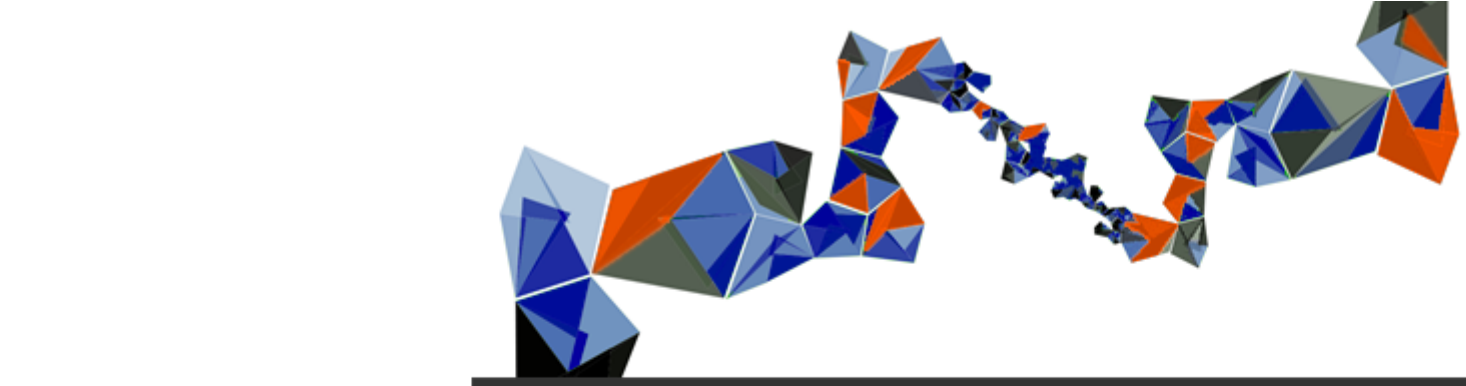

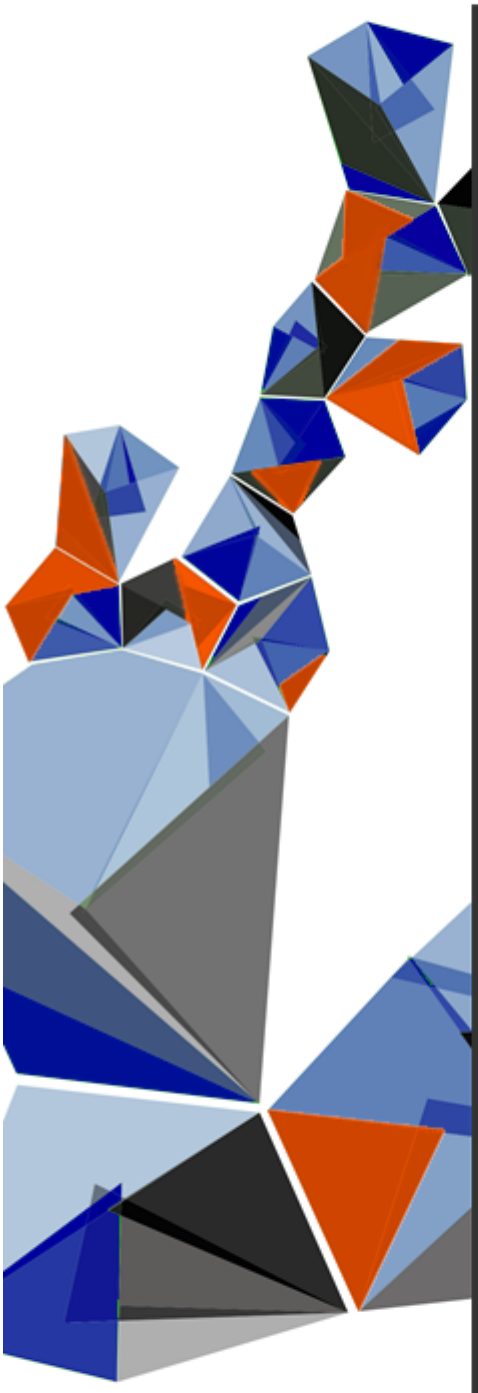

BACHELOR THESIS CREATIVE TECHNOLOGY

DESIGNING AN ESCAPE ROOM FOR A BROAD RANGE OF AGE AND SKILL LEVELS

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Abstract

Escape room games are a recent and quickly growing phenomenon. They are primarily targeted at adults, though specially designed variations for children are also available. However, singular designs that cater to a large range of age levels are a rarity. This research aims to discover what factors are important in the designing of an age-agnostic escape room game. Research on the state of the art for escape rooms in the Netherlands is performed, specifically for those targeting younger audiences. An escape room themed after local history is developed for the Museum Hengelo (Netherlands), with an intended target audience of children between 8 and 14 years old. A design is ideated and multiple iterations are built and tested. Qualitative data is gathered using questionnaires and observations made during the experiments, and this data is used to improve the design. Generally, users enjoyed the resulting escape room, though the inclusion of some language-based puzzles appeared to be difficult for younger players. A possible relation between children's curricular contents and the age-agnosticism of escape room puzzles is theorized, and further ways to improve upon the escape room design are presented. Additionally, part of this thesis may serve as documentation for the developed escape room game.

Acknowledgements

The author would like to thank Edwin Dertien for his role as supervisor and his continued help in the realization of the project. Thank you to Robby van Delden for the sharp and eloquently formulated feedback on this report.

Thanks to Chulakit Dumnoenchanvanit, my fellow student in this project. This was not a one-man job, and good collaboration was necessary for completing the project in this way.

Many thanks to the Museum Hengelo, and in particular our supervisor Jan van Alsté, for the very pleasant collaboration and assistance throughout the development of the escape room.

Lastly, the author would like to thank all the friends and family members that provided feedback or other forms of support.

Index

1. Introduction

1.1 Context

In this section, the subject of the report and the stakeholders that are relevant to this project will be introduced.

Subject: Escape rooms

An escape room is a real-life adventure-based game in which a group of players solves a series of puzzles in order to reach their goal. As the name implies, this goal is often to escape from the physical room in which the game takes place, but it can also be something entirely different (such as preventing a missile launch or opening a safe). Usually, a group of two to ten participants is given a predetermined amount of time to complete all objectives (Penttilä, 2018).

Escape rooms are a relatively new phenomenon. Though the concept behind them can be traced back to other forms of entertainment such as scavenger hunts and haunted houses, as well as a certain genre of video games in which the player is tasked with finding his / her way out of a room. The first physical realization of this concept was developed in 2007 by the Japanese company SCRAP (Corkill, 2009). The concept spread throughout Asia and other parts of the world in the following years. In the Netherlands, the first escape room was established in 2013 (Van Hoenselaar, 2017). As per June 2019, there are more than 800 different escape rooms to be played in the country ("Escape Rooms Nederland", n.d.).

Apart from being an entertainment phenomenon, escape rooms are also often recognized as team building exercises for companies and other (professional) groups. The main reason for this is the players' requirement to work together: communication, trust and collaboration are often required to work through a room in an efficient manner (Escape Rooms Nederland, n.d.; Atri, 2018).

Client: Museum Hengelo

The Museum Hengelo is a relatively small museum that focuses on the history of its hometown, Hengelo (the Netherlands). It is situated in a mansion within the city center. The Museum Hengelo aims to tell the story of how Hengelo and its residents developed over the many years since the town's inception. Much attention is paid to the industrialization that started in the second half of the nineteenth century, as that is what transformed Hengelo from a small village to a city.

AssortiMens

AssortiMens is a care foundation located in Oldenzaal, the Netherlands. It is the party that took on the escape room project from the museum and in turn offered it as a graduation project for students at the University of Twente.

AssortiMens works with people who are diagnosed to be on the autism spectrum (often referred to as 'participants' rather than patients) to provide them with day-to-day activities. AssortiMens differs from many other care facilities by focusing on people who were able to enjoy higher education but have difficulties in business scenarios due to social issues. The activities may stem from the participants' own interests and hobbies or the projects that AssortiMens accepts from external clients (usually in the form of companies). These external projects are usually

'nice to have' side projects from companies: ideas which they appreciate being researched or worked on, but that do not have much priority or urgency.

AssortiMens has access to a number of production facilities such as 3D printers, laser cutting machines et cetera. Furthermore, the participants are able to help with matters such as research and production.

The researchers

This project is carried out by Jordi Agricola and Chulakit Dumnoenchanvanit, who both study Creative Technology (Bachelor's degree) at the University of Twente (The Netherlands). The project serves as a graduation project for both students. The development and realization of the escape room is performed jointly; however, each student treats a different topic and research question for their graduation thesis.

As mentioned above, the project is executed by the researchers on behalf of AssortiMens, and the client is the Museum Hengelo.

1.2 Problem Statement

The Museum Hengelo decided some years ago that it wanted to modernize: the museum was to become more dynamic and interactive (De Twentsche Courant Tubantia, 2016). With this goal in mind, the museum wants to incorporate an Escape Room into its exhibition. This escape room is to be aimed at children between eight and fourteen years old. Much like the rest of the museum, the escape room should be themed around the history and development of Hengelo as a city. The museum would prefer if there was some educational aspect related to Hengelo's history in the escape room, but the main focus should be that it is entertaining.

The core problem that this research will treat is the following: the age category specified by the museum is a relatively broad one. One can imagine that the level of critical thinking, reading comprehension and logical reasoning will vary widely within even a group of 12-year-olds, so taking children from age eight to fourteen will result in a large range of skill levels.

Furthermore, having a proper level of challenge is essential for making the puzzles that make up the escape room (and therefore the experience as a whole) as enjoyable as possible (Reeve, 1989). Since a puzzle that is immediately obvious does not confront the player(s) with a challenge, the production of dopamine that is associated with the so-called 'Aha!-erlebnis' or eureka moment (Tik et al., 2018) is not triggered. Obviously, if a puzzle is too difficult and no solution is found, this also does not trigger the eureka moment.

1.3 Research Question

Keeping the challenges and requirements mentioned in the problem statement in mind, the following research question for this research was devised:

How does one design an escape room for a large range of age and skill levels?

1.4 Outline of report

The report will be structured in the following way:

First, an analysis of available literature and the current state of the art of Dutch escape rooms will be performed. Then, the methodology for the development of the escape room will be discussed. Hereafter the various stages of the design process (ideation, specification, realization, evaluation) will be described. The results of these experiments will then be given and interpreted.

The research and the project will then be critically discussed, the conclusions that follow from the research will be presented and finally recommendations drawn from this project will be described.

Note that section 6.3 (Final Version) is written in such a way that it may serve as (a basis for) a standalone document describing the escape room in detail. Therefore, the section contains multiple pieces of duplicate information that is also present in earlier chapters; this is intentional.

2. Analysis

2.1 Literature

As will be discussed in the State of the Art section below, designing escape rooms for children in this project's targeted age group is not new. However, literature (scientific or otherwise) on how to design escape rooms for children is sparse at best. There is some research on the use of escape rooms in an educational context, but these papers are limited to academic-level use cases (Eukel, Frenzel, Cenusca, 2017; Gómez-Urquiza *et al.*, 2019; Kinio, Dufresne, Brandys, Jetty, 2019).

The main game elements in an escape room game are the puzzles contained within. Puzzles designed for multi-player experiences are especially important, since escape rooms are collaborative games. The way people interact with this type of puzzles is significantly different from single-player puzzles, and factors such as group dynamics and social roles require a different approach than traditional single-player puzzle designs (Manninen & Korva, 2005).

2.2 State of the Art

Existing escape room design at the museum

The museum already has an escape room design, which was developed by the project supervisor from the museum. It uses the same room that is intended for this project. This escape room design consists of multiple assignments that are given to the participants in text form. There are three main sections to these assignments; once all three have been completed, the locks corresponding to them can be opened and the room can be left without triggering an alarm. The instructional handout for this version of the escape room can be found in Appendix I.

It must be noted that the museum's project supervisor developed this escape room design as a temporary solution; the design that will be developed by the researchers of this report will be the permanent version.

Indexation of escape rooms in the Netherlands

To get a good overview of the current state of escape rooms, looking at what is available in the Netherlands is likely to give a good representation of the development of the format as a whole. As stated before, the Netherlands saw its first escape room open its doors in May 2013 (Van Hoenselaar, 2017) and now has over 800 different rooms to choose from.

This data is taken from Escape Rooms Nederland, an independent online repository that aims to document all escape rooms in the country. Additionally, they provide background news, a curated selection of recommended escape rooms and the possibility for players to leave reviews on rooms they have participated in. The website also sorts its database by category, including one category for children's escape rooms. By indexing this data, an overview of the children's escape rooms may be created.

First is a division of minimum ages for participation in the children's escape rooms.

Minimum required age for participation	*Frequency*
6	13
7	7
8	17
9	2
10	19
11	0
12	14

Table 1: Distribution of minimum participation age in Dutch escape rooms, according to Escape Rooms Nederland's database.

Further inspection of these children's escape room shows some of the ways they are made appropriate for a younger audience. For example, the storylines associated with these types of escape rooms are typically a lot less dark and violent than those found in rooms for more mature audiences. Where murder and kidnapping are common themes for escape games aimed at older players, children's rooms may instead be centered on a lost item.

Another tactic employed by many escape rooms targeted at children is the inclusion of some kind of supervisor within the room itself. This may be in the shape of an employee, who sometimes is given a role within the story behind the escape room. Often, the parent(s) or guardian(s) of the participants are required to accompany the children into the escape room to fulfil a similar purpose.

The presence of a supervisor (within the room or remotely) is not something that can be counted upon for this project, thus in the next section alternative ways of making an escape room suitable for younger audiences will be explored.

2.3 Suitability of escape rooms for wide age groups

One major thing which differentiates children within the specified age group is the amount and level of education they have received. Looking at the curriculum for the years that make up the age group will give an indication of what children learn during this period of their lives.

In the Dutch school system, 8-year-old children are generally in their fourth of fifth year (in Dutch: '*groep*') of primary education. Primary school lasts eight years; after this, children (then usually twelve years old) will move on to secondary school. When they reach the age of fourteen years old, the tail end of this project's target audience, they will be in their second or third year of secondary school (provided that they did not fail any years).

The main points of focus in primary school curricula (from year 5 and onward) are on language (mainly Dutch, with a basic understanding of English (Stichting Leerplanontwikkeling, n.d.)), mathematical skills and general knowledge like topography and history. In 2010, the government indicated that language and mathematics should be primary schools' main focus (Rijksoverheid, 2010). Secondary school continues this trend, but broadens out the curriculum with things like chemistry, biology, economics and additional foreign languages.

Additionally, the Foundation for Curriculum Development (Dutch: *Stichting Leerplanontwikkeling, SLO*) identifies a number of competences that students will need to successfully partake in modern society (Stichting Leerplanontwikkeling, 2019). These eleven competences, called '21st century skills' are (in part) based on the work of Trilling & Fadel (2009) and include skills such as creative thinking, basic ICT usage, collaboration and problem solving. These competences are not part of any particular class (Fisser & Van der Hoeven, 2014), rather, they are interdisciplinary skills that are picked up through experience and social factors.

From this, three main developmental areas can be identified:

3. Language (grammar, speech, conversation, etc.)
4. Mathematics
5. General knowledge (geology, history, biology, etc.) and 21st century skills

These three developmental areas are the core of what children learn in school between ages 8 and 14. Therefore, it can be hypothesized that these main fields are important factors of what differentiates the audience for the escape room project. Should this hypothesis hold true, then escape rooms that do not rely on these developmental areas (much) could be more suitable for a broad age group.

3. Method

For designing the escape room, the Creative Design Process by Mader & Eggink (2014) will be used as a basis. This process is divided into four major phases: ideation, specification, realization and evaluation. It focuses on iteration: the cyclical repetition of steps (or phases) as necessitated by the design and the results achieved. The designing, developing and testing of the escape room will be performed with these principles in mind. Three main iterations of the design will be produced, with smaller changes happening along the way.

3.1 Ideation Phase

The first phase of the design process, ideation, will begin with the generation of ideas of puzzles (and / or puzzle elements) to integrate into the escape room. This is the first step performed, but it is a process that continues throughout the entire phase (and even beyond it). The goal of this phase is to get a clearer, more elaborate idea of what the project should be like, along with a set of project requirements that the final product should adhere to (Mader & Eggink, 2014).

To determine these requirements, a number of steps will be performed. Most importantly, meetings and discussions with the client will be organized to identify their desired functionality and results from the escape room. Furthermore, a practical assessment of what is and is not possible within the confines of this project's space, environment and budget will be made. Lastly, the targeted user group(s) will be analyzed, and requirements will be constructed from the result of this analysis. All of this is done to ensure that the ideas generated in the ideation phase can be properly evaluated on how suitable they are for this specific project.

3.2 Specification Phase

Once the ideation process is completed, the generated ideas will be evaluated on their feasibility for use within the project. Ideas that do not pass this evaluation may be adapted to better suit the needs of the client or may be discarded. After this filtering is completed, the list of suitable ideas will be used to create an initial design idea for the escape room.

This first design will be discussed with the relevant stakeholders to receive initial thoughts and feedback. If necessary, adaptations based on this feedback will be incorporated to improve the design. Then, an initial, simple prototype will be developed. This will be tested using the principle of hallway testing as described by Reeves (2016): quick, simple user tests using whoever may be nearby to identify usability problems. Adaptations may be made in between tests if certain elements stand out as a problem with the testing methodology rather than the product design itself.

Lastly, the design and the test results will be shared with the client to once more gauge their opinions and suggestions.

3.3 Realization Phase

After the specification phase, there is an escape room design that has already seen usability testing to improve it. Based on this design and input from the client regarding it, work on a first physical version will be started. Since escape rooms are very much a combination of logical, mental puzzles and physical puzzles (Wiemker, Elumir & Clare, 2015), it is important to perform another usability test with a physical version of the room.

The design work for the physical realization of the puzzles is started. This includes the planning and creation of any self-built elements, as well as the purchase of any furniture, tools and miscellaneous items that will be needed for the escape room. The focus, initially, is on getting the desired functionality to a usable level. Aesthetics are of a lower priority. The reasoning for this is that it is desirable to get a working version of the escape room as soon as possible, so that the physical usability testing can be performed (relatively) early on. This leaves more time to adapt and improve upon the design after the usability testing has been completed.

When all formative testing is completed and the design is finalized, work on the final version of the escape room will be started. Puzzles may be physically remade from the ground up or development may continue from a prototype version.

3.4 Evaluation Phase

The final phase will be the evaluation of the product. At this point, the design will have been fully realized and no further (large) changes will be implemented. In order to evaluate the effectiveness of the design, summative testing will be conducted. The result thereof will be a number of measurements (both qualitative and quantitative data) that indicate how well the final product performs its desired functions. This data will be used to evaluate whether the design meets the product requirements that were determined in the earlier phases of the project.

4. Ideation

In this section, the process of idea generation for the escape room will be described.

During the ideation phase, ideas for potential puzzles, technologies and puzzle elements were generated using brainstorms, Internet research and the items already present at the museum. After the first meeting with the museum staff, measurements of the escape room and its most prominent furniture were taken. These measurements were then used to create a floor plan of the room, which can be seen below. A full-size version of this floor plan image can be found in Appendix II. Additionally, an inventory of the furniture and materials already present in the room was made. These items were available for use if so desired, therefore documenting them is important.

Already present in the escape room were:

6. Numerous code locks / padlocks
7. Large wooden ('treasure') chest with large key and space for two locks
8. Old rotary telephone, manufactured in Hengelo
9. Board with many LEDs, switches and dials
10. Model of House Hengelo inside a display cabinet
11. Transposition cypher puzzle (framed on the wall)
12. Faux book: English dictionary that is actually a safe
13. Encyclopedias marked with Roman numerals (I – X, V is missing)
14. Metal frame in the style of Hengelo Station's construction beams
15. Six wooden stools
16. Many aerial photos of Hengelo, from multiple time periods
17. Three Android tablets (Samsung) with protective cases
18. Television that is to be wall-mounted (but is not yet)
19. Headphones, for use with the tablets
20. Printed 360-degree panorama photo on the floor
21. Drawn panorama view of Hengelo (same location as the photo on the floor)
22. Large wooden table with three drawers
23. Many miscellaneous items for decoration

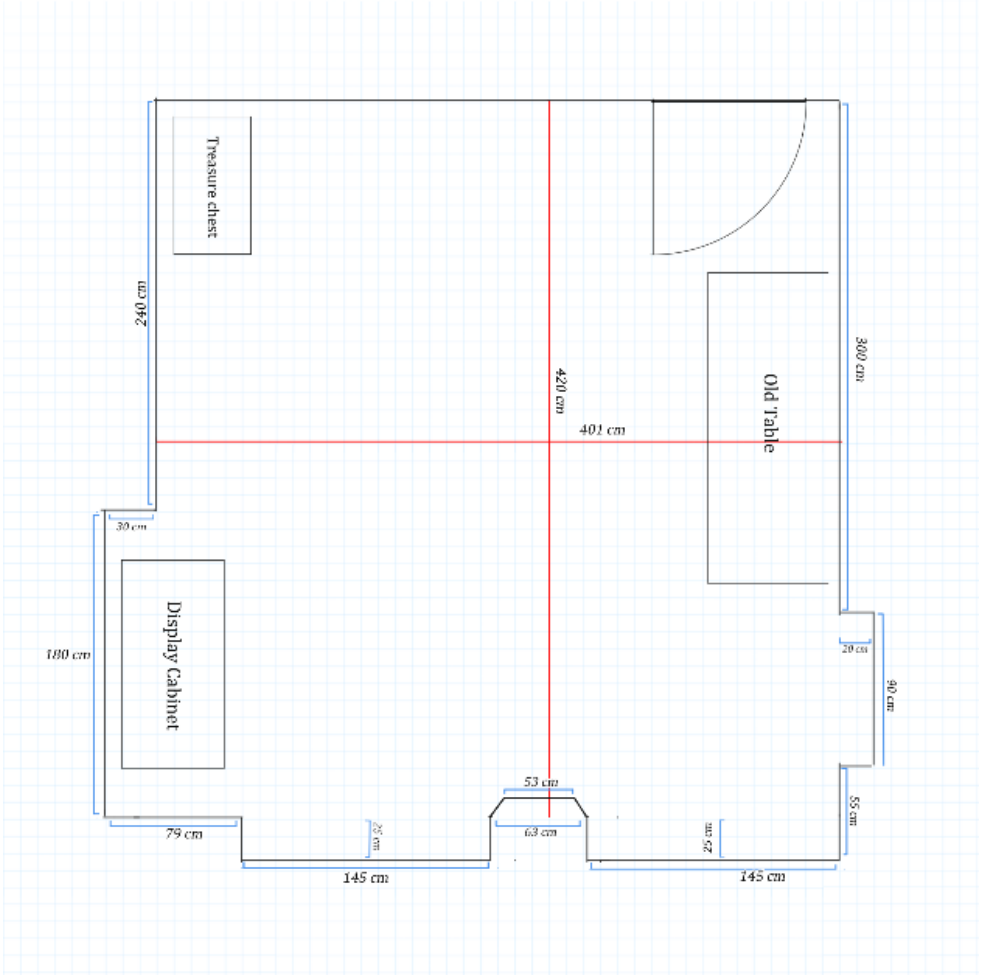


Figure 1: Floor plan of the escape room space.

The results of this initial ideation can be seen in the mindmap below. A full-size version of this image can be found in Appendix III. In the mindmap, the ideas are (roughly) divided into categories; this was done for the sake of clarity. This division was not present in the list of ideas that resulted from the first ideation session.

This ideation process was carried out in multiple sessions, both before and after the initial meeting with the client. It is for this reason that some of the generated ideas are not realistic for incorporation in the museum's escape room.

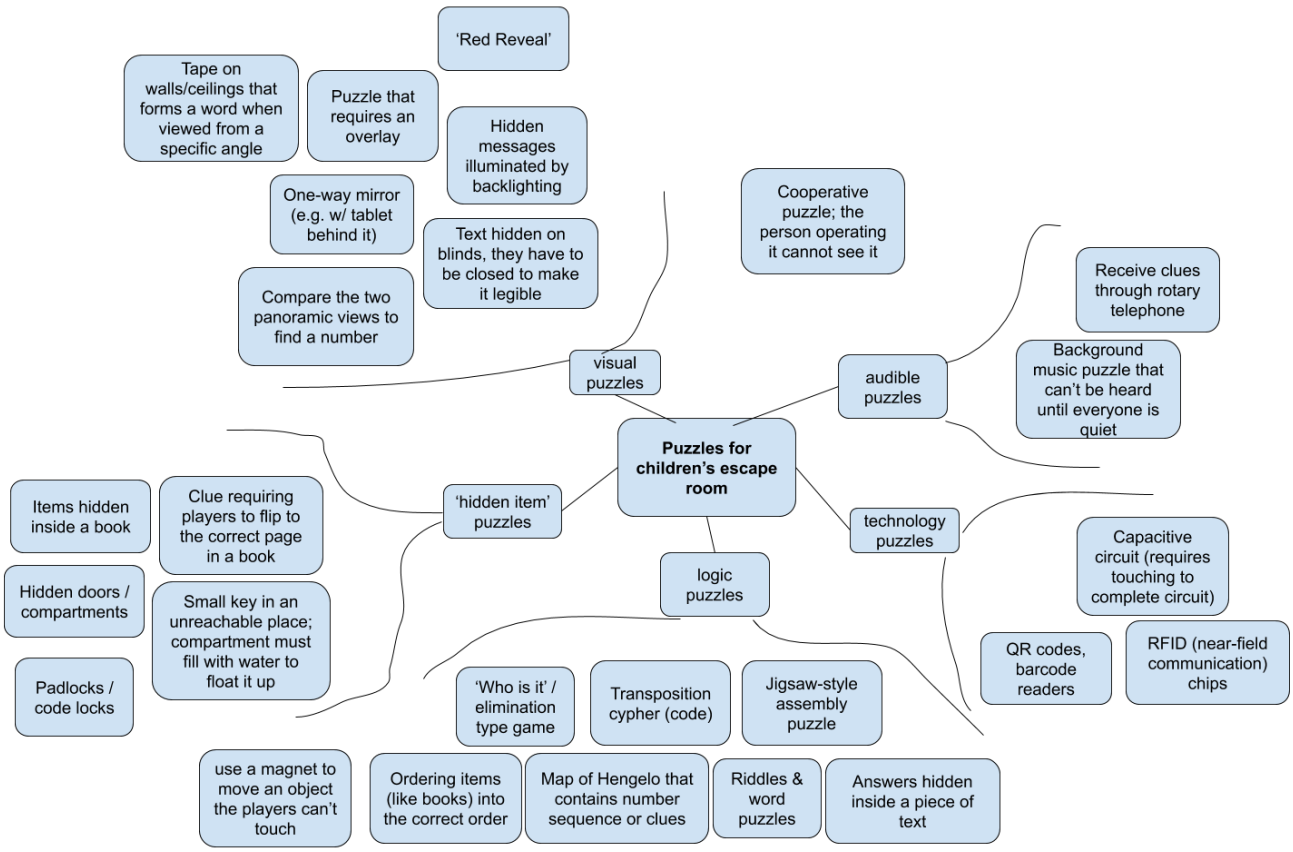


Figure 2: Mindmap of the ideation results, categorized.

5. Specification

5.1 Requirements

After the (initial) Ideation phase was completed, an extensive list of puzzles and puzzle elements (see Figure 2) was obtained. Through the very divergent nature of the ideation process a lot of different ideas were generated. However, not all generated ideas may be suitable for this particular escape room, its owner(s), target audience or environment. Creativity, in this context defined as a process that produces an outcome that is both novel and valuable (Sternberg, 2006), requires both convergent and divergent thinking to ensure appropriateness and originality (Dineen, Samuel, & Livesey, 2005). Thus, a way to filter this large pool of ideas is required.

For this purpose, a list of requirements was created, based on input from the client, practical considerations and the measurements of the physical room that is available to the project. The generated ideas were then tested against these requirements: if one or more requirements were not met, the idea was discarded.

The requirements can be split into two categories. Design requirements are factors that have a central role in the creation of the escape room's design; they are the core goals that the final result must fulfil. The practical considerations are constraints that limit the design in some way, but which are not necessarily related to functional aspects of the escape room.

The requirements and practical considerations for this project are as follows:

Design Requirements

- *The escape room must be suitable for children aged 8 to 14.*

Since the target age group is relatively large, care must be taken to ensure that the difficulty level of the escape room is sufficient (but not excessive) for both the younger and older children. Prior knowledge about the escape room's subject should not be required.

- *The escape room should be as self-sufficient as possible.*

There is not enough manpower available at the museum to provide players with a (constant) supervisor, and the presence of an adult in the room is not guaranteed. Thus, the escape room should be as self-explanatory as possible, to minimize the amount of hints and other external guidance needed. Help from museum staff is available if necessary, but it should not be needed too often.

- *The escape room must be themed after the history of Hengelo.*

Since local history is the main focus of the museum, the escape room must also address this theme in order to be fitting. The industrialization, which was the main driver in transforming Hengelo from a relatively unremarkable town to a large city, is a preferred subject. It would be appreciated if the participants learned something about this theme.

- *The escape room must be entertaining for the target audience*

The main purpose of this escape room is to be fun. Therefore, it is essential that the final game is considered enjoyable by the target audience.

- *The escape room must be easy to maintain and operate.*

Since all museum staff are volunteers and the majority of them are senior citizens, the maintenance and operation of the escape room should be relatively simple. High-tech elements, for example, may be too difficult to reset or troubleshoot when issues arise. The same goes for puzzles that take many or difficult steps to return to their entry state.

- *The escape room should be playable with up to six children.*

The museum wants the escape room to be playable by groups of up to six children.

Practical considerations

- Only one relatively small room is available to the escape room project.
- The escape room's puzzles should not have the potential to become dirty or create stains.
- Participation in the escape room should be safe; there should be no sharp edges, exposed wiring et cetera.
- The escape room should be finished within the project's time frame (February – July 2019).

5.2 Selection

Reasoning for discarded ideas

Some ideas are interesting and have a certain novelty aspect to them, but are simply not practical (such as the idea of retrieving a key by it floating in water, which can get very messy). Others would be very feasible but are not practical for this particular escape room. A good example of this would be the use of barcodes, QR codes or RFID tags. This is an aspect that would be quite feasible in terms of technology, but it was ultimately not implemented because the maintenance was considered to be potentially too confusing or difficult for the user group.

For instance, the Android tablets that could scan / detect an RFID tag or QR / barcode would have to run some kind of app. The functionality could be broken by future software updates to the tablets, physical damage to the tablets et cetera. Additionally, if some aspect that requires an Internet connection were added, any trouble with the Wi-Fi connection at the museum would render that puzzle element unusable. Moreover, these are all issues that the museum staff members would generally not know to troubleshoot and repair easily. Since there were plenty of other ideas, the decision was made to minimize the reliance on 'smart' connected devices.

5.3 Initial design

The puzzles and puzzle elements that were selected for incorporation into the escape room were:

- Jigsaw / assembly puzzle
- Overlay / 'Red Reveal' effect
- Hidden messages illuminated by a backlight
- Padlocks and code locks
- UV (flash-)light to reveal hidden messages
- One-way mirror
- Use of the old computer switchboard to display a code
- Finding a clue on the correct page of a certain book
- Number / code incorporated into map / photos / model of Hengelo
- Items hidden inside (faux) books
- Receiving clues / entering codes into rotary telephone
- Use panorama views to hide clue / number

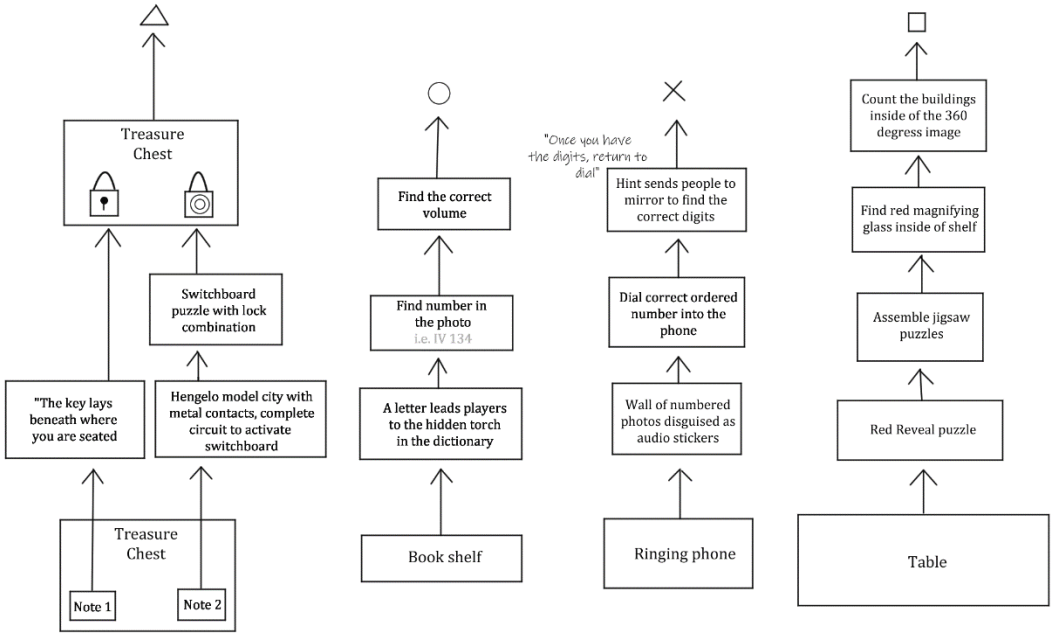


Figure 3: The first (interaction) design for the escape room.

The way the selected puzzle elements were divided into the initial design can be seen in Figure 3. The escape room is divided in four major puzzle sequences, which are represented by simple geometric shapes: A cross, a circle, a square and a triangle. These symbols were chosen because they are easily recognizable.

The symbols should not be confused with any other elements or clues in the escape room; alphabetical letters are not used throughout the escape room (with which the cross could possibly be confused as being a letter X), and the symbols will likely not be mistaken for numbers.

Dividing the escape room into four separate paths was a conscious choice. A group of five or six children, especially on the younger end of the target audience, will likely not have a clear, thought-out division of work when playing through the escape room. Learning to collaborate and communicate are part of the 21st century skills, after all. In an escape room with one continuous path, this could result in some children not playing a (significant) role in the solving of the puzzles, either due to them simply not understanding what the next step should be or other children (intentionally or not) excluding them from the process.

Having multiple puzzles that need to be worked on at the same time helps alleviate both of these issues: if a certain puzzle step is not clear to a child, they can simply decide to look at one of the other puzzles. Similarly, if one child is working on a puzzle continuously without letting others contribute, the others can simply decide to focus their attention elsewhere and progress can still be made by both parties.

The resulting design can be categorized as a multi-linear puzzle path: a series of linear puzzles that can be performed in parallel (Wiemker et al., 2015). Completing all puzzle paths will allow the players to complete the meta-puzzle: a puzzle dependent on solving all other puzzles in the escape room (in this case: discovering the way to 'escape' by using the solutions from all other puzzles to form a code).

Additionally, the design incorporated both physical and mental puzzles. This is done to accommodate participants with different skills sets, so that the entire team is engaged (Wiemker et al, 2015).

In short, the four puzzle paths in the initial design were as follows:

- Treasure chest: The chest has two locks on it.
    - For one, a key must be found underneath a stool.
    - For the second, a wooden puzzle in the shape of Hengelo must be completed. This will trigger the code to the lock to be displayed on the computer switchboard.
    - Opening up the chest reveals the value for △.

- Bookshelf: A bookshelf stands in the escape room.
    - Through a hint located on the shelf, players must find a UV flashlight inside a 'dictionary'.
    - Using this flashlight, they reveal a code (located on a photograph near the bookshelf) that guides them towards a specific book.
    - Inside the book, a paper stating the value for ○ is found.

- Telephone: The telephone mounted on the wall suddenly rings.

    - It guides the players to the images mounted on the walls, which have audio guide stickers with numbers on them. Arranging these in the correct (chronological) order yields a code, which advances the phone to a new audio fragment when dialed into it.
    - The second audio clip hints players towards the hand mirror, which will reveal the value for ✕ when viewed with a bright backlight.

- Jigsaw puzzle: A disassembled jigsaw puzzle lies on a table.
    - Players must assemble the puzzle and turn it over, revealing a red mess of shapes, text and patterns.
    - Players must find a magnifying glass with a red lens (located in the bookshelf) and use it to read the hint on the puzzle.
    - The hint on the puzzle tells the participants that counting the number of buildings on the 360 degree panorama photo on the floor gives the value for ☐.

Finding the values for all four symbols (and thus completing all the puzzles) yields a code. When this code is dialed into the telephone, an audio clip played from it will tell the players how to escape from the room.

6. Realization and Iterations

6.1 Paper Prototype

The first fabricated iteration of the escape room was the so-called 'paper prototype': a cheap, relatively easy to fabricate substitute for the physical puzzles. In this prototype, all items in the escape room are emulated via paper cards. These cards (see Figure 4) contain a description of whatever item they represent. They are laid out around a printed floor plan of the escape room. On a laptop, a mockup of wall-mounted images is shown to the participants to simulate paintings and photos hanging on the wall of a physical version of the escape room. This image can be seen in Figure 5.

Figure 4: Example of the item cards used in the Paper Prototype.

Figure 5: The image used to simulate the paintings / photographs placed on the wall of the escape room in the paper prototype.

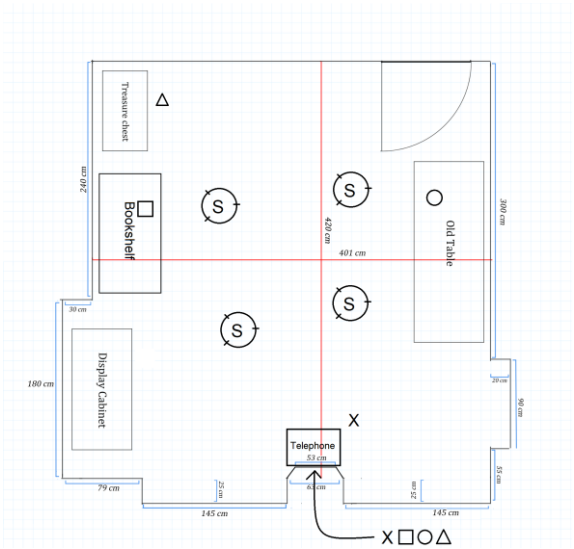


Figure 6: The floor plan 'game board' used in the Paper Prototype tests.

Representation of puzzles and changes relative to initial design

In the following section, the paper representations of the four puzzles will be described. Additionally, the changes mentioned below will be highlighted and the reasoning for them will be explained.

After creating the initial design (see chapter 5.3), it was shown to the client, the project's supervisor and peers of the researchers. Feedback received from these parties led to several changes in the design, which means that the paper prototype differs from the initial design in multiple ways.

Treasure Chest

Though the core principle of the treasure chest puzzle has not changed, the puzzle that gives the participants the numerical code to unlock the code lock is very different from the initial design's version. The idea of a physicalized map of Hengelo was dropped. The main reason for this was the realization that completing this puzzle would not require much knowledge about the city itself; participants would be able to simply arrange the different puzzle pieces in whichever way they fit together without paying any attention to why the pieces were the shape they were. Additionally, a jigsaw puzzle was already present in the design, reducing the novelty factor of this puzzle.

The concept of having a physical puzzle complete an electrical circuit (which in turn would trigger the showing of the numerical code) was kept, but the content was changed. The new version (which will be referred to as the 'logo puzzle') involves the logos of companies that were located in Hengelo during the industrialization of the city. The objective of the puzzle is to match these logos to the product that said company produced (or: the industry that said company operated in). To provide the information about these companies in a clear manner, photographs of the companies which show both the product they are associated with and their

logo will be placed around the room. In the paper prototype, this is simulated by a digital collage of images displayed on a laptop, which can be seen in Figure 5.

The puzzle will be built out of wood: the logos will be etched onto small wooden pieces, which can be placed into recessed areas on a baseboard. The electronics for the puzzle will be located below this baseboard, and the products / industries that are to be matched to the company logos will be etched into this baseboard. In the paper prototype, this baseboard is represented by a piece of paper with the products / industries and empty areas in which the logos (printed and cut out) need to be placed. When completed successfully, a researcher will tell the participant(s) the code that would normally be displayed on the switchboard.

Bookshelf

The bookshelf puzzle functions as described in the initial design. The way it is represented in the paper prototype is as follows:

The bookshelf is described briefly to the participant(s) in the introduction of the escape room.

Upon inspection of the bookshelf, the participant(s) is (are) told what items are on the bookshelf: a magnifying glass, a piece of paper with some text on it and a flower in a small vase. Additionally, a list of books present in the bookshelf is given to the participant(s). This list is filled with random book titles among an English dictionary and a ten-volume encyclopedia. The purpose of all the random books is to prevent the participant(s) from simply checking all books until they find something.

The rest of the puzzle is represented using (spoken) text.

Telephone

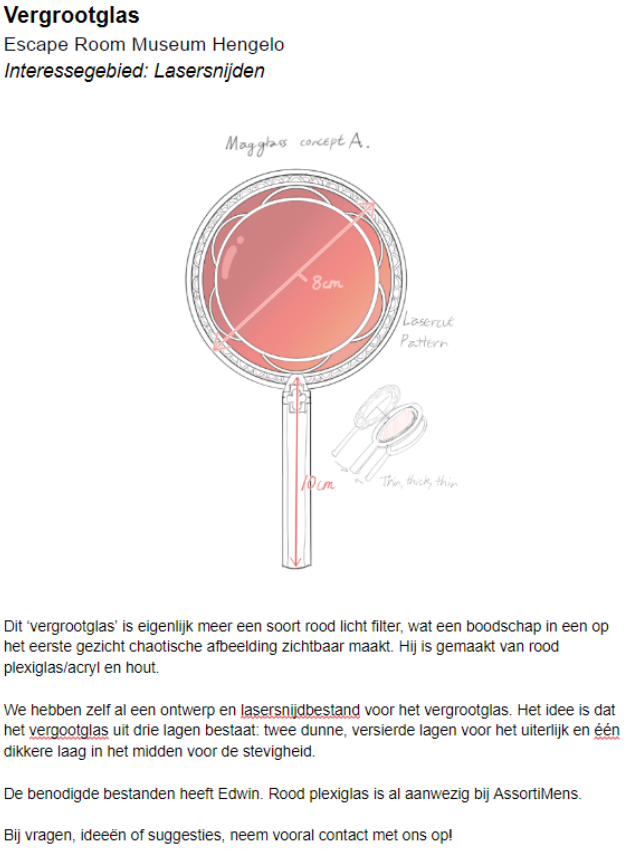
The telephone puzzle functioned as described in the initial design. No actual telephone was present in the paper prototype, so all of its functionality was performed by one of the researchers ('Wizard of Oz' testing, as described by Pernice (2016)). The telephone was represented on the floor plan, as seen in Figure 6. The hand mirror is described to the participants upon inspection.

Jigsaw Puzzle

The jigsaw puzzle worked as described in the initial design. However, because of the limitations of the paper format, the actual making of the jigsaw puzzle was not within the scope of this prototype. Instead, the puzzle pieces are described to the players. When the flipping over has taken place and participants use the red magnifying glass on the puzzle's rear, the hint that would appear is read to the participants.

6.2 Physical Prototype

After the paper prototype testing had been completed and revisions to the design were made, work on the first physical version of the puzzles was started. To produce these, the assistance of the participants at AssortiMens was brought in. Consultation with the supervisors at AssortiMens made it clear that the best way of instructing the participants would be to create short 'assignments' describing what needed to be done for each item that was required. An excerpt of one of these assignments can be seen in Figure 7, and all four full documents can be found in Appendix V through VIII.



Vergrootglas
Escape Room Museum Hengelo
Interessegebied: Lasersnijden

Dit 'vergrootglas' is eigenlijk meer een soort rood licht filter, wat een boodschap in een op het eerste gezicht chaotische afbeelding zichtbaar maakt. Hij is gemaakt van rood plexiglas/acryl en hout.

We hebben zelf al een ontwerp en lasersnijdbestand voor het vergrootglas. Het idee is dat het vergootglas uit drie lagen bestaat: twee dunne, versierde lagen voor het uiterlijk en één dikkere laag in het midden voor de stevigheid.

De benodigde bestanden heeft Edwin. Rood plexiglas is al aanwezig bij AssortiMens.

Bij vragen, ideeën of suggesties, neem vooral contact met ons op!

Figure 7: Screenshot of one of the 'assignments' created for AssortiMens.

Assignments were created for the red 'magnifying glass', the hand mirror, the bookshelf and the logo puzzle. While the first two were picked up and (at least partially) executed, the latter two were not picked up by the participants.

Puzzles and changes relative to paper prototype

As with the paper prototype, the escape room was divided into four main puzzle paths. The way the puzzles were realized will be discussed. In a similar manner to the previous section (6.1), any changes made between the paper prototype and the physical prototype will be noted and explained.

- **Treasure Chest**

The logo puzzle was developed by the researchers themselves. For this version of the escape room, the complete functionality of the logo board was not yet completed. Instead, an early version of the front panel and the accompanying logo pads were placed on the ground, in

addition to photos of the relevant products with logos in them. For convenience, photos found on the Internet were used, which did clearly represent the products but were not necessarily historically accurate.

Since the logo puzzle itself could not trigger a light sequence to be started on the Arduino, the USB power supply was kept by the researchers until the logo puzzle was properly filled in. The participants were able to recognize that this could be used to hook the USB cable coming from the Arduino up to the power without much delay.

The padlock half of the puzzle (find the key underneath a stool) works as described in the initial design and the final version (chapter 6.3).

Unlocking both locks allows the treasure chest to be opened and ✕ = 87 to be observed.

- **Bookshelf**

The bookshelf was not built by the researchers or the AssortiMens participants; rather, it was bought from a second-hand store. As such, it does not exactly match the ideated design seen in the AssortiMens assignment and earlier concept designs. The final bookshelf has two shelves behind wooden doors, with a drawer above. It can be seen in Figure 13 in chapter 6.3. Its functionality remains largely unchanged, however.

Another small change was the location of the hidden UV code: since the UV pen seemed to absorb any (printed) ink it touched, the code is beside a photograph, rather than on it.

The rest of the puzzle was the same as described in the initial design (section 5.3) and the final design.

- **Telephone Puzzle**

The planned modifications to the telephone had not yet been completed, so the phone was not present in the first physical prototype of the escape room. The second half of the puzzle (involving the hand mirror with the hidden message) was present; the mirror was fully functional and was placed in one of the drawers of the wooden table.

- **Read Reveal – Jigsaw Puzzle**

The jigsaw puzzle was not fully complete in this version of the escape room. The acrylic puzzle pieces had already been produced and the front image (of a Hengelo street) had already been applied, but the rear 'red reveal' pattern was not yet present on the pieces. Since the flipping over of the completed puzzle would not yet yield an intact red reveal pattern, participants would be given the pattern on a piece of A4 size paper upon flipping over the completed jigsaw puzzle. This printed version is approximately the same size as the puzzle itself.

The red magnifying glass was already completed and functional.

The hint present in the red reveal pattern was changed between the paper and physical prototypes. For reference, the paper prototype's version of this hint was "◯ can be found by counting windows on the floor" (◯ was said as 'circle'). Two factors led to this change: most importantly, the number of windows visible in the 360-degree panorama on the escape room's floor was both very high and quite ambiguous, as it was not clear where one window ended and the next one began in multiple locations. Secondly, as one of the participants mentioned during

the paper prototype experiments, ‘counting windows on the floor’ can also be interpreted as counting windows present in the escape room itself (by using an alternative definition of the word ‘floor’).

Alternative versions of this clue were evaluated. Ultimately, the decision was made to not let the clue involve the counting of objects to avoid ambiguity. Instead, the clue was changed to ‘☐ is the number on the church’. Stickers with (random) numbers were placed throughout the panorama image, including one on the church. The number written on that sticker represents the value for ☐.

6.3 Final Version

The finalized version of the escape room is quite similar to the version used in the first physical experiment. The same structure of four parallel puzzles found in earlier designs is retained, and the content of the puzzles is generally comparable. The main differences lie in the aesthetics and physical realization of the puzzle element. For example, the logo puzzle was remade because the original design was found to be too large. The final version of this puzzle used the same design, but scaled it down to be less cumbersome.

Some changes in content were in order, too, though. The photos associated with the companies in the logo puzzle, for example, were changed to include photos from the museum’s archive. Not only is this a better use of the available resources, but this also helps improve the historical accuracy of this puzzle. Authenticity is desirable in a puzzle like this, especially inside a museum.

A note on the structure of the following section

Following is a more detailed description of the four puzzles and the items associated with them. As opposed to section 6.1 and 6.2, changes relative to the paper prototype will not be explicitly highlighted and reasoned for within the puzzle descriptions. This is done because this description of the final puzzles is intended to also be available as a standalone document which serves as a full explanation of the escape room’s intended procedure. Therefore, many of the puzzle elements and design choices that have already been explained in previous will again be discussed here.

Puzzle 1: Jigsaw Puzzle, Red Reveal

This puzzle is indicated by a square symbol (☐) which can be seen on the wall directly behind the large wooden table in the escape room. On top of the table is a disassembled jigsaw puzzle, along with an acrylic frame. One side of the puzzle pieces shows a photograph of a central street in Hengelo (taken in the 1960s), while the other shows a pattern of meaningless red text. The (completed) jigsaw puzzle can be seen in Figures 8 and 9.

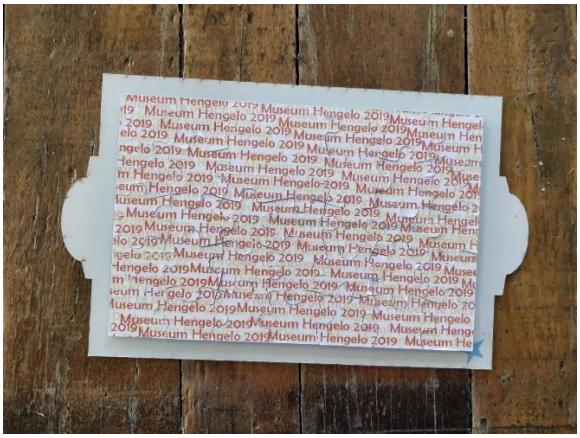


Figure 8: The rear of the jigsaw puzzle (assembled)

Figure 9: The front of the jigsaw puzzle (assembled).

The frame has an instructional text on it which reads "*Maak de legpuzzel hierin, zodat je hem om kan draaien*." ("Complete the jigsaw puzzle in here, so that you can flip it over."). It is pictured in Figure 11.

Figure 10: The red 'magnifying glass'.

Figure 11: The acrylic jigsaw frame.

As instructed, the objective is to complete the jigsaw puzzle and flip it over, so that the rear side is visible. The rear image of the jigsaw holds a hidden message in its center, which is printed in a cyan hue. The other text, which consists of red hues, makes it so that reading the hidden message normally is very difficult. In order to make it visible, the players must find a red-colored 'magnifying glass' inside the bookshelf (of Puzzle 2). This tool, which does not actually magnify, has a red-tinted piece of acrylic inside rather than a piece of glass (see Figure 10).

Holding this over the jigsaw's rear will filter out the red hues of the background text, making the secret message visible. This effect can be seen in Figure 12.

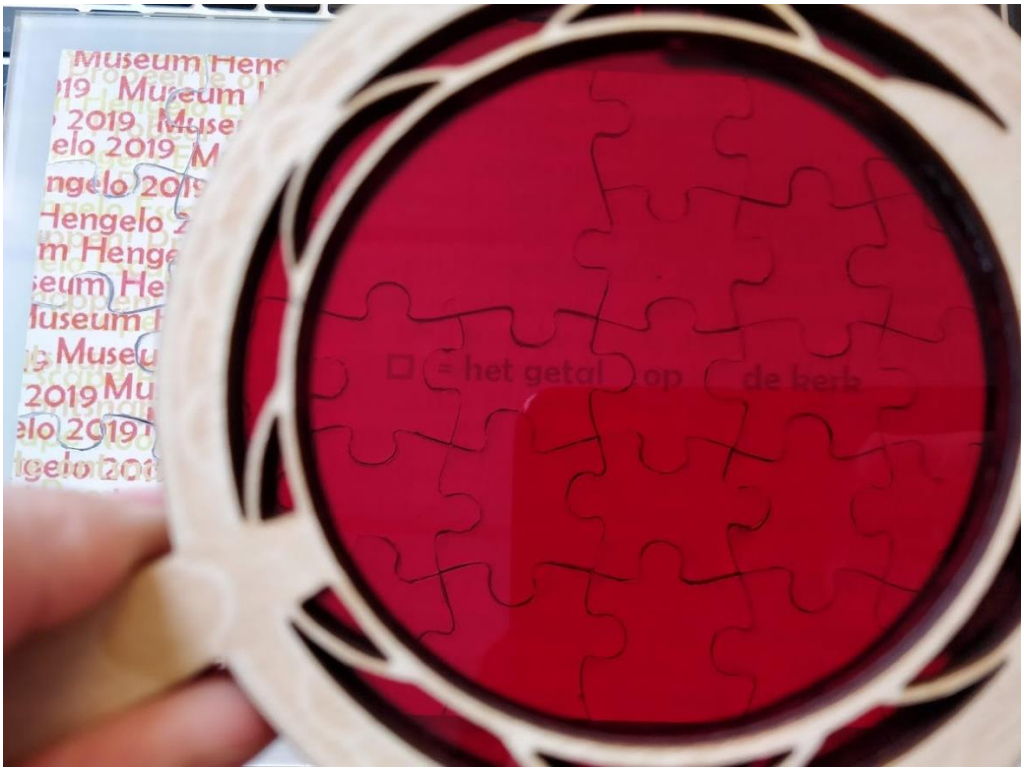


Figure 12: The red 'magnifying glass' makes the hidden text on the jigsaw puzzle's rear visible.

The text on the jigsaw's rear reads "☐ = *het getal op de kerk*" ("☐ = the number on the church"). This number can be found by locating the 360-degree panorama photo on the floor of the room, which has been labeled with stickers. On the photo, a church can be seen, and it is marked with a sticker with the number 48 on it. Correctly working through this puzzle thus yields ☐ = 48.

Puzzle 2: Bookshelf, UV flashlight

The second puzzle is marked with a circle symbol (◯). It is centered around an old bookshelf placed against one of the escape room's walls. In the drawer of this bookshelf a hint paper can be found, along with the 'magnifying glass' from puzzle 1. The hint paper reads "*Soms raken er dingen verloren bij het vertalen.*" ("Sometimes things get lost in translation."). This hint should lead the players to the English dictionary, found in the lower section of the bookshelf.

Figure 13: The bookshelf (opened).

Apart from this dictionary, there are many other books in the lower half of the bookcase. Most of these books are not related to the puzzle in any way and are there solely to make taking out books at random to see if there is anything inside less attractive to the players. There is also an encyclopedia consisting of ten volumes, which are marked in Roman numerals. Volume five (V) is missing; the English dictionary is instead decorated with this symbol.

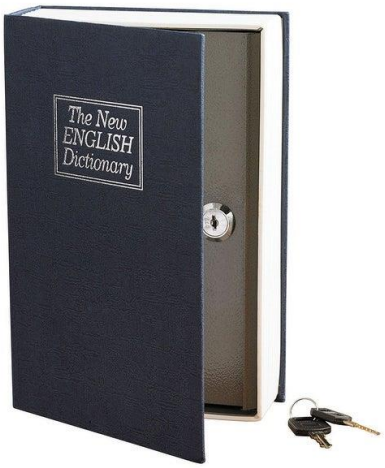


Figure 14: Product photo of a faux dictionary, as used in the escape room (2016).

The dictionary is not actually a book, but a safe in which items can be stored that is made to look like a book (as can be seen in Figure 14). Inside of the safe is a small flashlight that emits ultraviolet light. Shining this light over one of the photographs hung on the wall directly behind the bookshelf reveals a code: *IV 139*. This code refers to the fourth book of the encyclopedia collection, page 139. Opening the book and navigating to this page reveals that there is a slip of paper hidden inside, which states that ◯ = 17.

Puzzle 3: Rotary Telephone, Hand Mirror

Indicated by a triangle symbol (△), this third puzzle revolves around the use of an authentic Heemaf type 1955 wall-mounted rotary telephone (seen in Figures 15 and 16). This telephone, which was produced in Hengelo, has been modified internally to be controlled by an Arduino microcontroller.

Figure 15 (left): A close-up of a Heemaf type 1955 rotary telephone, as used in the escape room (Schaddelee, 2017).

Figure 16 (right): The Heemaf type 1955 telephone mounted on the room's wall. The Arduino control box is not visible in this mage.

After five minutes of playtime in the escape room, the telephone rings. When the earpiece is picked up, an audio fragment plays. The hint "*De volgorde van de geschiedenis van Hengelo vormt een code. Kom hier terug als je deze code gevonden hebt.*" ("The order of Hengelo's history forms a code. Return here when you have found this code.") is spoken in this audio fragment. The 'order of history' refers to the four photographs of Hengelo (see Figure 17) that are located on the walls of the escape room. They are marked with numbers (on a sticker).

Figure 17:Two of the four photos of Hengelo from different eras.

Taking the numbers from these stickers and ordering them in the chronological order of the photos yields an 8-digit code. This code needs to be dialed into the telephone, because doing so will cause a new dialog fragment to be played. The new fragment contains the hint "*Gebruik de spiegel, en zie het licht.*" ("Use the mirror, and see the light."). This refers to a small hand mirror, which can be found in one of the drawers of the large wooden table (the same upon which puzzle 1 mostly takes place). This mirror, seen in Figure 18, is made from laser-cut wood, a piece of half-mirror acrylic (????) and is covered on the back by a piece of cardboard.

Figure 18: The hand mirror with hidden message.

It is a half-mirror, so only one side (the front) is reflective. Hence, if a strong enough backlight is placed behind the mirror, it will shine through. This must be done to reveal that the cardboard backing of the mirror actually reads "△ = 31".

Puzzle 4: Treasure Chest, Logo Puzzle

This puzzle, which is indicated by a cross-shaped symbol (✕), is focused around an old chest that is located in the corner of the escape room. This chest is locked by two padlocks, one of which requires a key and one of which needs a four-digit code to be opened. Hint papers are placed on the chest, which tell the players how to proceed with opening the two locks. A photo of the chest can be seen in Figure 19 below.

Figure 19: The 'treasure' chest with its two locks.

The first hint, placed near the padlock that requires a key, reads "*Vind de sleutel. Je zit dichtbij!*" ("Find the key. You are close!"). The second sentence has a double meaning in this case, as it also means that the participants are sitting close to the key when literally interpreted. Said key is attached to the underside of one of the stools that is present in the room.

The second hint reads "*Maak de juiste combinatie van Hengelose bedrijven en hun producten om de code te vinden.*" ("Make the correct combination of Hengelo companies and their products to find the code."). This refers to the logo puzzle, which is located next to the chest on the floor. It consists of an old computer system's control panel, five labeled holes and five wooden pads with company logos on it (which fit the holes). The objective of the puzzle is to correctly match the company logos to the product that these companies produced. Doing this will light up the switchboard, revealing a number sequence which corresponds to the code that opens the second padlock.

The logo puzzle, which can be seen in Figure 20, is powered by an Arduino microcontroller. Underneath the wood surface where the recessions for the logo pads are, circuitry (made out of copper tape) runs from the Arduino past all five recessions and finally back to the Arduino again (see Figure 21). The logo pads themselves also have a small piece of copper tape on their rear. When a pad is placed in the correct recession, the circuit on the back of the wooden panel is completed. Placing all five pads in the correct position means that the entire circuit (from and to the Arduino board) is completed. This is measured by the Arduino.

Figure 20: The (completed) logo puzzle, seen here on top of the chest.

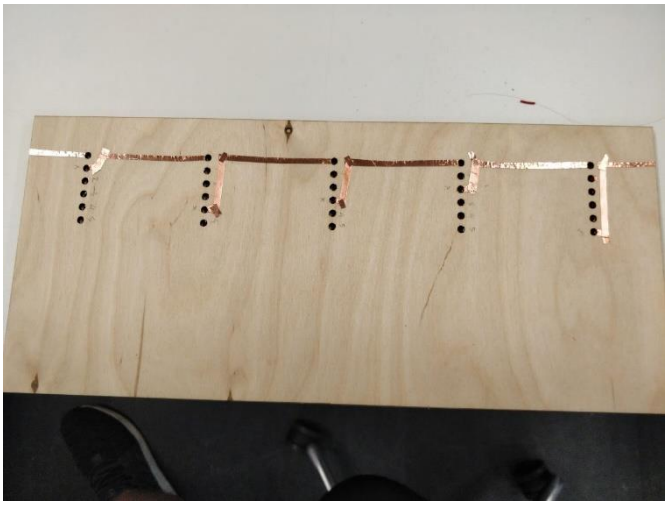


Figure 21: The circuitry on the bottom side of the wooden panel.

Completing the circuit (and thus allowing current to run through it) triggers a variable in the Arduino's code, which activates a row of LEDs on the control panel. The lights, which are accompanied by numbering on the panel itself, first go through an animation to catch the players' attention, and then blink in a particular order (1 - 8 - 6 - 8) on repeat. This number sequence opens the code lock on the chest.

Opening up the 'treasure' chest reveals a small piece of paper inside, which states $\times = 87$.

7. Experiments

7. 1 Paper Prototype experiments

For the paper prototype, participants were gathered in the style of hallway testing (Reeves, 2016). The researchers randomly selected students sitting around the University of Twente and asked them if they wanted to participate in an escape room test. A time indication of about 30 minutes was given for the first few participants; since reality showed that the duration of the full experiment was consistently longer than these 30 minutes, later recruiting gave a time estimation of 45 minutes.

To clarify what the scope of this paper prototype test is, the one-page test plan principle (Reckless, 2016) is used. The format used is inspired by the work of Talks (2013), using the so-called 'dashboard layout'. The test plan can be seen in Figure 22.

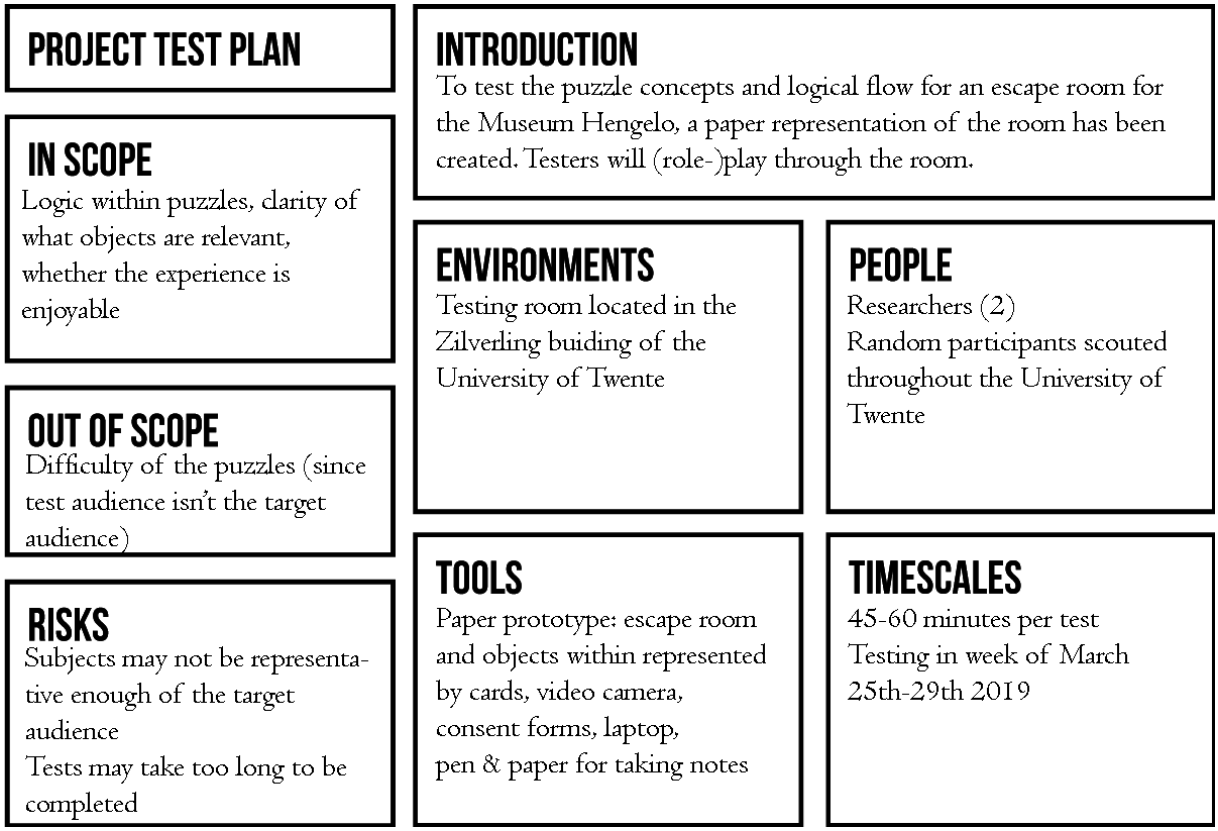


Figure 22: One-page test plan for the paper prototype.

As is noted in the test plan, the paper prototype is merely intended to test whether the logic within each puzzle is sound. The physical aspect of the escape room is not within the scope of these tests, since that can obviously not be emulated accurately using this format.

As participants entered the room where the test would be conducted, they received a short briefing on the contents and method of the experiment. Then, they were given a consent form (as can be found in Appendix IV) and were allowed to read through it carefully. In the case that the participant(s) did not agree to being filmed, the camera placed atop the table on which the

paper prototype was situated would be powered off and removed. Since all participants agreed to being recorded, though, this did not happen during the paper prototype testing.

The experiment itself started with a short explanation of the escape room and its rules, as well as some pointers with regard to the paper prototype format (e.g. when a clue is found or a puzzle is solved, the researchers will say so). The participant(s) is (are) asked to speak all their logical reasoning out loud, so that the researchers may follow their thought process and can make note of the participants' successes and failures. After this introduction is completed, a stopwatch is started and the participant is told to commence with the escape room.

Figure 23: A participant during the paper prototype experiment (anonymized).

During the experiment, the researchers generally refrained from engagement with the participant(s) unless they were asked a question or the participant(s) experience prolonged difficulties with a particular element of the escape room. This was done in an attempt to keep the participants' experience as genuine as possible. Instead, the researchers took notes, tracked the progress of the participant(s), answered questions and operated elements of the game when necessary. For example, after about 5 to 10 minutes, a researcher would inform the participant(s) that the telephone was 'ringing' and tell them the message that would be heard in the earpiece.

The participants' actions were noted on a chronological basis, creating a step-by-step list of their progress through the escape room's puzzles. The video recording was later used to verify that this list of actions was correct, and to add any significant details that the original transcript missed. These transcripts can be found in full in Appendix IX.

After the experiment had concluded, participants were asked questions about their experience. Their opinions and suggestions were noted down and discussed with them. Once all questions had been asked and neither the researchers nor the participant(s) had any remarks left, some butter cake was offered to the participant(s) as a token of gratitude and they were allowed to leave.

7.2 Physical Prototype experiment

The first physical version of the escape room was tested with one group of six children (four 11-year-olds, two 12-year-olds). This group of children was recruited through one of the museum's collaborating schools. All of the children lived in Hengelo. Prior to participation, the children's parents received an informational brochure about the experiment and a consent form, which the children were asked to bring with them on the day of the experiment. These documents were verified and approved by the Ethics Committee of the EEMCS faculty of the University of Twente and can be found in Appendix X and XI, respectively. A date was agreed upon (May 28th, 2019) and the children (without parents) came to the museum to participate in the experiment.

Upon arrival, the aforementioned documents were retrieved from the children and inspected to ensure that all parents gave their permission for the experiment, the video recording of the experiment and the complimentary piece of chocolate the children would receive afterwards. Then, a short explanation of what an escape room is, how the experiment would proceed, and some house rules from the museum was provided. The children were allowed to ask any questions they had and were given a moment to use the bathroom if necessary.

After this, the children were taken to the escape room itself. Some final clarification on what items were and were not part of the game was given (since some of the researchers' equipment was also present). Then, the timer was started and the children were allowed to begin their playthrough of the escape room.

During the escape room, the researchers once again sought to interfere with the process as little as possible. They observed, made notes, and manually operated the puzzles that were not fully self-sufficient yet. Questions from the participants were answered, provided that they were not related to the content or answers to the puzzles.

After the escape room itself had been completed, the participants were gathered for some evaluation. Amongst other things, they were inquired about the (perceived) difficulty of the puzzles, whether they enjoyed themselves and if they would recommend the escape room to their friends. The list of questions they were asked can be found in Appendix XV.

Once the question and feedback session had concluded, the children were given a candy bar to thank them for their participation and subsequently dismissed.

7.3 Final experiments

To recruit participants for the final experiments, different schools from the Hengelo area were contacted by either e-mail or telephone. Unfortunately, this approach did not yield any test participants in the end. One school never replied to the e-mail message that was sent to them, two were not willing to extend the information about the experiment to their student's parents and one had already planned a school-wide activity on the selected date.

Alternative methods for recruiting participants were evaluated. In the end, it was decided that a Facebook event page promoting the experiment would be created. This event page would then be shared on local community pages and group pages. Additionally, to maximize the reach of

this small social media campaign, friends and family of the researchers were asked to share the event.

To help with recruitment, the project's supervisor informed some friends and colleagues as well.

In the end, two groups of suitable participants were acquired. The first group was a family, who had replied to the Facebook event. The other was a group of three children who were recruited by the project supervisor. The experiments took place on June 29th, 2019.

As with the physical prototype experiment, the participants were welcomed into the museum lobby and a short introduction was given. Since the consent forms had not been sent out beforehand, the parents were told all information present in the informational brochure used before verbally, and they subsequently received the consent form. Once the consent form had been signed and nobody had any questions left, the participants were given a moment to use the bathroom if necessary. Then, they were taken to the escape room itself.

Before the game started, the parents (if participating in the room) were reminded that they should let the children do the majority of the work, and only help them if they seemed to be stuck. The house rules of the museum were explained, the participants were given their note sheet and a pen, and the procedure for disabling the door's alarm was given. Then, the timer was started and sealed into the safe, marking the start of the experiment.

After the experiment was over, the children were asked a few questions. This used the same questionnaire as the physical prototype experiment. The adults were asked to fill out a form with questions; this can be found in Appendix XVI.

8. Results and Evaluation

In this section, the results from the experiments will be presented. Additionally, some interpretation will be given, and actions taken in direct response to the findings will be discussed.

8.1 Paper Prototype

Seven students participated in the paper prototype testing, divided over six sessions (five students participated individually, two students worked together in a pair). During the paper prototype, the participants' actions were noted in chronological order (as described in the Experiments section). The full transcripts of the experiments can be found in Appendix IX. Furthermore, as described in more detail in chapter 7.1, the time each playthrough of the escape room took was noted, and participants were asked for feedback after the experiment had been completed. Any observations, ideas or concerns the researchers had during the experiments that were not related to the participant(s) were written down.

Out of the fully completed sessions, only the one that involved two students lasted less than half an hour. Times ranged from 29 minutes and 22 seconds to 55 minutes and 28 seconds. The full list of completion times can be seen in Table 2 below.

Experiment number	Number of participants	Number of actions performed	Completion time (mm:ss)
1	1	39	15:42*
2	1	28	34:58
3	1	28	41:33
4	2	36	29:22
5	1	49	55:28
6	1	36	38:26
** Experiment was terminated early*			

Table 2: Completion time and number of steps taken for each experiment session of the paper prototype.

Unfortunately, the first experiment had to be terminated before the escape room was completed due to interruption by a third party, who had reserved the room in which the experiment was being conducted (unbeknownst to the researchers).

The fact that only one session stayed within the envisioned time frame of half an hour is not necessarily problematic, since the time to completion is not within the scope of this experiment. It gives a measure of the variance that can be expected between groups (e.g. the slowest groups may take up to about twice as long as the fastest groups). This is something to keep in mind for later tests or when the escape room is completed and functional.

The amount of actions performed is another measure that was taken, but it is not particularly relevant. It may describe participants' accuracy and efficiency during play. For usability testing of a different product, such as a user interface, these could be interesting data points (as described by Reeves (2016)). However, since it is puzzles that are being tested, they are only telling of two things: The difficulty of the puzzles, which is not within the scope of this experiment, and how some participants prefer trial and error over more restrained, reasoned action.

More important in this test are the qualitative results: the opinions of the participants, and what things stood out during the experiments. The major findings in this regard are described below.

Mirror (Telephone puzzle)

One issue that multiple participants ran into is that they did not understand the phone's hint on how to use the hand mirror ("Hold your image to the light"). The participants in question did not connect the term 'your image' to mean a mirror reflection of themselves, or thought that they should shine a light on the reflective side (the front) of the mirror. Obviously this is undesirable, but it is not entirely conclusive on the difficulty of the puzzle because the mirror could not be physically seen and handled. Holding the mirror, and moving it around, participants could get a glimpse of the hidden message inside of it, which could trigger further investigation. Additionally, rotating the mirror and looking at it from different angles is something that can be done in a matter of seconds (and again, sometimes without expressly meaning to) in real life. With the paper prototype's format, these kinds of accidental discoveries are not possible because every action must be explicitly initiated by a command.

After evaluating, it was decided that the hint spoken from the phone would be changed to explicitly mention the mirror. The interpretation of how to use the mirror is left mostly unchanged, as it was decided that this would likely become clear after (thorough) inspection of the object.

Distracting props / objects

All participants spent some amount of time inspecting and thinking about objects that were not part of the escape room's puzzles. This was to be expected, since identifying what items are and are not part of the game is something that is present in nearly every escape room. However, in some cases a significant amount of time and effort was placed into objects (most noticeably: the display cabinet) that did not serve any purpose other than decoration of the room.

Like the issues with the hand mirror mentioned above, the fact that the display case attracts so much attention may be (at least partially) due to the format of the prototype. It is a piece of furniture in the room and is represented on the floor plan as such, but it is the only furniture that does not have a role in the puzzles. The other starting points for the puzzles were marked with the symbol of the puzzle which starts there (and thus the display cabinet was left unmarked), but that did not seem to help in reducing interest in it. The fact that all items housed within the cabinet are individually described on a separate card may also have to do with it: participants could reason that when there are that many cards in one place, there must be something useful for them there.

The question is, again, how this problem will translate to a physical version of the escape room. Indicating the different puzzles clearly will remain important, because many participants tried to use items from one puzzle with another, unrelated item or puzzle.

Indicate more clearly what the goal / expectation is

Another error which was made by multiple participants is the association and attempted use of a code with a puzzle it is not a part of. For example, participant number six tried to dial a six-digit code into the telephone (by combining the solutions for three of the symbols with the order retrieved from the historical photos), while only a three-digit code was required. This kind of mistake was never seen with the code lock on the treasure chest, however, possibly because it is immediately clear that the lock requires a four-digit key (from looking at the lock, or in this prototype's case, the fact that the description states so).

This ties in to the point addressed earlier about making the four separate puzzle paths more clearly divided. Confusion between the puzzle elements may lead to frustration and / or significant time waste, which is of course undesirable. One participant remarked that he would greatly prefer if the exact number of digits needed to solve the escape room (i.e. the length of the final code, and the procedure of using it) would be clearly specified. In evaluation after the full prototyping process was finished, it was decided that the participants' notepad would be changed to include an indication of the final code and its length. The four symbols were added, along with empty spaces to indicate how many digits each symbol represented. This addition can be seen in Figure 24.

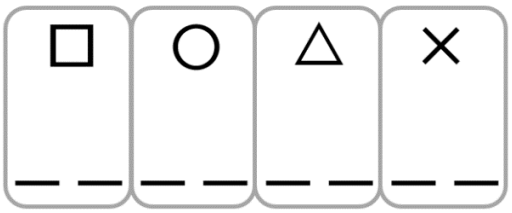


Figure 24: The addition to the participants' notepad, indicating how long the final code should be.

Opinions of participants

All test participants indicated that they enjoyed playing through this paper version of the escape room, regardless of their (relative) performance. Many participants made some remark about the items that were not part of any puzzle; they identified them as a challenging aspect but not necessarily as problematic.

Multiple participants thought the parallel design of the puzzles would be helpful in making the escape room suitable for groups of children. However, as mentioned above, not all participants found the structure of the escape room (solve the four main puzzles to retrieve the final code) to be clear.

Miscellaneous changes

Apart from these major revisions, many smaller changes were made to the design following the paper prototype experiments. Listed below are some examples of these changes.

- The symbols for the telephone puzzle and treasure chest puzzle were switched around, because a triangular piece of cardboard was easier to produce than a cross-shaped one.
- The companies used in the logo puzzle were changed based on feedback from our client, since one of the companies used before did not actually originate from Hengelo.

- The code used for the code lock on the treasure chest was changed to a code that was already in use at the museum.
- The individual numbers that made up the codes for both the telephone puzzle and the final escape sequence were made larger (to be two digits long rather than one) to decrease the feasibility of guessing or 'brute forcing' the code when only one element was unknown.
- The numbers on the historical images of Hengelo (for the phone puzzle) were changed to no longer be disguised as audio guide numbers, to prevent confusion.

8.2 Physical Prototype

The group of six children who participated in the first physical experiment (four aged 11, two aged) managed to complete the escape room in 33 minutes and 5 seconds. During their playthrough, they received three hints to help them along. As with the paper prototype testing, the actions the children performed were transcribed in chronological order. This transcript can be seen in Appendix XII.

The group performed 39 actions in total. Compared to the results from the paper prototype this is on the higher end of the spectrum, but since the amount of participants has gone up by (at least) a factor of 3, it seems relatively low. However, since an 'action' is not a clearly designed unit of measurement and the amount of actions will vary greatly between groups depending on playstyle (regardless of proficiency), no conclusions will be drawn from this measure.

The playtime, on the other hand, is a relevant metric because this experiment places a representative group of players in a (mostly) representative version of the escape room. The time spent was just north of the intended length of 30 minutes, but there are some considerations regarding the time. Firstly, not all the puzzles of the escape room were present, since the first half of the telephone puzzle (with the historical photos that need to be put in order, see section 6.3) was not present in this version. This omission will have saved the children some time; it is unfortunate that this part was not available, since it is suspected to be one of the more difficult puzzles.

Unintended objects present in the room

Another factor that had an effect on the playtime of the group was the unintended presence of some unrelated items in the escape room at the time of the experiment. These included some small items (e.g. nuts and bolts) in some of the drawers and on the floor underneath or behind some of the furniture. These items were missed during the inspection of the room before the experiment had started. They were found by the children and, on multiple occasions, interpreted as being an item that has to be used within the escape room's puzzles. With the exception of one case, they were taken away by the researchers after being found, accompanied by a short explanation (and apology). Though not something that is easily quantified, this will likely have had a negative influence on the children's experience and did cost them some time.

Participants indicated that they enjoyed the escape room. When asked what their favorite puzzle was, the responses were mixed; the language-based puzzles were not underrepresented, despite them being perceived as more difficult.

8.3 Final summative experiment

The final version of the room was tested in two experiments. One was conducted with a family consisting of two parents, one 14-year-old girl, a 11-year old boy and a 9-year-old boy. They managed to complete the escape room in 41 minutes and 15 seconds. The second group, with the three 9-year-olds, finished after 43 minutes and 23 seconds. First, each of the sessions will be described individually, to highlight any observations or problems specific to their playthrough. Then, more general observations will be addressed.

Group 1

Influence of parents

The family in the first experiment played through the escape room at a fairly consistent pace. The participants were enthusiastic and got to work quickly. They worked in parallel at times, one of the parents sometimes taking one or two children with them to work on a different puzzle than what was being attempted at the time. This controlling role from the parents was not necessarily intended for the experiment, because it does not allow the experiment to show how a group of children would go about tackling the escape room's challenges by themselves. However, it was not deemed much of an issue at the time of the experiment and no action against it was taken.

Unfortunately, the parents' involvement went further than merely structuring the approach. The mother, in particular, participated heavily in the actual solving of the puzzles, despite being told to let the children do the work before the experiment started. She was reminded of this after about 10 minutes of play in the escape room, after which the situation improved slightly. However, the logo puzzle was solved with practically no effort from the children, because the mother recognized three or four of the company logos and instantly matched them to the corresponding product / industry. This was rather unfortunate, because (as will be discussed later) the logo puzzle in particular was an area of interest, for which more valid testing results would have been preferable.

Complications with the puzzles

The first group also suffered from unexpected behavior by some of the puzzles themselves. First and foremost, the telephone was not functioning at the time of the experiment. It was working the day before, but when it was installed on the day of the experiment it would not perform. Thankfully, it was able to be repaired in time for the second experiment, but its functionality had to be replicated by the researchers for the duration of the first group's playthrough.

By chance, this technical issue may have actually prevented the first group from getting stuck on the phone's puzzle. After recognizing the imagery that represented the development of Hengelo as a city, the group subsequently formed the (correct) code that was to be dialed into the telephone. For reference, this code is 74-52-68-21. The parents interpreted this code as a phone number, because the area code (with which most Dutch phone numbers start) for Hengelo telephone numbers happens to be 074. So, when the code had been found and it was time to dial it in, the parents instructed their children to dial the sequence 0 74 52 68 21 – without the 0 ever appearing in the escape room itself – which would not have worked if the telephone had been functioning by itself. Since one of the researchers was performing the functionality of the

telephone, however, it was decided that this mistake would be ignored in order to not let the group get stuck on this puzzle.

A second issue with the puzzles themselves arose when the group went to search for the small key to unlock the second lock on the treasure chest. This key is supposed to be taped to the bottom of one of the wooden stools located in the escape room. It took the group a while (and one relatively obvious hint) to come to this solution, but when they inspected the stools, no key was to be found. At first, the researchers thought they had not inspected one of the six stools and were simply unlucky not to have found the key yet.

However, when another strong hint was given alluding to the stools, it became clear that none of the stools contained a key on its bottom. Additionally, the key was not located on the floor somewhere. After explaining that they had come to the right solution and some other issue had apparently occurred, and an apology for the confusion, the reserve key to the lock was retrieved and given to the participants. Only much later it was discovered that the key (and the tape securing it) had fallen off the stool and that one of the participants had stepped on it. The tape had adhered to the sole of the participant's shoe and rendered the key unfindable.

One last thing that had an undesirable impact was the large metal 'editing table' located in the center of the room. This table, the removal of which was requested long before this experiment, contained a few (not properly removable) maps of Hengelo from different time periods. The (approximate) year each map dated from was noted in the corner of the images. The table can be seen in Figure 25, though it must be noted that the tablets and film seen on it there were removed before this experiment.

The table was still present in the room at the time of group 1's experiment, because the museum insisted that a table was present in this location and a replacement was not yet available. The labeled maps on it were interpreted as being related to the telephone puzzle initially, until the researchers informed the group that they were not related to any element of the escape room.

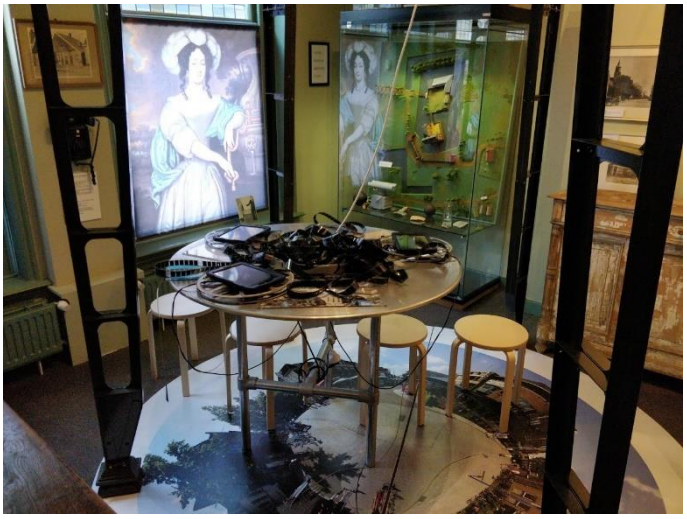


Figure 25: The metal 'editing table' that was present in the room until the final experiment.

Group 2

The second group fortunately encountered significantly fewer technical problems with the room itself: the telephone was functioning (mostly) as intended, all furniture in the room was as specified in the design and all tape applications performed as expected.

During this test, it could be seen that some of the text-based hints caused difficulty for the participants. The hint towards the key taped under a stool and the telephone puzzle, specifically, were problematic: both required several hints and tips before the intended meaning was identified.

The three 9-year-olds alternated between working together on the same puzzle and splitting up to work in parallel. The latter was mostly observed when one child was occupying a puzzle (by using or holding items associated with it) and did not want to collaborate or let someone else try to solve it.

They were quite efficient: many puzzle elements were understood quickly, such as the UV flashlight found in the bookshelf puzzle. The children quickly started shining the light on the objects around them in order to discover hidden messages. With the logo puzzle, however, they did not appear to try and find the information they needed about the companies within the escape room. Instead, they tried out mostly random combinations of logos and products, hoping that something would happen. More on this will be discussed in the 'General' section below.

General

Imagery on the walls

One behavior that was observed in both sessions of the final experiment was the continued non-use of the imagery placed on the walls. Both the logo puzzle for the treasure chest and the telephone puzzle require the participants to retrieve information from photos and paintings located on the walls of the escape room. However, the participants seemingly did not perceive these images to be a part of the escape room, at least for these puzzles. When using the UV flashlight, the photos on the wall were checked for hidden messages just as any other object in the room.

This observation was less strong in the first group, but that was likely due to the fact that the parents largely eliminated the need to use the photos for the logo puzzle by solving it from prior knowledge. Additionally, the interference of the metal editing table in the phone puzzle may have skewed the process there as well.

A smaller, somewhat related note is that the first group experienced some difficulty finding the hidden message on the photograph behind the bookshelf. This difficulty did not only stem from the given fact that the message is hidden, but also from the way in which it was incorporated into the photograph. Because the UV pen did not work properly when writing over an existing image, as mentioned in chapter 6.2, the message was written on the empty, exposed area of the picture frame above the actual image. The participants did shine the light over the picture multiple times, but only focused on the image itself rather than the frame surrounding it; the light of the flashlight never hit the upper area of the picture frame. They had to be hinted into checking more than just the images themselves before finding the hidden message. To prevent

the same from happening to the second group, the hint was also placed below the photograph, to make 'accidentally' revealing it more likely.

Use of the telephone

Another observation that could be made is that the children, especially the younger ones, simply are not familiar enough with rotary telephones to understand how they should be operated. In the first group, the parents explained to their children how they should go about dialing numbers, though the researchers suspect that at least the 9-year-old would not have understood the phone initially. This could be seen very clearly in the second experiment – one participant did not even consider the numbers on the front of the telephone and instead opted to speak his input into the earpiece, expecting that the telephone would be able to recognize what he was saying.

Perception and experiences

During the evaluation after the completion of each experiments, participants reacted mostly positive to the escape room. All children indicated that they enjoyed playing through the room.

The parents received different questions than the children and were asked to complete their (paper) questionnaire in a different room to ensure that they did not influence their children's answers. Perhaps predictably, they were more critical than the children. Though they enjoyed the escape room in general, they made remarks about practical matters such as the temperature in the room (testing took place on an especially hot day) and the restricted amount of space in the escape room. While these are valid comments, they are not related to the actual contents of the design.

The parents did remark on the strong presence of the Hengelo theme in the room: it was something they had noticed and enjoyed, although it must be noted that they incorrectly perceived the 'phone number' (as described earlier) to be part of this theming.

As seen in the testing of the physical prototype, the children's favorite puzzles seemed quite evenly divided. Noteworthy was that some players disliked the second half of the jigsaw puzzle (locating the number on the church to reveal the answer) because they felt it was too simple (not enough steps involved). The puzzles that were perceived as difficult (mainly the hand mirror) were not rated worse, however.

9. Discussion

In this section, concerns, notes and other remarks regarding the research and project will be discussed. Then, a list of (possible) ways to improve the escape room will be presented.

9.1 Relevance of Paper Prototype testing

The effectiveness of a paper prototype, like the one we developed, for a complex game like an escape room can be called into question. As mentioned in the relevant chapter (7.1), the physical element of an escape room cannot be properly emulated in the paper prototype format. This limits the scope of the associated experiments to the 'logical' aspect of the design, but how well can that be tested if the representation of the room is not equal to the real life experience?

For example, many participants in the paper prototype testing spent at least some time inspecting the display cabinet and the items within it. This could well be because of the way it is represented within the paper prototype: the display cabinet is a piece of furniture much like the starting points for all of the puzzles, and there are many item cards associated with it, making it look like an area of interest. In the physical escape room, the display cabinet isn't nearly as interesting: there is nothing to be interacted with, since it is not possible to touch any of the items inside. They are not marked by any symbols (unlike the other pieces of furniture, save the center table) and there is no movement going on inside the case. Though we still saw participants pay attention to the display cabinet in the physical experiments, the amount of time spent on it was not nearly as large as with paper prototype participants. The paper prototype overrepresents the display cabinet, and may in general not give a good impression of the importance and role of items in the escape room.

Other elements, like the hidden messages in the hand mirror and the bookshelf photograph (UV writing), also do not translate very well to the role-playing format of the paper prototype. The factor of 'accidental' discovery for this kind of puzzle element is practically absent. It can be hinted to in item descriptions, but that will often make it overly clear or obvious. In the actual, physical escape room, a hint can be much more subtle without giving away the core of the puzzle. This subtlety is very difficult in the limited scope of the paper prototype.

Secondly, the paper prototype testing was conducted exclusively with university students – while good from a 'test and iterate quickly' point of view, it obviously limits the number of conclusions that can be drawn from it when making a design that is intended for children. We saw that the logic within the puzzles makes some kind of sense to one (or two) university students at a time – but that does not give us any conclusive information about how suitable the design will be for younger children. It merely tests whether the escape room is too difficult: if the students would not have been able to figure out the puzzles, we could have said with a reasonable degree of certainty that it would be too difficult for our target audience.

9.2 Theory regarding developmental areas of children

The theory proposed in chapter 2.3, which hypothesizes that excluding the skills that children learn in school between ages 8-14 from the puzzles will help in making the escape room suitable for the entire age group, seems to hold some truth. The puzzles that include language-based clues are the ones that consistently appeared to be problematic for the younger participants in particular. Of course, the small sample size makes it so that this observation is not (significantly) validated by the results of our experiments. Further, more specified research

would be required to properly test the effect of the identified developmental areas on age-appropriateness of puzzles.

9.3 Sample Size / Representation of audience

With only three instances of experiments that involved the target audience, and strictly speaking only one test with a truly 'final' version of the escape room (since the phone was non-functional and the editing table was still present in the first instance of 'final' testing), the sample sizes for this research are very limited. This makes it difficult to draw any significant conclusions regarding our design. Further testing would be needed to make our research statistically relevant. Only the paper prototype testing, with its six experiments, crosses the threshold of five participants for a 'good enough' usability test (Nielsen, 2000).

Additionally, our small group of participants does not cover the target audience perfectly. The younger end is relatively well represented, with four 9-year-old children appearing in the tests. Five 11-year-olds and two 12-year-olds makes for a nice representation of the middle ground, but with only one 14-year old appearing in our test sample the oldest children in the targeted age group were not well represented in our tests. If, for example, the escape room was too easy for children of this age, we would likely not know because our testing does not include enough 13- and 14-year-olds.

An additional concern regarding our data is the method of retrieval and the validity of the responses; this will be discussed below.

9.4 Validity of questionnaire answers

The method of questioning participants in the physical experiments (both prototype and final version) may have had an influence on their answers. Entire groups of participants were asked about their experiences at once – though their answers were given individually, one at a time, the previous answers or even the presence of their peers could influence what they had to say. For example, it is possible that some of the children did in fact find more puzzles difficult than they admitted to, but they did not want to say so in the presence of their friends, for fear of looking unintelligent.

Furthermore, as described by Read (2008), there are multiple known hurdles associated with retrieving valuable data from children. Satisficing, the selection of answers based on what is deemed a suitable response (rather than one that properly illustrates the participant's thoughts), is an important example. Multiple factors may influence the level of satisficing that takes place, including the cognitive ability of the respondent (Borgers & Hox, 2001). It is possible that satisficing took place during the questioning after the escape room experiments.

9.5 Self-sufficient escape room: a reachable goal?

The feasibility of our goal of designing an escape room which does not require external resources can be called into question. It is rare for escape rooms to not offer any hints whatsoever (Wiemker et al., 2015), and combining this with our young audience creates a very difficult design problem. As was seen during the experiments, the escape room (in its current form) will likely require hints or assistance in some form, especially if the participating group is in the lower end of the target age group.

Removing problematic puzzle elements from the escape room may help alleviate this concern to an extent, but a fully self-sufficient escape room for children may not be feasible in general.

9.6 Role of parents or teachers in the escape room

Our design is intended for a group of children without any further supervision, but that does not mean that parents or teachers will never accompany their children into the escape room. As was seen during the final version's testing, the adults can have a significant influence on how the escape room is played (even when instructed not to interfere). This is not something that our design accommodates for; an oversight.

It may be possible to utilize the adults' presence in a way that is complementary to the escape room, rather than interfering with it. A potential way to achieve this will be discussed in the following section.

9.7 Potential improvements to the escape room

There are still numerous improvements and additions that could be made to the escape room to improve it. Ideas for such additions and improvements will be described below. Some of these suggestions are already being implemented into the escape room, but were not present at the time of the final testing round (which is why they are not mentioned in the final design description).

Further removal of language-based elements in puzzles

Adapting the design in such a way that the few language-dependent elements that are currently in the escape room are eliminated may help in making the escape room less problematic for the younger children within the specified age group. However, the influence of doing this on the experience for the older children should be watched closely: it is possible that this may make the escape room too easy for them.

Possible ways of eliminating said elements may be to include more visual clues such as icons.

In progress: Manual for resetting the escape room

To simplify the process of maintaining and resetting the escape room, a manual describing the steps required to reset the room to its base state will be written by the researchers. This will hopefully make it relatively easy for any given museum volunteer to reset the escape room.

This idea was conceived before the completion of the project, but due to time constraints it is not yet implemented as of this report.

In progress: Addition of a hint system

As discussed earlier, creating an escape room for children without any kind of hind system may not be feasible. During the project, the idea to allow the participants to contact the front desk of the museum was conceived by the museum's project supervisor. For this purpose, a baby monitor with video functionality was purchased. The camera in this set would be located in the escape room; the screen would be placed at the front desk, so that the receptionist can keep an eye on the children. The unit's voice transfer function could then be used to ask and receive hints. This would require a step-by-step walkthrough of the escape room, along with suitable hints for each step.

The benefits of such a system would be the relatively low cost of implementation and the human factor, which allows hints to be subtle yet applicable to the participants' current situation. Negatives include the increased workload on the museum staff and some reliance on technology, which adds complexity and potential points of failure.

Another idea on how to include a hint system was formed; this will be discussed below.

Making parents / teachers perform the role of game master

The issue of unwanted parent influence on progress through the escape room may have a relatively simple remedy: if a manual of sorts is created for the parents which includes the full procedure for completing the escape room, they could perform as a game master / supervisor (Wiemker, 2015) of sorts. Should this work, then it would effectively alleviate two concerns at once: the parents would (hopefully) no longer have a negative influence on the children's progression and there would be a hint system present within the room which does not require any additional work from the museum.

Method to indicate items / elements that are not part of the escape room

Having a way to clearly mark items that do not play a role in the escape room will likely reduce the amount of 'red herrings' the participants run into. A manner of achieving this may be to mark all items that are not part of the escape room's puzzles with a sticker (along with an instruction regarding these stickers for the participants). Alternatively, the opposite (marking all pieces that *are* relevant to the puzzles) could accomplish the same goal.

10. Conclusion

In this section, the results of the project (both the physical product and the conducted research) will be discussed and tested against the requirements determined in section 5.1 to evaluate how successfully the project has been executed. After this summary, a more general conclusion will be presented.

The escape room should be suitable for children aged 8 to 14.

In its current state, the escape room is somewhat suitable for the intended age group. Most puzzle elements are properly recognized and understood, and children within the target audience have an enjoyable experience when playing through the room. However, there are still some elements that are difficult for the younger children in the target age group. These are mainly the clues and instructions that rely on linguistic interpretation. This could be an indicator of the theory regarding developmental areas (hypothesized in section 2.3) holding truth, but the rather limited number of samples makes it impossible to draw any hard conclusions in this regard.

The escape room should be as self-sufficient as possible.

As mentioned in the Discussion chapter, further work is required to get the escape room to a truly self-sufficient state. The design as tested in the final experiments is not self-sufficient, in the sense that hints are likely to be needed and there is no (internal) mechanic present for receiving them. However, as noted in the Discussion section (chapter 9.5), escape rooms that do not provide hints of any kind are a rarity. So, keeping that in mind, perhaps the current escape room *is* as self-sufficient as possible, if true self-sufficiency is not reachable.

The escape room must be themed after the history of Hengelo.

The escape room incorporates Hengelo and its history in all of its puzzles. In two puzzles, the treasure chest puzzle and the telephone puzzle, an active use of this history (which can be found in the room itself) is required to proceed. The remaining two puzzles have a more passive implementation of the subject matter, mainly including it through pictures which are not essential in solving the puzzle.

Though the low number of samples prohibits the drawing of any general conclusions, the responses from the test participants do indicate that they clearly recognized the escape room's theme. This gives reason to believe that this requirement was met.

The escape room must be entertaining for the target audience

All participants in testing throughout the entire process of designing this escape room indicated that they enjoyed playing through it. While it is possible that some participants' answers were skewed slightly by the presence of their peers (as mentioned in the Discussion section), the lack of distinctly negative experiences gives reason to believe that the target audience found the escape room enjoyable. Additionally, it appears to be interesting to university students as well.

Thus, though properly measurable in a statistic, the final product does appear to fulfil this requirement.

The escape room must be easy to maintain and operate.

The escape room, in its current form, is relatively easy to restore to its base state. The procedure of resetting consists mainly of placing items in specific locations. However, a museum staff member who has no prior knowledge of the escape room would have a difficult time resetting it.

Creating a manual on this procedure, as discussed in chapter 9.7, would likely alleviate this problem. As stated, development of such a manual will take place in the near future.

Maintenance is often problematic for escape room owners, in part due to the damaging of puzzles by participants (Wiemker et al., 2015). With children as the target audience, this problem could become even more relevant. Though the puzzle elements in the escape room are not particularly fragile, damage could (and likely will, given enough time) occur. However, this would likely be the case with most designs.

In conclusion, the escape room as tested in the final experiment does not properly fulfil this requirement. With the future addition of the manual, however, the situation should improve.

The escape room should be playable with up to six children.

Testing with a group of six children did not reveal any major issues arising from the group's size. Additionally, the multi-linear nature of the puzzles (the presence of multiple, separate puzzle paths) allows participants to work largely independently of one another. This decreases the likelihood of participants being left excluded.

The physical dimensions of the room do make it so that there is not much space left over when there are six participants in the room; more than six participants would likely be problematic because of this.

Based on the observations made during the experiments, the escape room appears to fulfil this requirement. However, more testing would be necessary to determine whether the escape room is as enjoyable with six children as it is with fewer participants, to ensure that it is not only playable but also well-suited to groups of six children.

General conclusion

In general, the escape room designed and produced in this project appears to fulfil its intended functionality reasonably well. After three iterations and as many rounds of experiments, a product that was well received and recognized by its intended audience was developed. However, the final result still leaves much room for improvement. Not all of the design requirements are met (yet), though ideas on how to achieve this are already present.

The educational aspect mentioned in the problem statement was not tested in this research, but it may be present in some degree thanks to the active involvement of Hengelo's history in some of the puzzles. Different testing would be required to assess whether this incorporation can fulfil an educational role.

From a research perspective, the research question of this paper ("*How does one design an escape room for a large range of age and skill levels?")* can be partially answered by the final product. The exclusion of puzzles that rely heavily on language, mathematics and other skills that children develop throughout their school careers appears to have a positive influence on the appropriateness of the escape room for younger children, without making the escape room uninteresting for older children. The theory posed in section 2.3, thus, appears to hold some merit. However, far more research is required before these findings can be generalized.

In summary, the developed escape room is a good start, though it is not yet a truly final solution to the posed challenge. More work needs to be done to achieve this. However, it can serve as a solid basis from which to continue and finalize development. Early experiences from test participants are positive, and the way forward is already quite clear.

11. Recommendations

In this section, recommendations based on the findings in this research will be presented.

More research on children's developmental areas and their effect on puzzle solving

The theory regarding the exclusion of children's developmental areas in escape room puzzles posed in section 2.3 appears to hold at least some truth. However, the low sample size and limited data recorded in this research does not allow for any hard conclusions to be drawn in regard to this theory. Further research, focusing more explicitly on the age-agnosticism of puzzles for children and the effect of curricular subjects thereon, is required to back up the limited findings in this report.

Age-agnostic escape rooms

The idea of a single escape room design that is suitable for a large age group is relatively novel; though there may be some examples of such escape rooms in the field, there appears to be no scientific material on them yet. The idea makes for an interesting design challenge that requires the combination of multiple scientific fields, and further research on the topic could lead to new discoveries regarding game or puzzle design, group dynamics in children, or educational aspects.

Museum: further evaluate and implement suggestions from Discussion

For the museum, the consideration and eventual implementation of (some of) the suggestions listed in the Discussion section is strongly recommended. The escape room as is does not quite fulfil all the purposes desired by the museum, and the ideas described there have the potential to alleviate the issues currently present.

The suggestion of letting parents (when present) perform as the 'game master' in particular appears capable of addressing multiple issues at once – the author would like to suggest placing this idea at the top of the 'to do' list for the escape room.

Finally, perhaps the museum should re-evaluate the amount of resources (both monetary and in terms of manpower) they are willing and able invest into this escape room and weigh this against its possible functionality and effectiveness. Some more work should probably be done - but the potential gains appear to be worthwhile.

12. Appendices

I. Instructions for the museum's version of the escape room

Welkom in de Escape Room van Museum Hengelo !

In deze kamer zie je een oude schatkist die geopend moet worden door haar sloten te openen. Dat kan met informatie die je in deze kamer vindt. De kamer is ingericht als een tijdmachine waarmee je door de historie van Hengelo gaat.

- De oudste periode gaat over Hengelo als een dorp met een kasteeltje.
- Hengelo wordt 160 jaar geleden via wegen en spoorlijnen beter verbonden met de rest van Nederland en Duitsland. Er komen veel fabrieken en meer mensen. Hengelo groeit en bloeit.
- Zo'n 50 jaar geleden gaat het minder goed met de fabrieken en komen er meer dienstverlenende bedrijven. De welvaart stijgt echter wel en er komen nieuwe wijken met woningen en bedrijven.
- Hengelo is nu nog steeds volop in beweging. Er komen nog meer woningen en bedrijven en sommige oudere gebouwen worden vervangen door nieuwe.

Je hebt een uur de tijd om te ontsnappen.

Jullie krijgen 60 minuten de tijd om een vragen over de geschiedenis van Hengelo te beantwoorden en een aantal opdrachten uit te voeren. Daarmee kun je de code van een aantal sloten vinden en de sleutel van een oude schatkist. Als het je lukt om binnen een uur de oude schatkist te openen kun je het alarm van de deur uitschakelen en de escaperoom als winnaar verlaten. Je bent dan geslaagd als kenner van de geschiedenis van Hengelo. Lukt het je niet dan ben je toch veel over Hengelo te weten gekomen.

De deur is beveiligd met een alarm.

De deur is dicht maar zit niet op slot. Je kunt er dus altijd uit, maar dan gaat een alarmsignaal af en ben je dus niet voor de escaperoom geslaagd. Je kunt het alarm alleen uitzetten met de afstandsbediening die in de oude scatkist zit.

Haal geen foto's van de muur en breek geen zaken open.

Voor het uitvoeren van de opdrachten hoef je geen foto's van de muur te halen of de vitrine te openen. Het is de bedoeling dat jullie zonder vernielingen, dus met alleen goed nadenken en speuren achter de codes van de sloten en daarmee uiteindelijk bij de afstandsbediening van het deuralarm komen om te kunnen ontsnappen.

Verdeel de taken

Om op tijd de codes te vinden is het verstandig om de taken onderling te verdelen. Een en manier om dat te doen is om de opdrachten te verdelen en wel zo dat je elkaar niet in de weg loopt. De drie wanden zonder ramen beslaan ieder een ander tijdvak uit de geschiedenis van Hengelo. Je kunt er voor kiezen om alleen of met zijn tweeën de opdrachten uit te voeren die bij een bepaalde wand horen. De resultaten gebruik je om de oude schatkist samen te openen

OUDE SCHATKIST, LINKER CIJFERSLOT

Vergelijking van twee posters

In Hengelo verandert altijd veel. Vergelijk de grote half ronde poster boven aan de muur met de situatie van 140 jaar geleden met de grote ronde poster op de vloer. Het gaat hier om dezelfde locatie in Hengelo alleen 140 jaar later. Hoeveel panden zien er nog bijna hetzelfde uit?

Verhoog het antwoord met 1 en je hebt het eerste cijfer.

De fotopuzzel

Zoek de fotopuzzel van Hengelo in 1960, zet de puzzel in elkaar en draai die om.

Dit geeft het tweede cijfer.

Half ronde grote foto poster aan de muur

Hoeveel boerenkarren met huif zijn er te zien?

Het aantal geeft het 3e cijfer

Luchtfoto uit 1960 aan de muur vergelijken met plattegrond van Hengelo nu.

Hoeveel van de hierna genoemde wijken waren nog boerenland in 1960?

Centrum, Dalmeden, De Noork, Groot Driene, Hasseler Es, Hengelose Es, Klein Driene, Nijverheid, Tuindorp, Veldwijk, Vikkershoek, Vossenbelt, Weijinkshoek, Wilbert, Woolder es,

Het aantal geeft het 4e cijfer.

Open het linker cijferslot

Gebruik de gevonden code om de cijferwieltjes van het hangslot zo in te stellen dat je de juiste code kunt aflezen op de streep aan de zijkant van het slot. Nu kan de beugel omhoog en het kettinkje uit het oog van de kist worden gehaald. Leg slot en kettinkje op de houten muurtafel.

OUDE SCHATKIST, RECHTER CIJFERSLOT

Zoek een kluisje en open die met de sleutel die je ook moet vinden door te zoeken

In het kluisje ligt een papier met het eerste cijfer van het rechter cijferslot van de oude schatkist.

Geheimtaal

Zoek het lijstje met een tekst in geheim taal en los op wat er staat.

Maquette Huis Hengelo

In de maquette zie je Huis Hengelo rond het jaar 1800. Maar je ziet ook enkele zaken die daar niet thuis horen.

Onder de maquette liggen vondsten van de opgraving van Huis Hengelo. Daar zie je ook enkele voorwerpen die daar niet thuis horen.

Om hoeveel voorwerpen gaat het samen? Dat aantal levert je het derde cijfer.

Fotocollage opgraving Huis Hengelo

De kapel bij Huis Hengelo, op de rechterkant van de maquette, is net als het Huis al in de 19e eeuw afgebroken. Het kerkhofje om de kapel bestaat nog steeds met een poortgebouw met torentje aan de Bornsestraat tegenover de Beukweg. Op welke foto van de fotocollage van de opgraving uit 2005 zie je nog een stukje van het kerkhof? Het goede antwoord levert je het vierde cijfer.

Foto linksboven = 2

Foto linksonder = 4

Foto rechtsonder = 8

Open het rechter cijferslot

Gebruik de gevonden code om de cijferwieltjes zo in te stellen dat je de code kunt aflezen met de streep aan de zijkant van het slot. Nu kan de beugel omhoog en het kettinkje uit het oog van de kist worden gehaald. Leg slot en kettinkje op de houten muurtafel.

DE MODERNE KLUIS

Rij boeken

Een aantal boeken is genummerd. Het eerste en tweede cijfer kunnen gevonden worden door:

- B II, P 366, R 3, L 7, 4 (Boek II, Pagina 366, Regel 3, Letters 7 en 4)
- B IV, P 144, R 3, L 20, 21
- B VIII, P 253, Kol 2, R 8, L 16, 13
- B IX, P 295, R 9, L 17, 18, 19

In welk bedrijf uit Hengelo zijn de radarantennes van het grijze schip op de grote foto gemaakt?

Stork (3), Signaal (4), Heemaf (5), Hazemeijer (6) of de Zoutindustrie (7)

Het antwoord geeft het 3e cijfer

In welk bedrijf uit Hengelo is de zwarte telefoon aan de muur gemaakt?

Stork (3), Signaal (4), Heemaf (5), Hazemeijer (6) of de Zoutindustrie (7)

Het antwoord geeft het 4e cijfer

Spiegelklok

Lees de kloktijd goed af in uren en minuten. Lees de klok vervolgens fout af, alsof het een normale klok is. Denk er aan dat een uur 60 minuten heeft.

Tel de gevonden tijden op en het resultaat geeft de laatste twee cijfers.

Open de moderne kluis

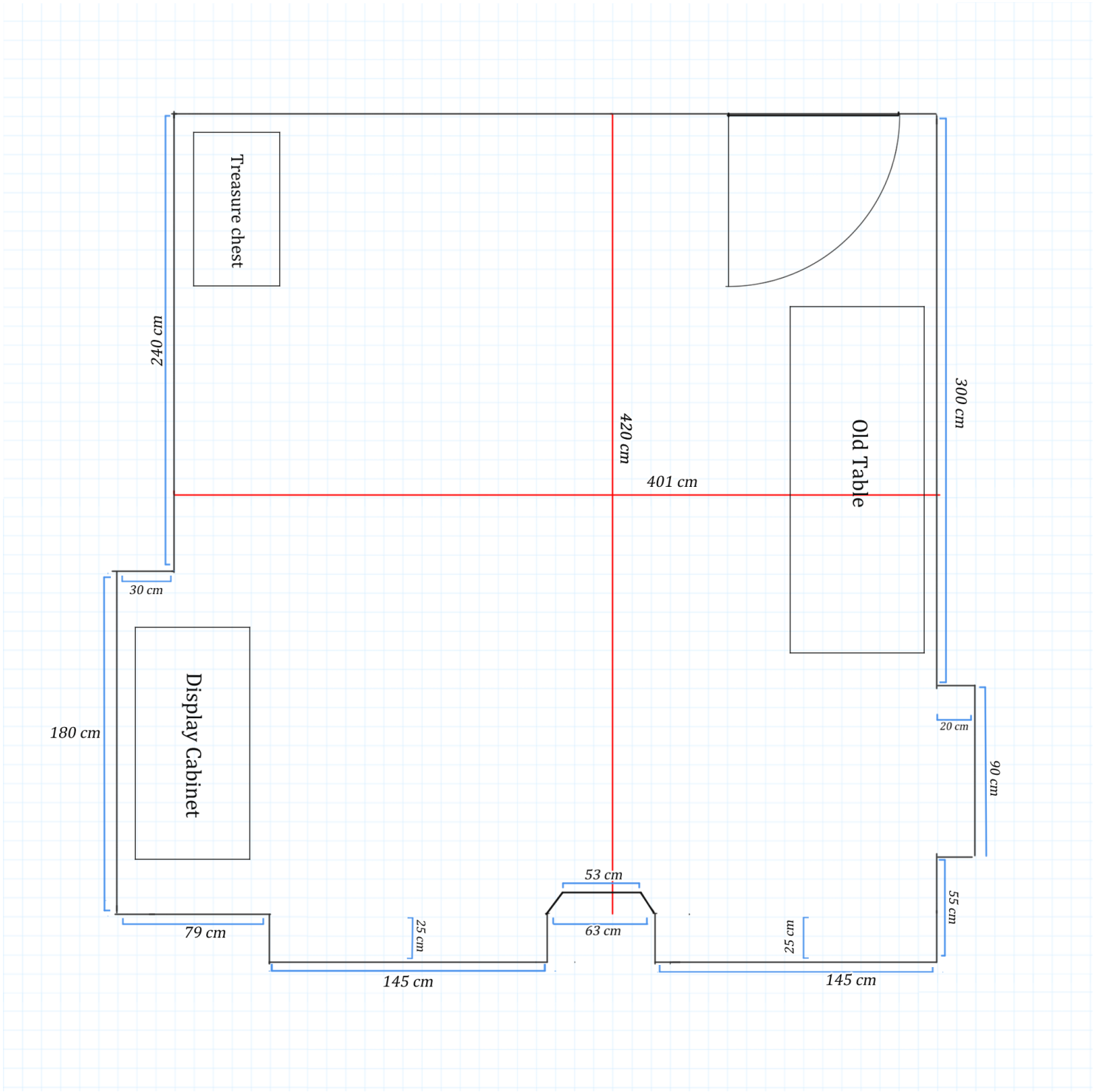
Toets de zes gevonden cijfers in de juiste volgorde in op het cijferpaneel gevolgd door de letter A. Als de code correct is kun je de kluis openen door de knop om te draaien. In de kluis vind je een grote sleutel van de oude schatkist.

Open de oude schatkist

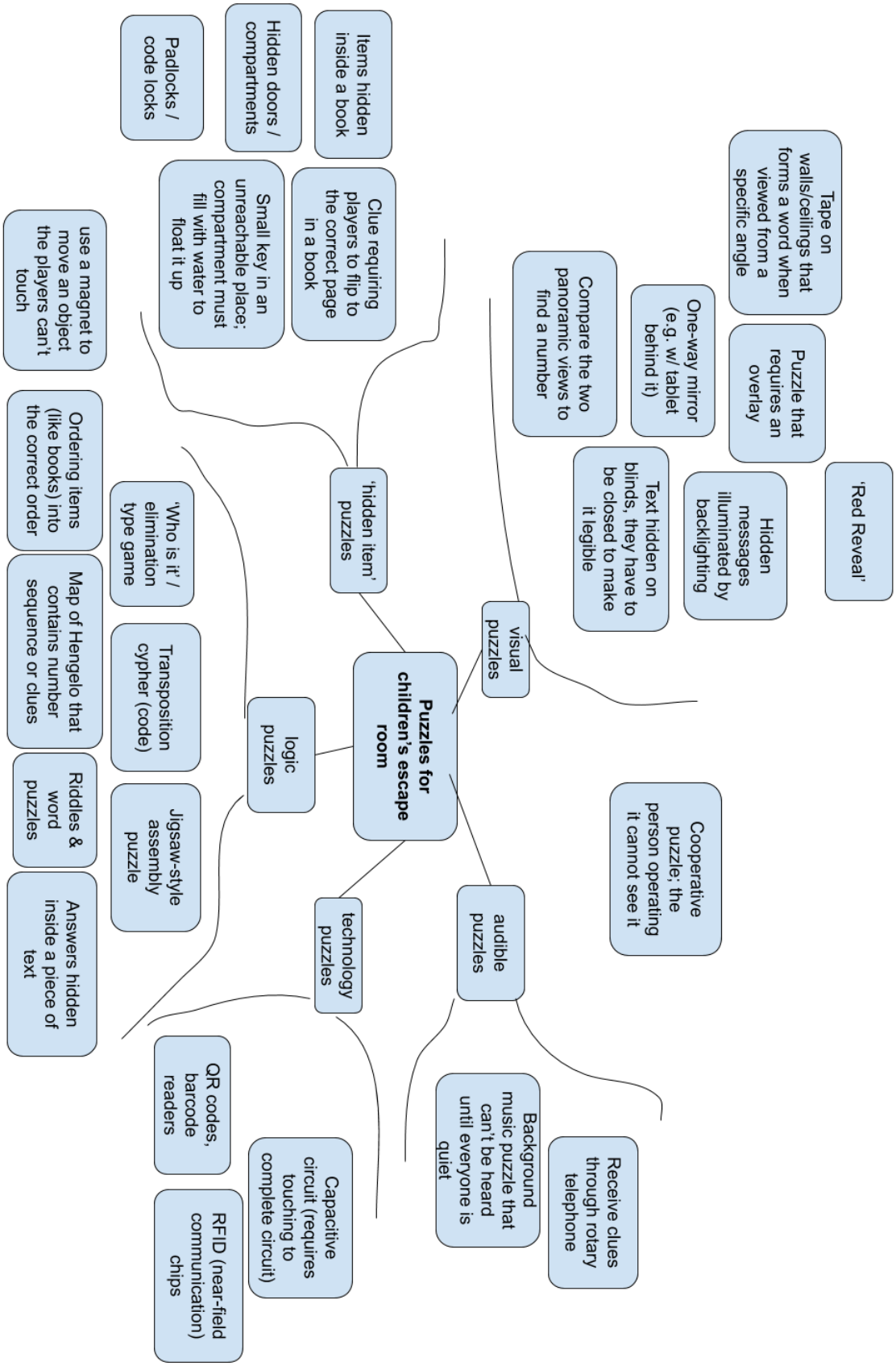
Open de oude schatkist waarvan je beide cijfersloten met kettinkjes hebt verwijderd en het slot met de grote sleutel hebt geopend. In de kist bevindt zich de afstandsbediening waarmee het deuralarm kan worden uitgeschakeld.

Nadat je het alarm hebt uitgeschakeld kun je ontsnappen, dat wil zeggen zonder alarm de escaperoom verlaten. Gefeliciteerd!!!!!!!

II. Full-size version of the escape room floor plan



III. Full-size version of ideation mindmap



IV. Consent Form for paper prototype experiments

Consent Form for Hengelo Escape Room Paper Prototype

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated 19-03-2019, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves my participation in a puzzle experiment, which is documented in both qualitative and quantitative measures.	☐	☐
Audio / Video Recording		
I understand and agree to the fact that my participation will be recorded in both audio and video. *Note: It is possible to decline to this aspect and still participate in the study. In that case, the only data collected will be some basic personal information and notes taken by the researchers during the experiment.*	☐	☐
Note: You may skip this question if you answered 'No' on the previous one. I understand that the recorded video footage will only be used for review after the experiment ends. It will only be viewed by the researcher and their supervisors. The videos will not be published or made publicly accessible online in any way.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for reviewing the effectiveness of the Escape Room design, the logic in the puzzles and their difficulty. Anonymized data may be seen by the researchers, their colleagues, their supervisors and others.	☐	☐
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐
I agree that my information can be quoted in research outputs.	☐	☐

UNIVERSITY OF TWENTE.

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	*Signature*	*Date*

Contact Information for Questions about Your Rights as a Research Participant

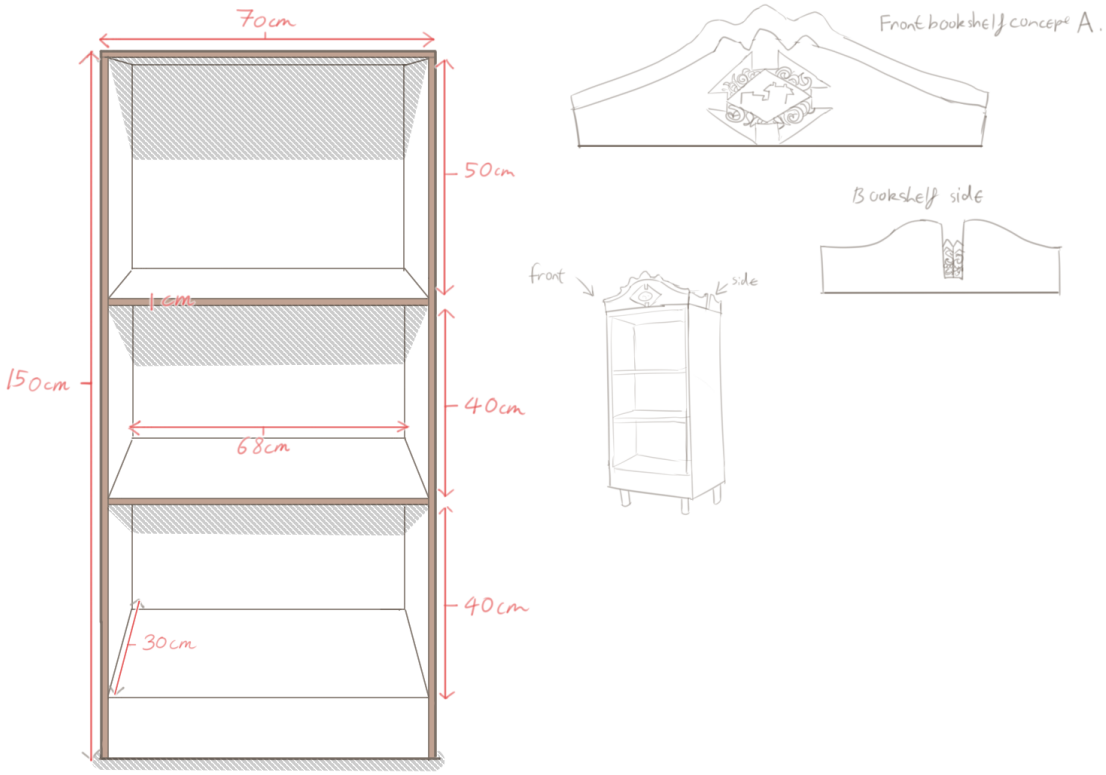
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente via ethics-comm-ewi@utwente.nl

V. AssortiMens assignment – Bookshelf

Boekenkast

Escape Room Museum Hengelo

Interessegebied: Houtbewerking / Bouwen



Voor de escape room in Hengelo hebben we een boekenkast nodig. Deze zou gekocht kunnen worden of zelf gebouwd. Belangrijk is in ieder geval dat de afmetingen ongeveer 150cm (hoogte) x 70cm (breedte) x 30cm (diepte) zijn. De boekenkast moet overzichtelijk zijn voor kleinere kinderen (vanaf ongeveer 8 jaar) en in een vrij kleine ruimte passen, dus hij moet **niet te groot** zijn. De afmetingen op de tekening zijn een indicatie; als je hiervan wilt afwijken kan dat in overleg.

Op de onderste twee planken komen boeken, dus het moet een stevige kast worden. Hout vanuit de lasersnijder zal waarschijnlijk dus te dun zijn. Ook hebben we graag dat de boekenkast er redelijk oud uitziet, waarvoor lasersnijd-hout ook niet echt geschikt is.

Op de bovenste plank komen een paar kleine voorwerpen, en daar willen we achterin een foto (of schilderij) plaatsen. Deze komt dus op de achterste plank te hangen. De achterkant van de boekenkast hoeft verder niet echt gewicht te dragen, dus deze kan van relatief dun hout (mdf?) gemaakt worden, zolang de kleur niet al te anders is dan de rest van de kast.

(meer op de achterkant)

Versieringen bovenkant
Bovenop de kast willen we *misschien* (afhankelijk van hoe goed dit mogelijk is) een soort sierlijst, zoals aangegeven op de tekening. Dit zou dan waarschijnlijk middels lasersnijden kunnen worden gemaakt. Als dit door middel van bijvoorbeeld verf of vernis mooi bij de rest kan kleuren zouden we het graag hebben.
Het ontwerp van dergelijke sierlijsten staat niet vast, dus creatieve input is erg welkom. Als je hier ideeën over hebt, neem dan a.u.b. contact met ons op! De stijl ervan is niet enorm belangrijk, zolang het de kast maar wat ouder en sjieker eruit laat zien.

Contactgegevens

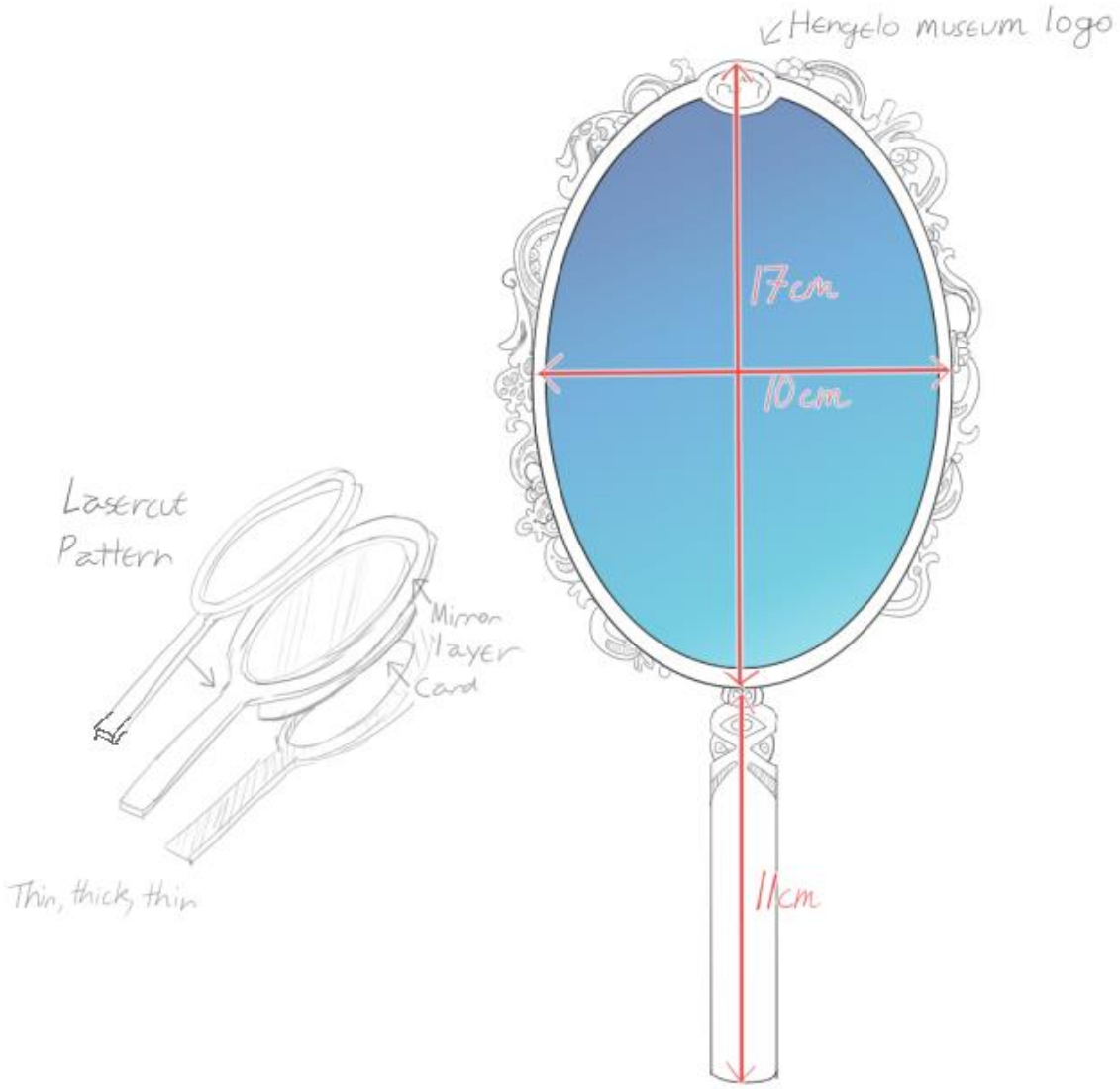
Jordi & Chulakit, bezig met de Escape Room voor Museum Hengelo
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur
E-mail: <removed for appendix>

VI. AssortiMens assignment – Hand mirror

Spiegel

Escape Room Museum Hengelo

Interessegebied: Lasersnijden / Ontwerpen



Dit handspiegeltje bevat een verborgen boodschap voor de deelnemers. Het is namelijk geen gewone spiegel, maar een half doorzichtige. De bedoeling is dat de deelnemers bedenken dat ze de spiegel in het licht moeten houden, en dat er dan een tekst zichtbaar is.

Om dit voor elkaar te krijgen gebruiken we halfdoorzichtig plexiglas in plaats van normaal glas. Hierachter komt een dik stuk karton, waar de boodschap op geschreven wordt.

We willen de spiegel er sjiek en ouderwets uit laten zien. Ons idee hiervoor is om drie lagen hout te gebruiken: twee dunne lagen aan de buitenkant waar mooie patronen en dergelijke in zijn ge-(laser)sneden, en één wat dikkere laag in het midden voor de stevigheid.

Voor het ontwerp van de (fancy) buitenlagen hebben we al een ontwerp. De bestanden om de te lasersnijden hebben we al gemaakt; deze heeft Edwin.

Omdat we waarschijnlijk een paar keer moeten testen met verschillende kleuren / soorten karton (vanwege de leesbaarheid) is het handig om de spiegel nog niet direct vast te lijmen. Als hij (aanvankelijk) redelijk makkelijk uit elkaar te halen is zodat de kartonlaag uitgewisseld kan worden is dat handig. Het eindproduct moet uiteraard wel stevig vast zitten.

Het plexiglas (al aanwezig bij AssortiMens) hoeft alleen nog op maat gesneden te worden.

Bij interesse, ideeën of vragen, neem contact met ons op!

Contactgegevens

Jordi & Chulakit, bezig met de Escape Room voor Museum Hengelo
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur
E-mail: <removed for appendix>

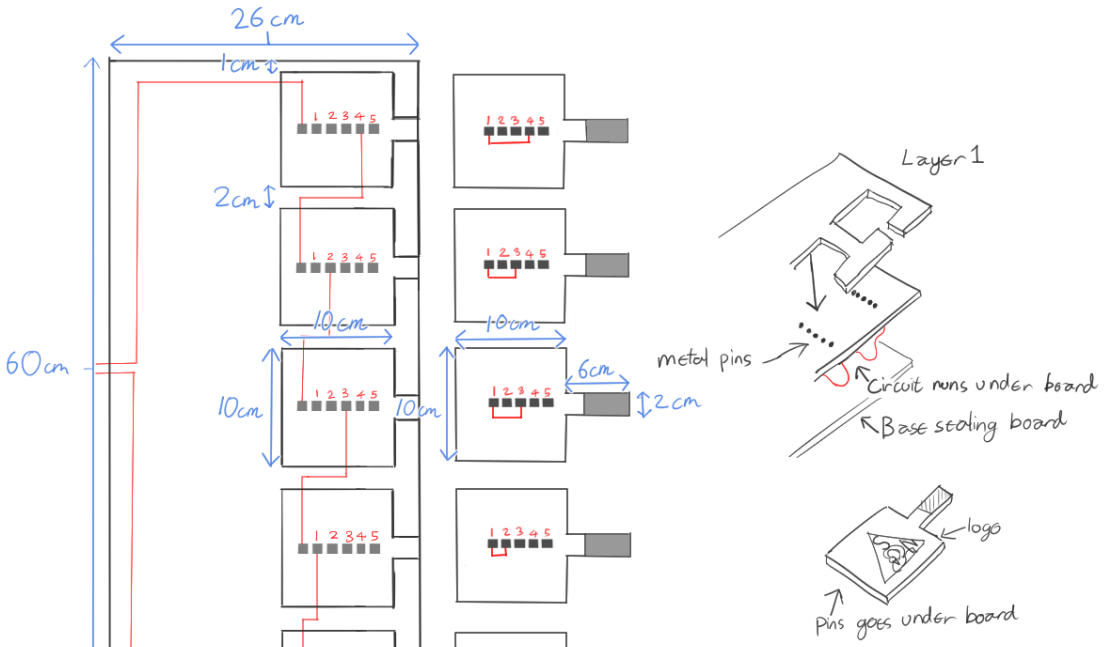
VII. AssortiMens assignment – Logo puzzle

Logopuzzel

Escape Room Museum Hengelo

Interessegebied: Houtbewerking / Elektronica

Puzzel



Deze puzzel bestaat uit vijf 'blokken' met logo's erop en een basis waar ze in gelegd kunnen worden. Het idee is dat er een stroomkring van boven naar beneden (of andersom) door het hele systeem loopt op het moment dat de blokken in de juiste volgorde geplaatst zijn.

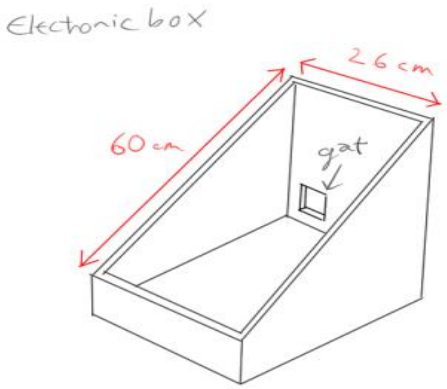
Het is belangrijk om de contactpunten (en stroomdraden) in de blokken en vakken zo te plaatsen dat er maar één combinatie is waarin de stroomkring compleet is.

Qua afmetingen lijkt 10 x 10 cm ons een mooi formaat voor de blokken, met een uitsparing aan één kant. Hierdoor zijn ze makkelijk uit de basis te pakken en kunnen ze niet ondersteboven geplaatst worden. Om te zorgen dat de vijf blokken in de puzzel passen, moet de basis zo'n 60 cm lang worden, en ongeveer 25-26 centimeter breed. Naast de blokken komt namelijk een woord (of term) dat gerelateerd is aan het logo op het blok, waarbij het uiteraard de bedoeling is om de juiste combinaties te vinden.

De constructie van de puzzel zelf bestaat uit 3 lagen (lasersnijd-)hout: een bovenste laag met de termen erop en uitsparingen voor de blokken, een middelste laag waarin de contactpunten zijn verwerkt en een onderste laag die de bedrading afdekt.

Houder

De stroomkring wordt aangestuurd met een extern apparaatje, waarschijnlijk een Arduino. Deze zal in de houder geplaatst worden. Deze houder houdt de puzzel schuin omhoog (zie tekening)



Het is belangrijk dat de houder even groot is als de puzzel zelf, zodat het samen een mooi geheel wordt. De overige afmetingen van de houder maken niet zoveel uit, liever niet al te groot. Achterin zit een gaatje waar (stroom-)kabels door kunnen worden getrokken.

Als je vragen, opmerkingen, ideeën of problemen hebt over deze opdracht, neem gerust contact met ons op! We zitten op vrijdag bij AssortiMens (achter het gordijn), of stuur een berichtje via de contactgegevens hieronder.

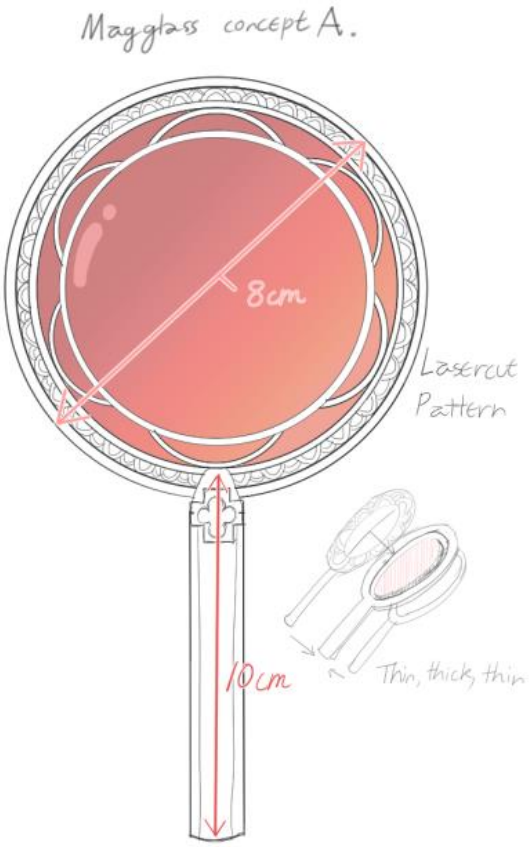
Contactgegevens

Jordi & Chulakit, bezig met de Escape Room voor Museum Hengelo
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur
E-mail: <removed for appendix>

VIII. AssortiMens assignment – Magnifying glass

Vergrootglas

Escape Room Museum Hengelo
Interessegebied: Lasersnijden



Dit 'vergrootglas' is eigenlijk meer een soort rood licht filter, wat een boodschap in een op het eerste gezicht chaotische afbeelding zichtbaar maakt. Hij is gemaakt van rood plexiglas/acryl en hout.

We hebben zelf al een ontwerp en lasersnijdbestand voor het vergrootglas. Het idee is dat het vergootglas uit drie lagen bestaat: twee dunne, versierde lagen voor het uiterlijk en één dikkere laag in het midden voor de stevigheid.

De benodigde bestanden heeft Edwin. Rood plexiglas is al aanwezig bij AssortiMens.

Bij vragen, ideeën of suggesties, neem vooral contact met ons op!

Contactgegevens

Jordi & Chulakit, bezig met de Escape Room voor Museum Hengelo
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur
E-mail: <removed for appendix>

IX. Transcripts of paper prototype experiments

Transcripts of paper prototype experiments

Subject number 1

1. Fixates on metal frame
2. Inspects jigsaw puzzle
3. Inspects treasure chest
4. Finds no methods to get into the treasure chest
5. Attempts to slot on the logos into the treasure chest
6. Recognizes the wall of images as a part of the puzzle
7. Inspects bookshelf
8. Assembles jigsaw puzzle, does not realize that the jigsaw puzzle needed to be flipped over to be resolved.
9. Finds the small mirror in the table cupboard.
10. Associates the logo of the shelf with the books
11. Fixates on bookshelf for quite some time.
12. Fills in logo panel incorrectly
13. Fills in logo panel incorrectly again
14. **Finds X**
15. Fixates on the items inside of the glass display cabinet
16. Returns to bookshelf
17. Takes a fair bit of time to recognize the dictionary as the important book in the shelf
18. Attempts to use a dummy book, attempts the use of the magnifying glass on the book
19. Finds the dictionary > finds UV torch
20. Attempts to use the UV torch on the jigsaw
21. Flips over jigsaw puzzle, finds message
22. Goes over to the floor to the 360 image
23. **Finds O**
24. Picks up phone
25. Uses UV torch on the glass metal cabinet
26. Uses UV torch on the wall full of paintings
27. Uses UV torch on the 360 image
28. Uses UV torch on the metal frame
29. Uses UV torch on the bookshelf image > IV 139
30. Uses UV torch on the mirror
31. Returns to telephone, puts 139 into the phone
32. Returns to bookshelf > looks through other books
33. finds volume IV
34. **Finds □**
35. Returns to inspect the phone
36. Attempts to use UV lights on the paintings again
37. Attempts different paintings and utilizes every order of the painting into the phone before inputting the correct order
38. Struggles with clue for the mirror puzzle
39. Test terminated before puzzle ends (after 15:42)

Concerns

- Change description of the destroyer
- Red reveal puzzle was not made obvious
- Struggles with order of the painting puzzle - addressed

- Metal frame is distracting

Subject number 2

1. Goes to old table > inspects puzzle
2. Old table > inspects cupboard > gets mirror
3. Everything is on the table
4. Inspects telephone > figures out sequence
5. Display cabinet > thinks of it as a puzzle > distracting
6. Inspects wall > figures out phone puzzle
7. Inspects bookshelf > finds magnification glass
8. Looks at the bookshelf, thinks that the correct book for the □ puzzle is a translated book rather than the dictionary.
9. Returns to the logo puzzle, instantly recognizes the logos from the images on the wall
10. Resolved logo > enters code into the number lock padlock
11. Fixes chest puzzle + opens the chest
12. **Finds X**
13. Returns to old table > resolves the jigsaw puzzle & turns it over
14. Uses magnification glass on jigsaw > finds clue & goes to floor
15. **Finds O**
16. Returns to bookshelf > finds dictionary > finds UV flashlight
17. Uses UV torch on picture on shelf > finds IV 139
18. Struggles as to what IV 139 means
19. Finds encyclopedia + goes to page 139
20. **Finds** □
21. Phone rings + finds phone clue
22. Returns to display cabinet > fixates on display cabinet
23. The wall images aren't obvious
24. Finally finds 816 & dials it into phone > gets phone hint
25. Grabs mirror
26. Time passes > figures out mirror puzzle.
27. **Finds** △
28. Finished room (34:58)

Concerns

- Player notices the English dictionary, marks it as a clue that definitely is not related.
- The location of the hand mirror confuses the test subject
- Paintings on the wall causes confusion
- Audio stickers too cruel?

Subject number 3

1. Inspects treasure chest
2. Inspects switch board > understands puzzle immediately
3. Realizes connection between switchboard puzzle and image wall
4. Successfully matches the logo puzzle on the first try
5. Unlocks combination lock
6. **Solves X**
7. Inspects exit door
8. Goes to bookshelf > finds magnifying glass
9. inspects magnifying glass
10. Reads bookshelf clue

11. identifies dictionary > finds UV flashlight
12. Inspects painting with flashlight > finds roman numerals
13. Inspects distracting display cabinet
14. Inspects table > assembles jigsaw
15. Immediately understands RR connection
16. Goes to 360 view
17. **Solves O**
18. Goes back to table > finds mirror
19. Phone rings > picks up phone and hint is received
20. Instantly makes connection > goes to painting wall > dials 813
21. Goes to inspect metal frame
22. Returns to bookshelf > uses UV torch > finds IV 139
23. **Solves** □
24. Inspects mirror > understands phone hint
25. Holds up mirror to sun > gets message
26. **Finds** △
27. Dials number into phone
28. Finished room (41:33)

Concerns

- Problems linking images to the switch puzzle
- Issues connecting UV flashlight with the rest of the bookshelf
- 'Light' in the mirror clue is not explicitly clear
- Room's lockbox detracts from the puzzle

Subject number 4 & 5

1. Focus on old table, stools stand out
2. Inspect old table, focuses on puzzle. Immediately asks if they can flip the puzzle over once completed
3. Inspects table drawers and find mirror
4. Assembles puzzle and flips it over, asks if there is mirrored writing on the back
5. Inspects display cabinet and items inside closely, tries to use city map
6. Inspects bookshelf and finds hint, scans through list of books
7. Connects red magnifying glass to rear side of puzzle rather quickly: "I'm immediately reminded of the back of the puzzle (pieces)". Not sure what it would do but try the mag. glass on the puzzle
8. Finds clue for O (circle), make connection to 360 view quickly
9. Recognize that symbols represent different puzzles
10. **Deduces that O = 5** because of the 360 view
11. Inspects treasure chest, connects padlock hint to stools right away
12. Inspects stool and find key (does not use it instantly)
13. Makes connection between paintings and company logo puzzle right away, completes industry puzzle first try
14. Connects switchboard puzzle and number lock, opens lock and opens chest after being (very lightly) hinted into using the stool key found earlier
15. **Finds X = 7**
16. Go to telephone (before it rings) and listens to voice message
17. Thinks of bookshelf / display cabinet
18. Is attracted to destroyer poster, inspects it
19. Realizes they haven't used the mirror yet
20. Asks if there's anything to be seen through the windows

21. Finds painting number stickers, asks about them. When told that they can't be pressed etc., reasons that they are probably used in some other way
22. Dial 816 code into the phone, proceed to listen to 2nd voice message
23. Instantly connect 'your image' and the mirror, mentions that Jordi said 'your image' when describing the mirror
24. Inspects mirror at the window, **finds Triangle = 0**. Remembers the bit about the cardboard on the mirror as the solution is being told to them
25. Recognizes that the bookshelf still needs to be finished
26. Takes some time to ponder on the 'lost in translation hint'
27. Asks if the dictionary is a translator or simply a dictionary of the English language (*are told it is not a translator*)
28. After some time, decide to take out the English Dictionary
29. Find UV flashlight
30. Use UV light on the model castle
31. Realizes the metal frame is still unused
32. Uses UV flashlight on bookshelf painting, finds IV 139
33. Directly connects IV 139 to page 139 of encyclopaedia volume 4 , **finds Square = 3**
34. Finds symbol sequence and asks if it is something they can see in the room
35. Confused about how the door is locked and how to enter their code
36. Experiment is terminated due to minor semantic issue, but participants escaped successfully in 29:22 (min:sec)

Comments / concerns

- Like the parallel puzzles, thinks it would work well in a group
- Figured out the mirror puzzle really quickly, apparently due to how the mirror was described

Subject number 6

1. Inspects display cabinet in detail
2. Attempts to open the cabinet
3. Goes to the bookshelf > finds note
4. Inspects bookshelf > understands dictionary hint
5. Attempts to use the magnifying glass on the book
6. Picks up english dictionary > UV flashlight
7. Inspects 360 view with red magnifying glass
8. Inspects chest > finds hints
9. Inspects rotary telephone > gets Heemaf logo
10. Inspects TV > tries to derive logo
11. Inspects frame > tries to find logo on frame
12. Inspects old table > inspects jigsaw
13. Assembles jigsaw puzzle > flips over puzzle
14. Returns to bookshelf
15. Tries to lift bookshelf painting
16. Inspects chest > finds clues
17. Goes to stools > finds key
18. Inspects metal frame
19. Inspects 360 view image
20. Returns to puzzle jigsaw, uses RR magnifying glass > finds hint
21. Counts the number of physical windows in the room
22. Tries to figure out the company that makes the furniture
23. Returns to bookshelf & inspects

24. Eventually notices images on the wall
25. Returns to chest > inputs correct logo order
26. Gets code > opens chest
27. **Solves X**
28. Goes to telephone to find X
29. Incorrectly summarizes that O = 2
30. Returns to red reveal > hint does not point subject to the floor
31. Attempts to use UV torch on all of the different books on shelf
32. Scans the bookshelf & books > finds IV 139
33. Incorrectly assumes □ code to be (4)139
34. Attempts to put 139 into the telephone
35. Gets phone hint "order of history"
36. Returns to bookshelf > gets obvious hint
37. **Solves** □
38. Returns to display case
39. Returns to telephone > tries 723
40. Returns to table > finds mirror
41. Tries 723 and triangle with random digits > was stopped
42. Was informed that the value for O is wrong
43. Reminded of window hint > 'windows on the floor' considered unintuitive
44. Inspects 360 view
45. **Solves O**
46. Returns to phone > tries 753816 (816 from the image wall)
47. Uses UV lights on painting wall
48. Returns to display cabinet
49. Mirror hint is eventually pushed through. (55:28)

Concerns

- Puzzles & introduction points need to be made crystal clear
- Windows on the floor may be interpreted as physical windows in the room
- Connection between the wall of images and the rotary telephone not immediately evident
- The missing encyclopedia number V might be interpreted as a hint
- Triangle might be interpreted as being more significant than necessary, the amount of numbers required to solve the room should be more clear
- 'Your image' does not obviously refer to the mirror to some
- Display cabinet is distracting

Subject number 7

1. Inspects display cabinet and items in it, asks if they can be used
2. Associates castle painting on the wall with castle model in display cabinet
3. Inspects old table + puzzle pieces
4. Solves puzzle, opens drawers, flips puzzle over
5. Inspects bookshelf and list of books quite closely, but does not write down the note's hint
6. Inspects 'Victorian Architecture' book, thinks it's related to the castles from #2
7. Uses magnifying glass to look at puzzle, associates clue with 360 view directly
8. Doesn't recognize O = 5 directly, asks about the map from the cabinet
9. Thinks for a moment, is reminded about the bookshelf hint
10. Inspects dictionary and finds flashlight
11. Uses UV flashlight on red reveal puzzle
12. Uses UV flashlight on display cabinet
13. Uses UV flashlight on metal foundry painting on wall and then the other paintings

14. Wonders what he could do with the mirror
15. Phone rings, looks at wall paintings after hearing hint
16. Is pointed to treasure chest after being stuck, inspects it
17. Matches industry logos on first try (recognizes logos from paintings
18. Finds code, uses it on number lock and opens it
19. Inspects stools, finds key, uses it on chest padlock, **finds X = 7**
20. Recognizes symbol code to represent numbers, **realizes O = 5**
21. Asks if the headphone symbols on the paintings can be used
22. Tries code from headphone stickers into phone
23. Ponders for a while on what 'image' phone hint 2 refers to
24. Tries UV flashlight on window paintings/images
25. Tries UV flashlight on bookshelf, finds IV 139
26. Thinks IV 139 is actually 4139
27. Uses UV light on mirror
28. Thinks (silently) for a while
29. Asks if there are lights in the room
30. After hint is repeated, realizes 'image' means mirror image
31. Is hinted to code on the mirror, tries to use UV light
32. Holds backside of mirror to the light, finds **Triangle = 0**
33. Realizes he's only missing Square
34. Inspects encyclopaedia IV page 139, finds **Square = 3**
35. Inputs symbol code into phone
36. Room finished (38:26)

X. Informational brochure for physical experiments

Enschede, gemaakt 16-05-2019

Informatiebrochure EWI: Escape Room Hengelo

Beste ouder / verzorger,

Via dit bericht willen we u graag informeren over de test die wij graag in samenwerking met uw kind willen uitvoeren in het Museum Hengelo (Beekstraat 51, 7551 DP Hengelo). In het onderzoek, met de naam 'Escape Room Hengelo' worden deelnemers gevraagd om een escape room te testen door de gegeven puzzels op te lossen. Het doel van het onderzoek is om het door ons gemaakte ontwerp te testen, oftewel om er achter te komen of de escape room leuk en uitdagend is zonder té moeilijk te zijn. De bedoeling van het ontwerp is namelijk dat het toegankelijk is voor kinderen tussen de 8 en 14 jaar oud, dus een goede balans vinden in de moeilijkheidsgraad is voor ons erg belangrijk. Ook zien wat de kinderen leuk en minder leuk vinden speelt een grote rol, omdat we het ontwerp daarop kunnen aanpassen om de ervaring zo leuk mogelijk te maken.

Wat achtergrondinformatie: een 'escape room' is een soort fysieke puzzel waarin een groep deelnemers de opdracht krijgt om alle uitdagingen in een ruimte op te lossen, meestal met als doel om zo uit de kamer te 'ontsnappen'. Puzzels, raadsels en andere obstakels moeten hiervoor overwonnen worden binnen een bepaalde tijdslimiet.

Het testen van onze escape room zal naar schatting al met al ongeveer een uur duren. Dit is inclusief ontvangst, wat informatie vooraf en evalueren achteraf. Gedurende de test zal de escape room niet daadwerkelijk afgesloten zijn, er wordt dus niemand opgesloten. Het enige wat uw kind ervan weerhoudt om de kamer uit te gaan is het niet 'winnen' van het spel.

Escape rooms kunnen vanwege hun format enige vorm van stress opleveren, met name door de tijdslimiet en het samenwerken met anderen. Mocht u, voor wat voor reden dan ook, van mening zijn dat dit voor uw kind problematisch kan zijn, dan kunt u er uiteraard voor kiezen om uw kind niet mee te laten doen.

De test zal begeleid worden door de onderzoekers (wij, twee studenten van de Universiteit Twente) en een medewerker van het museum. Uw kind mag te allen tijde ervoor kiezen om te stoppen met de test zonder daarvoor een reden te hoeven geven.

Indien u er toestemming voor geeft zouden wij graag video-opnames maken van de test. Deze video zal enkel worden gebruikt om de notities die opgeschreven worden tijdens de escape room aan te vullen. We zullen met z'n tweeën notities maken, maar aangezien er 5 á 6 kinderen tegelijk bezig zijn is het goed mogelijk dat we alsnog dingen missen.

Deze beelden zullen nadat de notities zijn aangevuld worden verwijderd. Ze zullen nergens anders voor gebruikt worden, en niemand buiten de onderzoekers en hun begeleider zal ze kunnen zien. Het videomateriaal wordt niet online gepubliceerd.

Ook andere persoonlijke informatie van uw kind, zoals geboortedatum, naam et cetera zal niet bewaard worden. Alleen de leeftijd van uw kind, zijn/haar acties gedurende het experiment (in tekstvorm) en zijn/haar antwoorden op de door ons gestelde vragen zullen voor het onderzoek gebruikt worden.

Mocht u, voor wat voor reden dan ook, willen dat de data van uw kind eerder verwijderd wordt dan kunt u contact met ons opnemen om dit te vragen. Aangezien het voor ons verplicht is om hiervan een bestand bij te houden zouden we het op prijs stellen als u dit via e-mail zou doen. Onze contactgegevens vindt u aan het einde van dit document.

Hieronder vindt u een beschrijving van hoe het experiment in zijn werk gaat.

1. De deelnemers (kinderen) worden ontvangen in het museum.
2. De deelnemers krijgen een introductie over de escape room en een aantal huisregels wordt vastgesteld. Denk hierbij aan zaken zoals 'wees voorzichtig met de puzzels en meubels' en 'maak niet te veel lawaai' en dergelijke.
3. De deelnemers worden naar de escape room gebracht en het spel gaat van start. Indien er toestemming voor is gegeven gaat ook de camera aan om de test op te nemen.
4. Uw kind, samen met maximaal 5 andere kinderen, speelt door de escape room en krijgt daarin volledige vrijheid.
5. De onderzoekers (wij) zullen notities maken over de voortgang van de kinderen in de puzzels. Ook zijn zij en een medewerker van het museum in de gelegenheid om te helpen als er moeilijkheden zijn.
6. Na de test wordt de escape room besproken met de deelnemers en wordt een korte vragenlijst afgewerkt.
7. Achteraf krijgen de deelnemers een klein chocolaatje als bedankje. Mocht u niet willen dat uw kind dit krijgt, dan kunt u dat aangeven op het toestemmingsformulier.

Bespreek a.u.b. geen details over het verloop van het experiment met uw kind, aangezien dat invloed kan hebben op het verloop ervan. Uiteraard doen wij ons best om te zorgen dat het een leuke en veilige ervaring is. Deelnemers aan eerdere testen die we hebben gedaan gaven aan het erg naar hun zin te hebben.

Contactinformatie voor vragen omtrent de rechten van uw kind als deelnemer aan onderzoek

Als u vragen heeft over de rechten van uw kind als deelnemer in onderzoek, of als u vragen over dit onderzoek wilt stellen aan iemand anders dan de onderzoekers, kunt u contact opnemen met de interim-secretaris van de ethiekcommissie van de faculteit EWI (Elektrotechniek, Wiskunde en Informatica), mevrouw J. Rebel-de Boer: e-mailadres ethics-comm-ewi@utwente.nl.

Mocht u vragen of opmerkingen hebben, neem dan contact met ons op.

Met vriendelijke groet,

Coordinator: Edwin Dertien, gebouw Carré kamerC3431, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente. Tel: +315 3489 2778 email: dertien@utwente.nl ***(Nederlands / Engels)***

Onderzoeker 1: Jordi Agricola. tel: 06 46144292 email: j.agricola@student.utwente.nl ***(Nederlands / Engels)***

Onderzoeker 2: Chulakit Dumnoenchanvanit. tel: 06 13901775 email: c.dumnoenchanvanit@student.utwente.nl ***(Engels)***

XI. Consent form for physical experiments

Enschede, gemaakt 16/05/2019

Toestemmingsformulier EWI: Escape Room Hengelo

(Lees a.u.b. eerst de informatiebrochure.)

Hierbij verklaar ik dat ik op een duidelijke manier ben geïnformeerd over het doel en de werkwijze van dit onderzoek, zoals beschreven in de informatiebrochure. Eventuele vragen zijn naar behoren beantwoord. Ik verklaar dat ik gerechtigd ben om toestemming te geven namens mijn kind, en geef deze toestemming vrijwillig.

Ik behoud het recht om deze toestemming op elk moment in te trekken, zonder daarvoor een reden te hoeven geven. Ik begrijp dat mijn kind op elk moment gedurende het onderzoek zijn / haar deelname mag stoppen. Als er onderzoeksresultaten van mijn kind gepubliceerd worden zal dit volledig geanonimiseerd gebeuren. Gegevens van mijn kind worden niet aan derden verleend zonder mijn uitdrukkelijke toestemming.

Als ik verdere informatie over het onderzoek wil, kan ik de onderzoeksbegeleider benaderen: Edwin Dertien(tel: +315 34892778 email: dertien@utwente.nl; adres: Universiteit Twente, gebouw Carré, kamer C3431 , Enschede). Als ik klachten heb over dit onderzoek kan ik deze melden bij de interim-secretaris van de ethiekcommissie van de faculteit Elektrotechniek, Wiskunde en Informatica van de Universiteit Twente: mevrouw J. Rebel-de Boer, postbus 217, 7500 AE Enschede, tel. +315 3489 3899, email: ethics-comm-ewi@utwente.nl.

Vink a.u.b. aan wat van toepassing is:

Ik verklaar dat mijn kind naar mijn inzien in staat is om aan de escape room mee te doen, en geef hiervoor mijn toestemming.	☐
Ik sta toe dat mijn kind gefilmd wordt tijdens het onderzoek, met als enige doel om de resultaten van het onderzoek te verbeteren.	☐
Ik sta toe dat mijn kind na het onderzoek een chocolaatje krijgt als dank.	☐

In tweevoud getekend op (datum) _____

Naam van kind _____

Naam van ouder / verzorger _____

Handtekening _____

XII. Transcript of physical prototype experiment

Test number 1 - 28/5/19

1. Found mirror immediately, put it back
2. Picked up mag glass, played with it
3. Picked up mirror again
4. Went to logo puzzle
5. Sorted through books
6. Opened drawers in table
7. Attempted jigsaw assembly
8. Went to logo puzzle, found the different images
9. Four children worked on logo puzzle, two worked on the jigsaw puzzle
10. Completed logo puzzle → Received the number from the arduino
11. Were unable to immediately identify the place where the number could be used
12. Were able to identify what the UV flashlight was meant for
13. Tried to use UV torch through magglass
14. Crowded around the Red Reveal paper
15. Found the number on the church
16. **Found square**
17. Managed to open the combination lock
18. Using the UV flashlight everywhere but the correct place
19. Attempted to use the UV flashlight on the Red Reveal paper
20. Attempted to brute force the book puzzle
21. Returned to the jigsaw, did flip it over
22. More attempts to bruteforce the books
23. Tried to climb up the shelf to inspect the radar models (on top of display cabinet) with the flashlight
24. Managed to bruteforce the mirror open
25. Tried banging the chest
26. Placed a chain around the big key
27. *Jordi gave a hint for the key underneath the stool*
28. They immediately went to search for and found the key beneath the chair
29. They found the number within the chest **(Found X)**
30. Attempted to use the phone
31. *Jordi gives another hint (for the mirror)*
32. Children attempted to use the mirror to reflect the light instead of looking through it
33. The children reached something of a plateau as far as it came to the experiment
34. *Jordi gave another hint for the UV flashlight*
35. Went down to the correct book and utilized the correct number **(Found O)**
36. Returned to the mirror, still confused by what they were meant to be looking for
37. Attempted to use the mirror on the camera
38. Found the digit below the mirror
39. **Found triangle**

XIII. Arduino code for logo puzzle

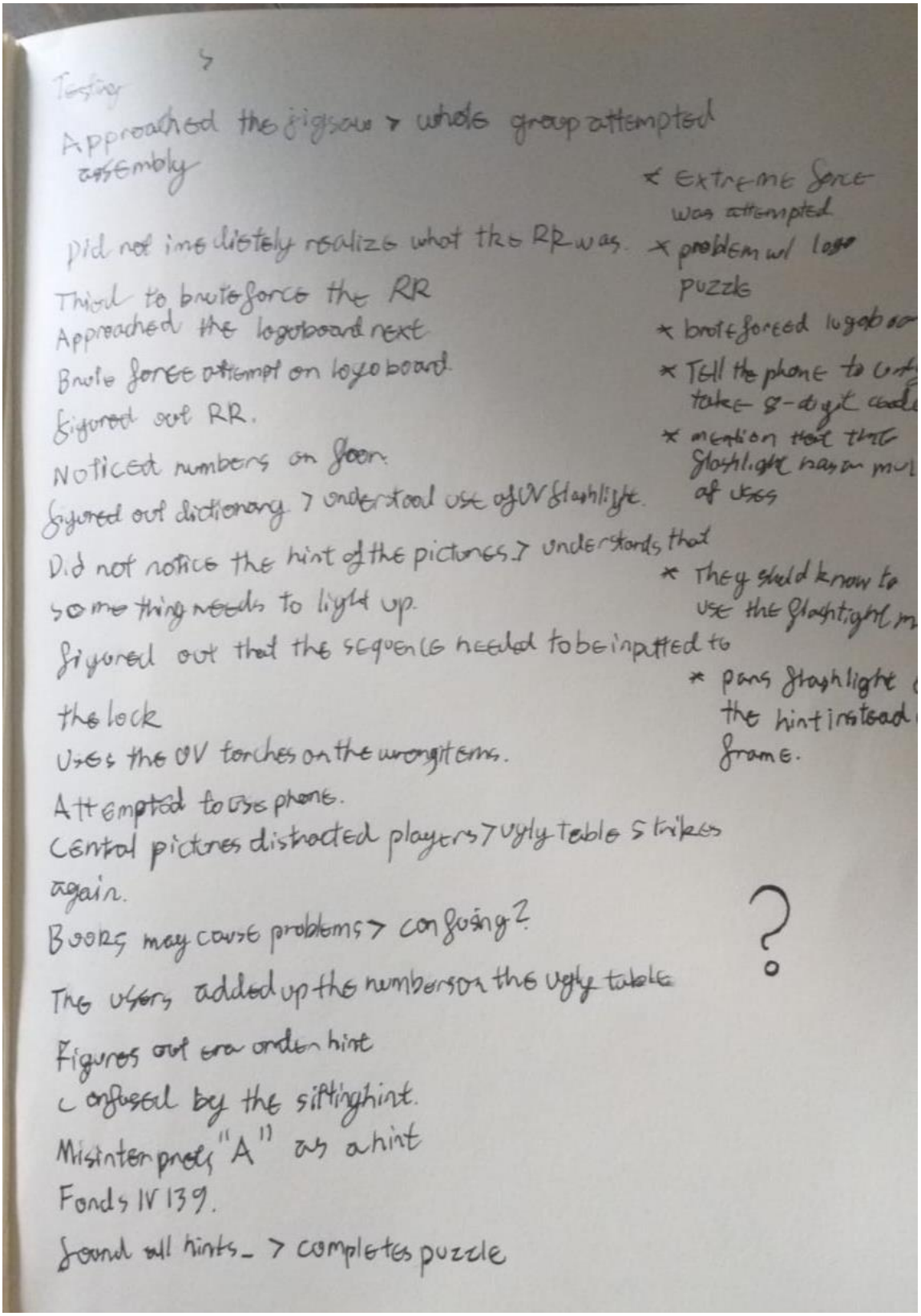
logoboard_code §

```
bool gamestate = false;
bool intro_ran = false;
int intro_loop = 0;
int intro_light_delay = 200;
int intro_delay = 0;
int light_on = 700;
int light_off = 200;
int hint_delay = 1000;

void setup() {
  for (int i = 2; i < 11; i++) {
    pinMode(i, OUTPUT);
  }
  pinMode(A0, INPUT);
}

void loop() {
  if (analogRead(A0) > 500) {
    gamestate = true;
  }
  if (gamestate && !intro_ran) {
    while (intro_loop < 4) {
      intro_loop++;
      int i = 2;
      for (i = 2; i < 11; i++) {
        digitalWrite(i, HIGH);
        delay(intro_light_delay);
        digitalWrite(1, LOW);
      }
      delay(1000);
      intro_ran = true;
    }
  }
  if (gamestate && intro_ran) {// code is 1868
    digitalWrite(2, HIGH);
    delay(light_on);
    digitalWrite(2, LOW);
    delay(light_off);
    digitalWrite(9, HIGH);
    delay(light_on);
    digitalWrite(9, LOW);
    delay(light_off);
    digitalWrite(7, HIGH);
    delay(light_on);
    digitalWrite(7, LOW);
    delay(light_off);
    digitalWrite(9, HIGH);
    delay(light_on);
    digitalWrite(9, LOW);
    delay(light_off);
    delay(hint_delay);
  }
}
```

XIV. Transcripts of final summative experiments



Testing 5

Approached the jigsaw > whole group attempted assembly

did not immediately realize what the RR was.

Tried to brute force the RR

Approached the logoboard next

Brute force attempt on logoboard.

figured out RR.

Noticed numbers on floor.

figured out dictionary > understood use of UV flashlight.

Did not notice the hint of the pictures > understands that something needs to light up.

figured out that the sequence needed to be inputted to the lock

Uses the UV torches on the wrong items.

Attempted to use phone.

Central pictures distracted players > ugly table 5 strikes again.

Books may cause problems > confusing?

The users added up the numbers on the ugly table

Figures out era order hint

Confused by the sifting hint.

Misinterprets "A" as a hint

Fonds IV 139.

Found all hints_ > completes puzzle

* Extreme force was attempted
* problem w/ logo puzzle
* brute forced logob
* Tell the phone to
take 8-digit
* mention that the flashlight has a mu
of uses
* They should know to use the flashlight
* pans flashlight
the hint instead
frame.

?

Test #2

Children went to the jigsaw first
Group went to logoboard.
Logoboard almost right the first time > brute forced
Found red mag glass.
Telephone rings.
Tried to fuse magglass w/ mirror
Flipped over RR puzzle
Attempted to use the fan's power sequence on the safe
Used magglass on jigsaw puzzle
Continues to ~~try~~ to brute force logo puzzle.
Got □ ~~[illegible]~~
Attempted to brute-force books > assumed book price was phone code
continues to try to brute-force the logoboard.
Got the thread of logic for logoboard.
Attempted the safe once more
Used the UV flashlight on everything
Found IV 139 > went to Encyclopedia
Recognizes importance of the number, sees no pattern
Finally noticed the last image
& Found the mirror number   43:23
Takes sitting very literally
found safe key.
found ☒
Clears room

* did not use the leveling board
* v. energetic.
* Picture frame seems too much like decoration
* confuses cotton with towels
* Hogwarts train

XV. Participant's questionnaire Physical Prototype

What do you think of the escape room? *Wat vind je van de escape room?*

Which was your favourite puzzle? *Welke puzzel vond je het leukst?*

Why was that puzzle your favourite puzzle? *Waarom vond je die puzzel het leukst?*

Which was your least favourite puzzle? *Welke puzzel vond je het minst leuk?*

Why was that your least favourite puzzle? *Waarom vond je die puzzel het minst leuk?*

Were there elements of the escape room that were too difficult or easy? *Waren er dingen in de escape room te moeilijk of makkelijk?*

XVI. Adults' questionnaire final experiment

Vragenlijst ouders - Escape Room Museum Hengelo

Wat vindt u (zelf) van de escape room?

Hoe geschikt vindt u de escape room voor de leeftijdscategorie van uw (groep) kinderen?

Wat vindt u van de lengte (tijdsduur) van de escape room?

Waren er bepaalde elementen naar uw mening te makkelijk of moeilijk? Zo ja, welke?

Heeft u nog suggesties voor de escape room?

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