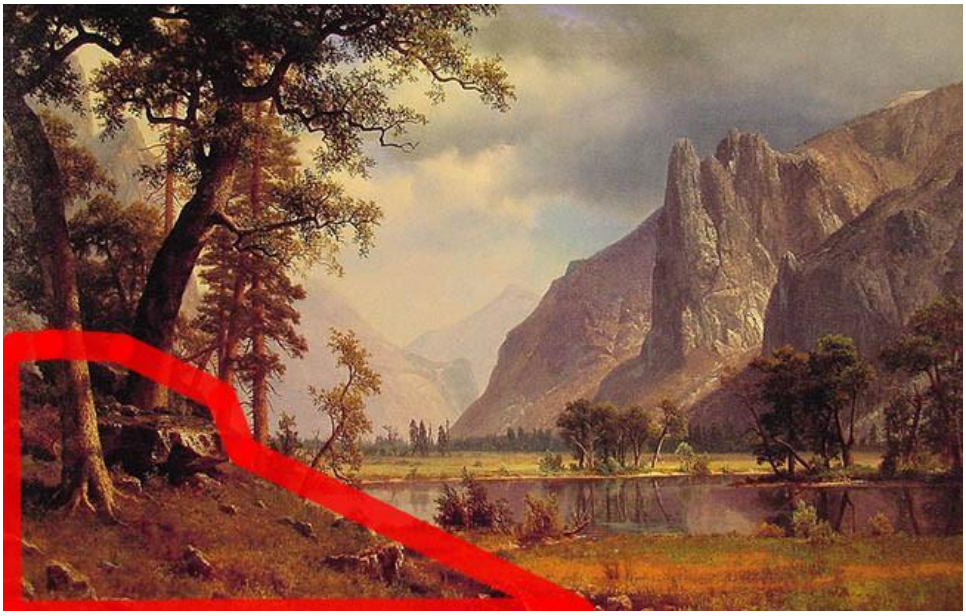
Dreng ☐

Pige ☐

Gruppenummer _____

Dybde

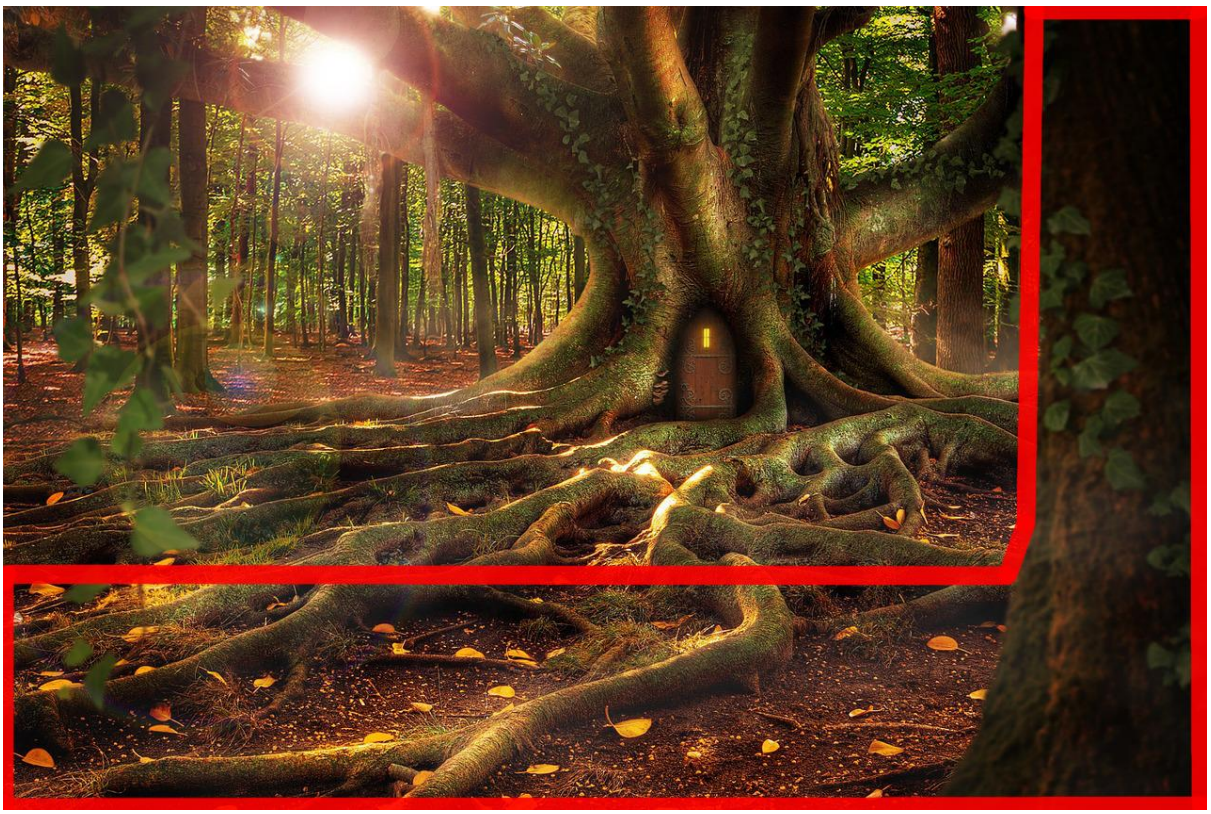
Her skal du sætte kryds i den firkant, du mener det røde omrids i billedet er omkring. Er det forgrunden, mellemgrunden eller baggrunden?



Forgrund ☐ Mellemgrund ☐ Baggrund ☐

Forgrund ☐ Mellemgrund ☐ Baggrund ☐

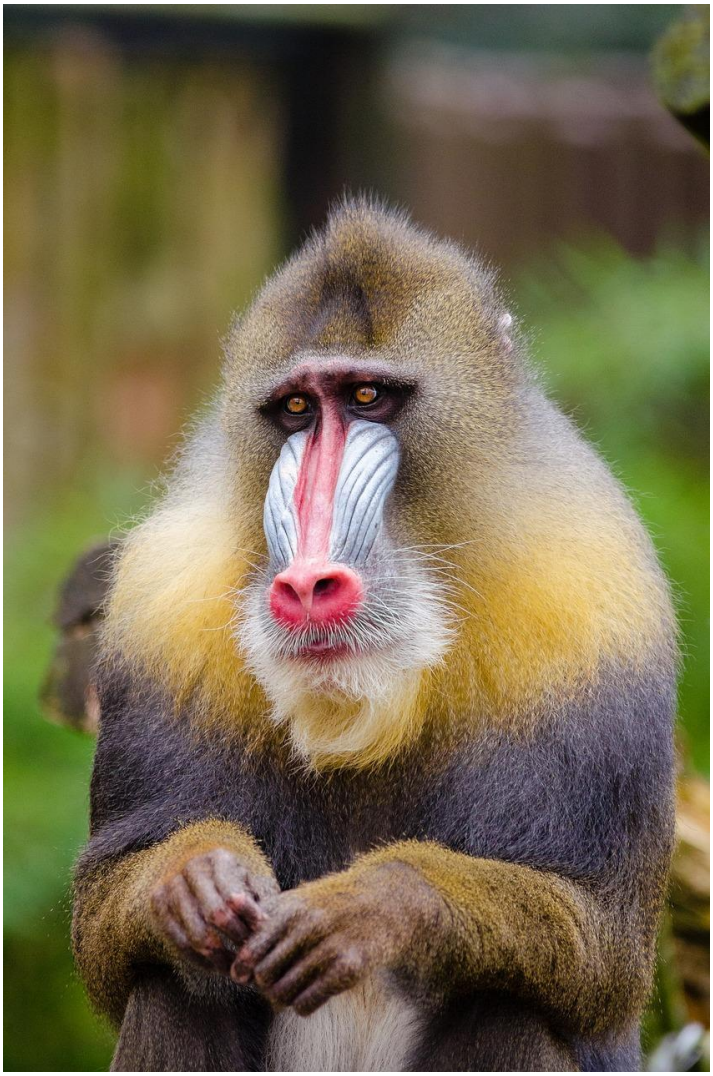
Forgrund ☐ Mellemgrund ☐ Baggrund ☐



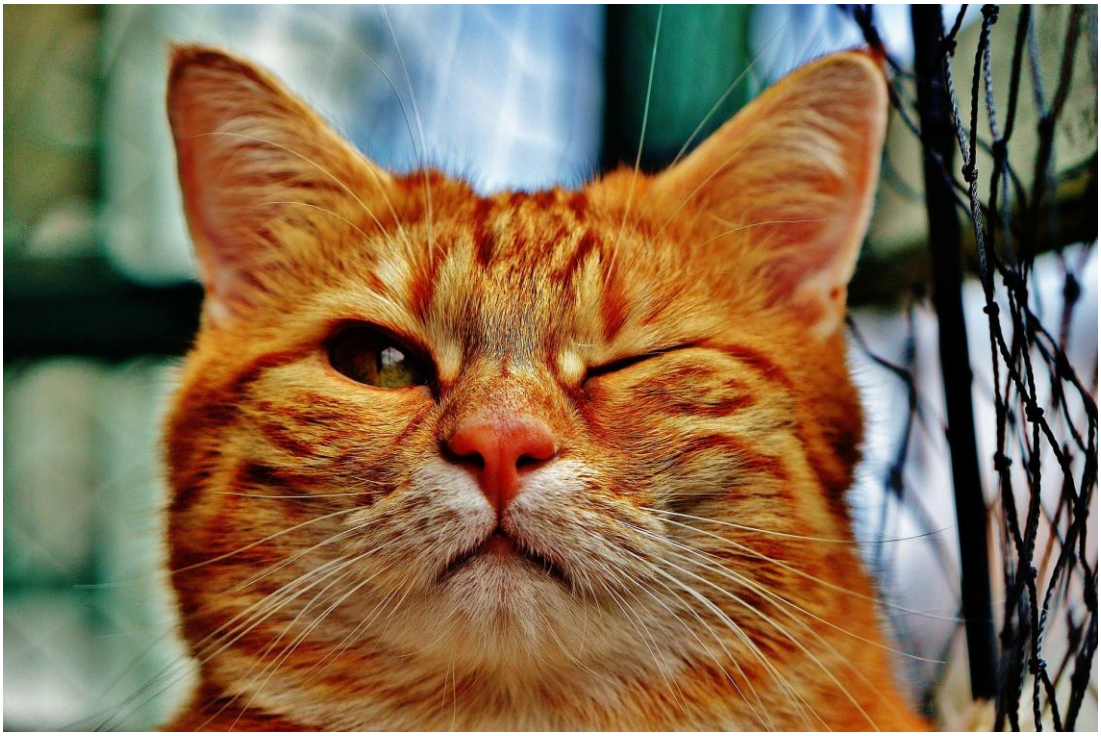
Forgrund ☐ Mellemgrund ☐ Baggrund

Billedbeskæring

Her skal du sætte kryds i den firkant, du mener billedet passer til. Er det supertotal, total, halvtotal, halvnær, nærbillede eller ultranær?



Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐



Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐

Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐

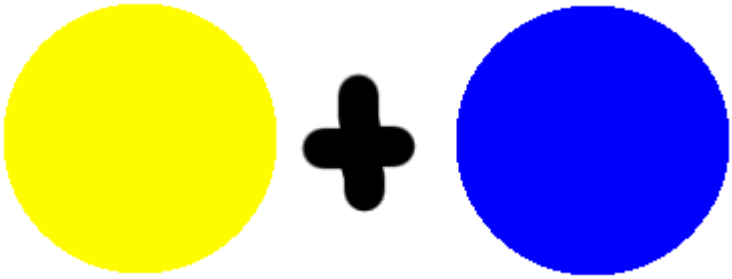
Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐

Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐

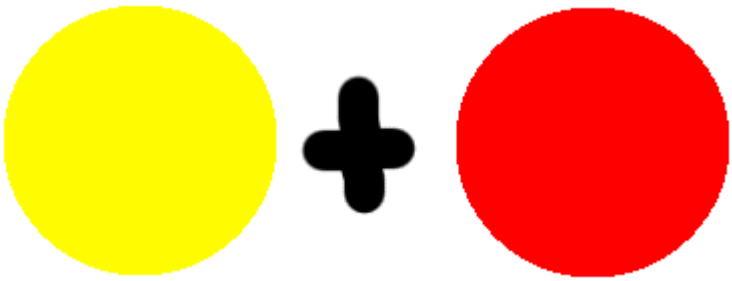
Supertotal ☐ Total ☐ Halvtotal ☐ Halvnær ☐
Nærbillede ☐ Ultranær ☐

Farveblanding

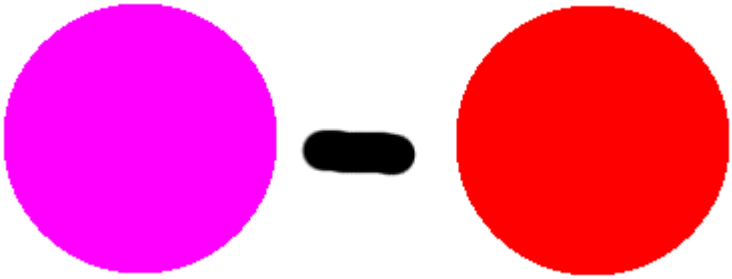
Her skal du sætte kryds i den firkant, du mener passer til den farve, man får, hvis man lægger de to farver sammen, eller hvis man fjerner en farve fra blandingen.



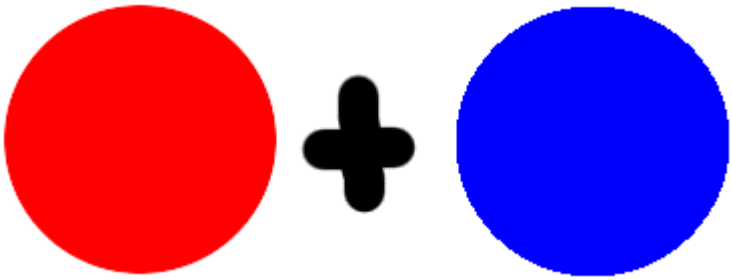
Gul ☐ Blå ☐ Rød ☐ Orange ☐ Grøn☐
Lilla ☐



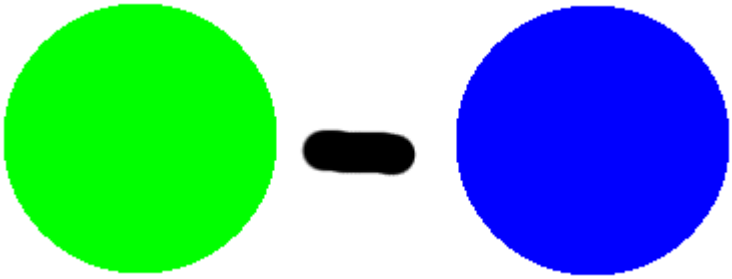
Gul ☐ Blå ☐ Rød ☐ Orange ☐ Grøn☐
Lilla ☐



Gul ☐ Blå ☐ Rød ☐ Orange ☐ Grøn☐
Lilla ☐



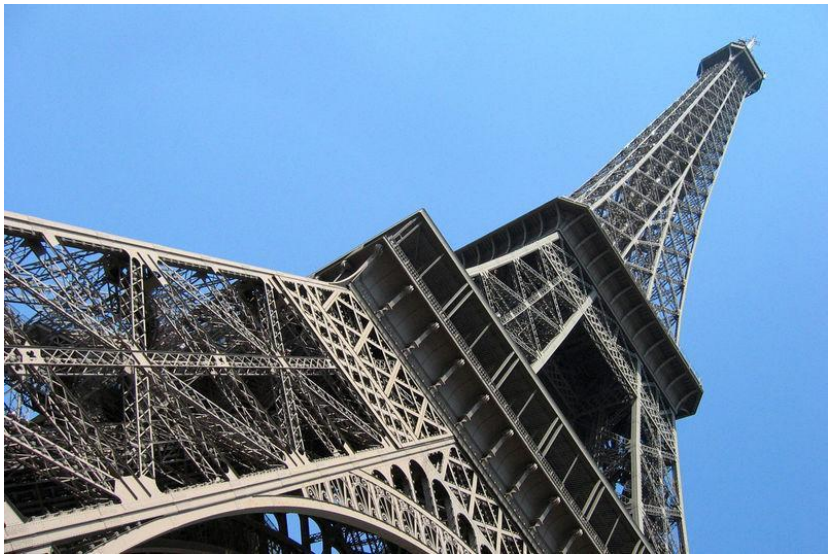
Gul ☐ Blå ☐ Rød ☐ Orange ☐ Grøn☐
Lilla ☐



Gul ☐ Blå ☐ Rød ☐ Orange ☐ Grøn☐ Lilla ☐

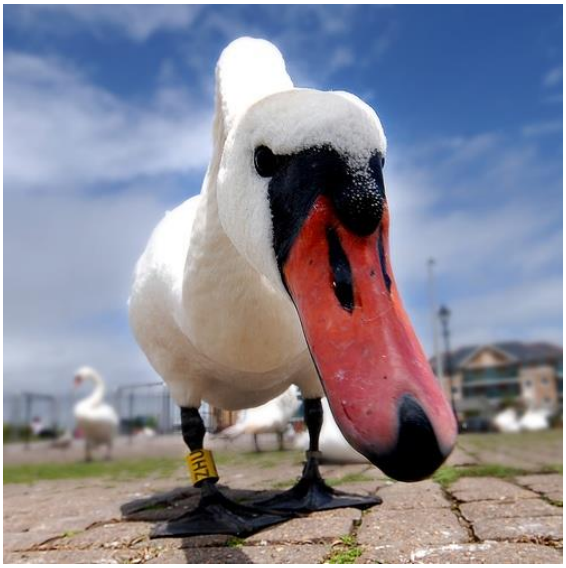
Perspektiv

Her skal du sætte kryds i den firkant, du mener passer til det perspektiv billedet har. Er det fugle-, frø- eller normalperspektiv?



Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐

Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐



Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐

Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐

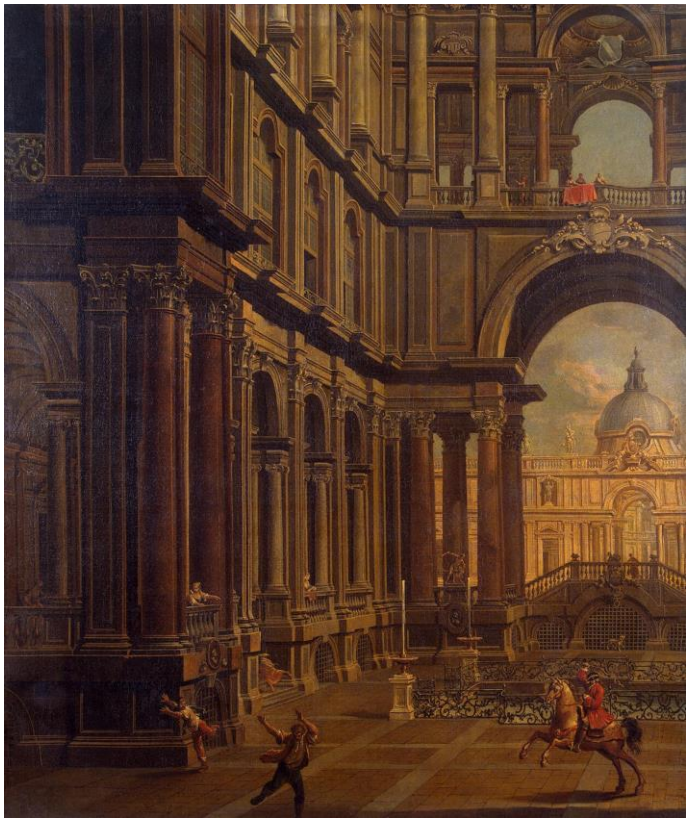
Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐

Fugleperspektiv ☐ Frøperspektiv ☐ Normalperspektiv ☐

Fantasi vs Naturlig

Her skal du sætte kryds i den firkant, du mener passer til billedet. Er det fantasifuldt eller naturligt?

Fantasifuldt ☐ Naturligt ☐



Fantasifuldt ☐ Naturligt ☐

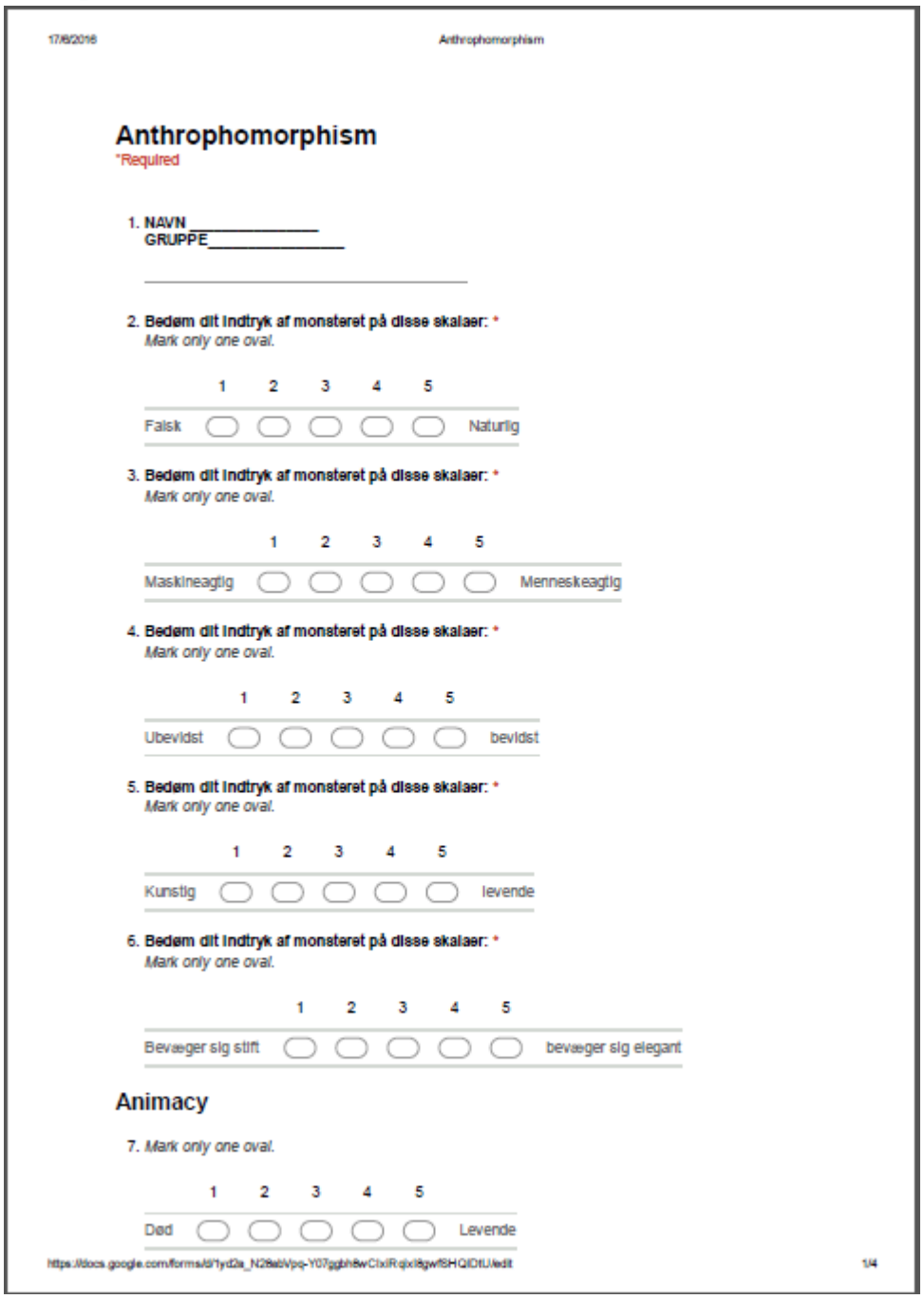
Fantasifuldt ☐ Naturligt ☐

Fantasifuldt ☐ Naturligt ☐

Fantasifuldt ☐ Naturligt ☐

Fantasifuldt ☐ Naturligt ☐

Godspeed Questionnaire



17/6/2016 Anthrophomorphism

Anthrophomorphism

*Required

1. **NAVN _____**
   GRUPPE_____

_____

2. **Bedøm dit indtryk af monsteret på disse skalaer:** *
   Mark only one oval.

	1	2	3	4	5	
Falsk	◯	◯	◯	◯	◯	Naturlig

3. **Bedøm dit indtryk af monsteret på disse skalaer:** *
   Mark only one oval.

	1	2	3	4	5	
Maskineagtig	◯	◯	◯	◯	◯	Menneskeagtig

4. **Bedøm dit indtryk af monsteret på disse skalaer:** *
   Mark only one oval.

	1	2	3	4	5	
Ubevidst	◯	◯	◯	◯	◯	bevidst

5. **Bedøm dit indtryk af monsteret på disse skalaer:** *
   Mark only one oval.

	1	2	3	4	5	
Kunstig	◯	◯	◯	◯	◯	levende

6. **Bedøm dit indtryk af monsteret på disse skalaer:** *
   Mark only one oval.

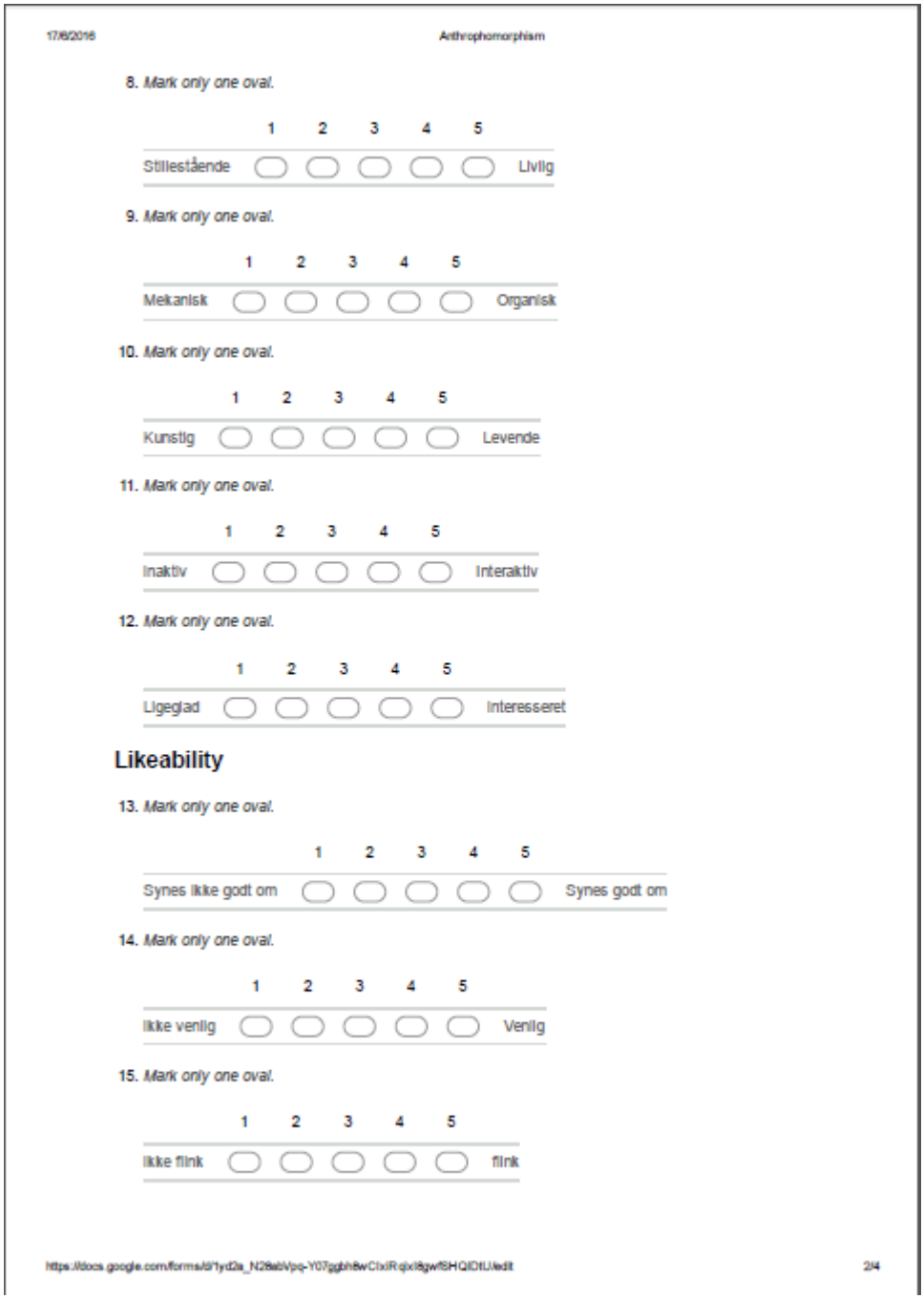
	1	2	3	4	5	
Bevæger sig stift	◯	◯	◯	◯	◯	bevæger sig elegant

Animacy

7. *Mark only one oval.*

	1	2	3	4	5	
Død	◯	◯	◯	◯	◯	Levende

https://docs.google.com/forms/d/1yd2a_N28ebVpq-Y07ggbh8wCIxiRqixl8gwf8HQIDtU/edit 1/4



17/6/2016 Anthropomorphism

8. *Mark only one oval.*

	1	2	3	4	5	
Stillestående	◯	◯	◯	◯	◯	Livlig

9. *Mark only one oval.*

	1	2	3	4	5	
Mekanisk	◯	◯	◯	◯	◯	Organisk

10. *Mark only one oval.*

	1	2	3	4	5	
Kunstig	◯	◯	◯	◯	◯	Levende

11. *Mark only one oval.*

	1	2	3	4	5	
Inaktiv	◯	◯	◯	◯	◯	Interaktiv

12. *Mark only one oval.*

	1	2	3	4	5	
Ligeglad	◯	◯	◯	◯	◯	Interesseret

Likeability

13. *Mark only one oval.*

	1	2	3	4	5	
Synes ikke godt om	◯	◯	◯	◯	◯	Synes godt om

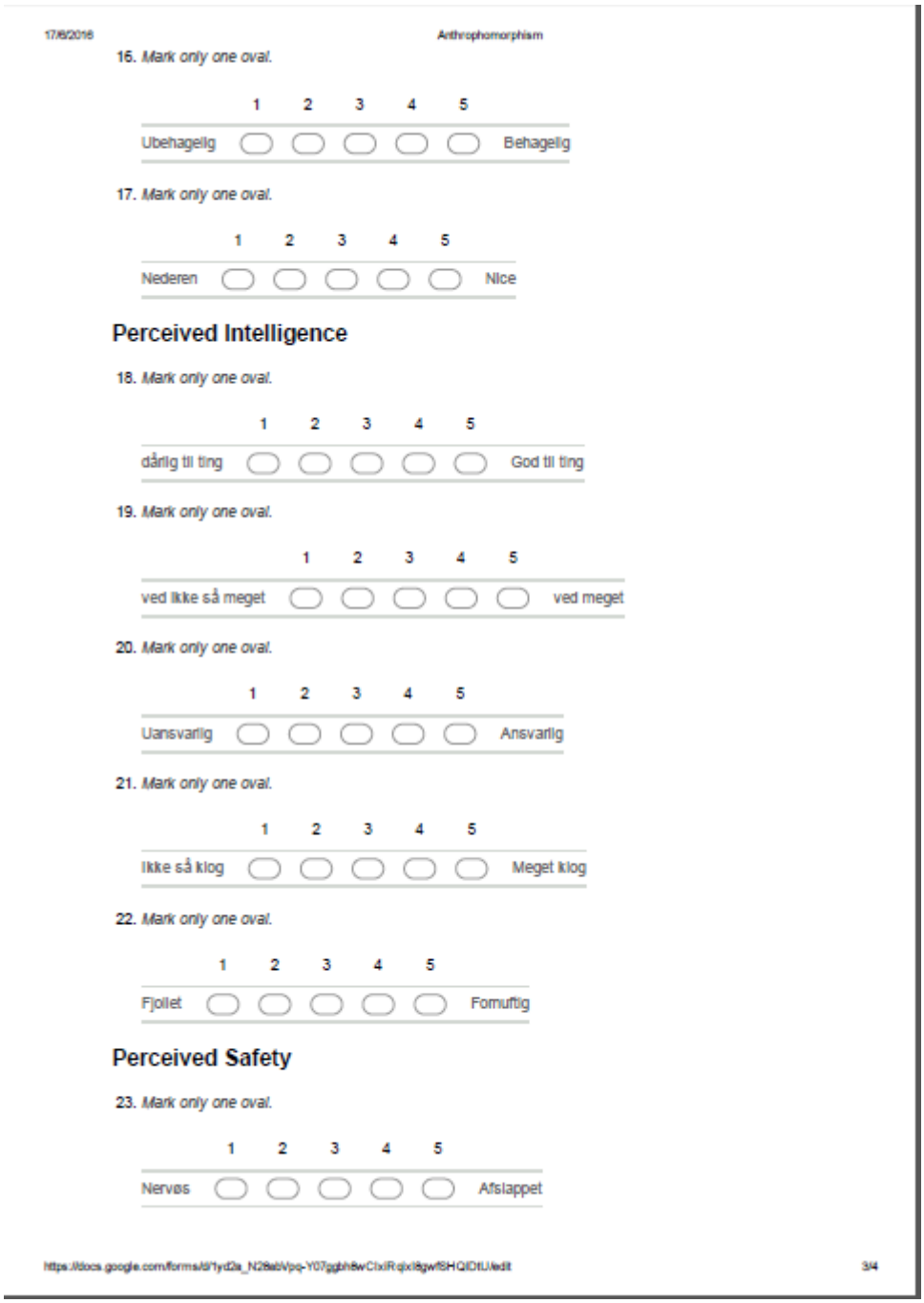
14. *Mark only one oval.*

	1	2	3	4	5	
Ikke venlig	◯	◯	◯	◯	◯	Venlig

15. *Mark only one oval.*

	1	2	3	4	5	
Ikke flink	◯	◯	◯	◯	◯	flink

https://docs.google.com/forms/d/1yd2a_N2BebVpq-Y07ggbh8wC1xiRqlxl8gwf8HQIDtU/edit 2/4



17/6/2016 Anthrophomorphism

16. *Mark only one oval.*

	1	2	3	4	5	
Ubehagelig	◯	◯	◯	◯	◯	Behagelig

17. *Mark only one oval.*

	1	2	3	4	5	
Nederen	◯	◯	◯	◯	◯	Nice

Perceived Intelligence

18. *Mark only one oval.*

	1	2	3	4	5	
dårlig til ting	◯	◯	◯	◯	◯	God til ting

19. *Mark only one oval.*

	1	2	3	4	5	
ved ikke så meget	◯	◯	◯	◯	◯	ved meget

20. *Mark only one oval.*

	1	2	3	4	5	
Uansvarlig	◯	◯	◯	◯	◯	Ansvarlig

21. *Mark only one oval.*

	1	2	3	4	5	
Ikke så klog	◯	◯	◯	◯	◯	Meget klog

22. *Mark only one oval.*

	1	2	3	4	5	
Fjollet	◯	◯	◯	◯	◯	Fornuftig

Perceived Safety

23. *Mark only one oval.*

	1	2	3	4	5	
Nervøs	◯	◯	◯	◯	◯	Afslappet

https://docs.google.com/forms/d/1yd2a_N28ebVpq-Y07ggbh8wC1xiRqlxI8gwfSHQIDtU/edit 3/4

24. *Mark only one oval.*

	1	2	3	4	5	
Rolig	◯	◯	◯	◯	◯	ophidset

25. *Mark only one oval.*

	1	2	3	4	5	
Fredfyldt	◯	◯	◯	◯	◯	overrasket

Powered by Google Forms

Treasure Hunt

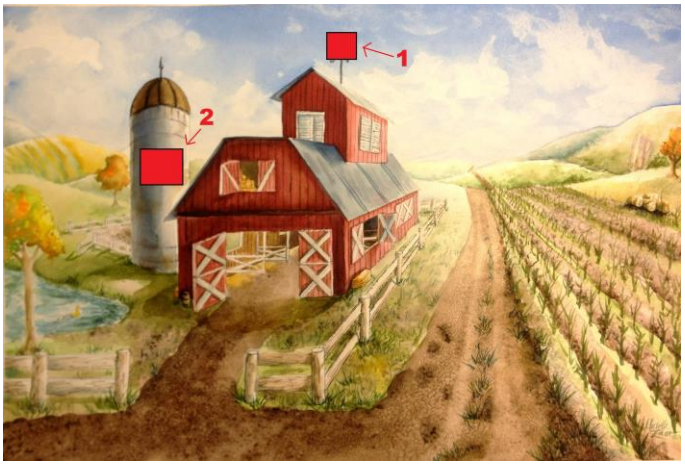
Selvportræt På 80-års Dagen af J. F. Willumsen

Opgave 1: Hvilken farve har mandens store pensel malet med sidst?

Svar: Rød, hvid, blå, eller grøn

Opgave 2: Hvilken farve er der på paletten under den røde firkant?

Svar: Lilla, gul, sort, eller rød



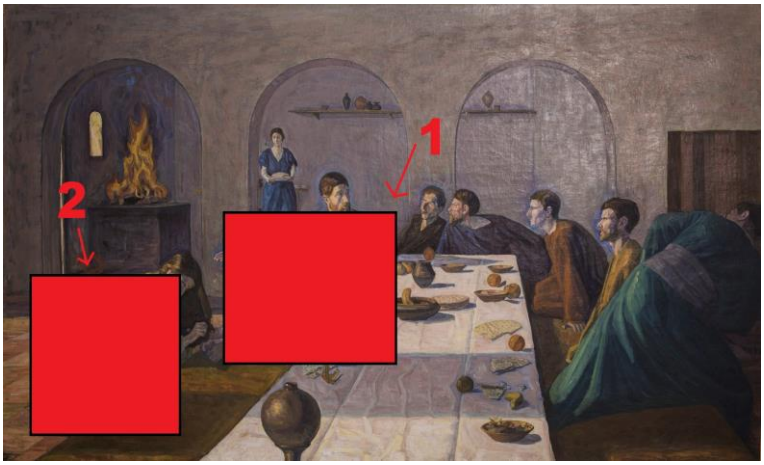
One Point Perspective Barn Painting af Michelle East

Opgave 1: Hvilket dyr er vejrhanen?

Svar: En ko, en hane, eller en gris

Opgave 2: Hvad står der på siloen?

Svar: Ingenting, Arla, eller Korn



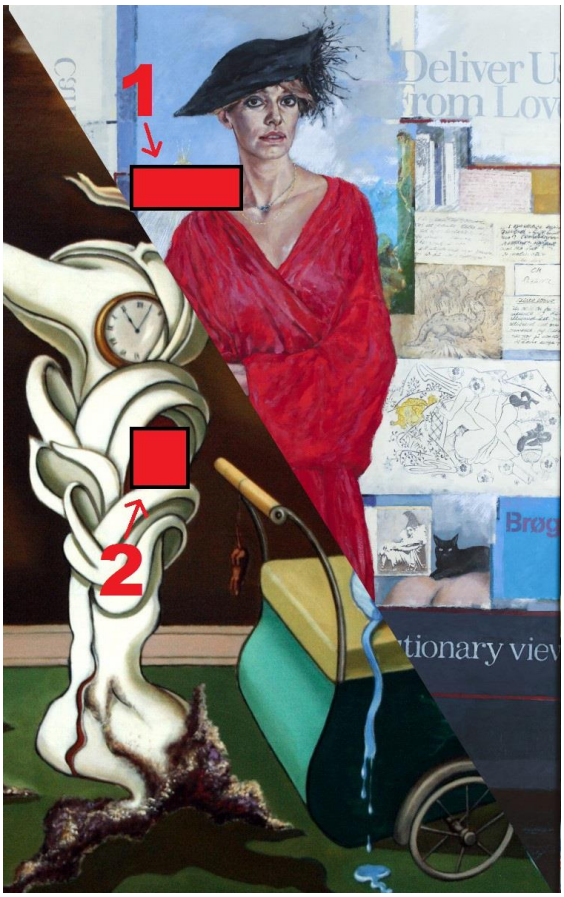
Maria Salver Kristi Fødder af Niels Larsen Stevns

Opgave 1: Hvilken farve har Jesus tøj?

Svar: Grønt, gult, blåt, eller rødt

Opgave 2: Hvilken farve har Marias tøj?

Svar: Gult, hvidt, sort, eller rødt



Portræt af Suzanne Brøgger af Niels Winkel/

Et geni kommer til verden af Harry Carlsson

Opgave 1: Hvilket dyr gemmer sig bag den røde firkant?

Svar: Et hamster, en fisk, en due, eller en hest

Opgave 2: Hvilken ting gemmer sig bag den røde firkant?

Svar: Et ur, en pibe, en mus, eller en bog

Københavns Vinterbane af Erik Hagens

Opgave 1: Hvilket flag gemmer sig bag den røde firkant? (Det er nummer tre fra venstre)

Svar: Dansk, Japansk, Grønlands, eller Tysk

Opgave 2: Hvilken farve har bilen, der gemmer sig bag den røde firkant?

Svar: Gul, sort, blå, eller rød