

Escape Room Hengelo

Balancing Educational Content and Participant Enjoyment Within Escape Rooms

Chulakit Dumnoenchanvanit

University of Twente 2018-2019 Student 1673238

Creative Technology Graduation Project

Supervisor: Edwin Dertein

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Introduction

How can we develop an escape room for the Museum Hengelo such that the educational content of the room does not interfere with the enjoyment of the room participants? The purpose of this project is to explore escape rooms as a gamified educational tool and find an appropriate balance between educational content and media engagement. The room should satisfy both the educational requirement of the client and the enjoyment of the children who are the target audience of the escape room. The report aims to review the relationship or lack thereof between the educational content and the enjoyment of the room by developing and analysing different puzzles within the room, each with a different level of practical comprehension of the learning material required to solve, and comparing the level of reported enjoyment of the test subjects for each puzzle.

There are components and design choices that make certain gamified educational platforms more effective than other comparable platforms. There is a need to create as good as product as possible and whilst it is possible to run contrasting products to narrow down the variable that creates for an interesting and effective educational escape room, that method is both time consuming and will only superficially answer the research question. Contrast testing is simply inappropriate for formatting a psychological and an academic analysis of escape rooms and what can be done to make them as good as possible. An approach that stresses interviews and the subjective experience of the participants will be able to better answer the question. It would also confirm whether or not the proposed hypothesis of negative correlation between learning oriented content and the participant enjoyment actually holds true. The design also aims to overcome these challenges through attempting to find a better compromise between the two metrics. Answers will likely be available within the literature, but this paper aims to create a project that is targeted specifically towards the sampled audience population of the children directly from the area in which the product will be deployed.

Project outline

This report will break down the design and creation process into multiple steps. Following the introduction, the paper will explore the various escape rooms that have existed and analyse what can be learnt from them without further experimentation. The analysis will cover, in more detail, the basis and the resources allocated to the project. The analysis will also break down the various project requirements into actual components that could then be tested and evaluated for both how enjoyable the room's puzzles are and how much educational content each puzzle piece actually has. The state of the art will cover potentially interesting commercial escape rooms and thoroughly cover a select number of academically sourced escape rooms in order to build an understanding of the functional components and the optimum design paradigms. The state of the art will also aid in the brainstorming process as it will allow the project to utilize the good ideas that others have already thought of. The methodology and specifications restates the project requirements and discusses implementation options for the project. The ideation and design part of the paper will cover the creation and elimination process of the various parts of the project. Utilizing the design ideas from both the state of the art as well as various other resources for escape room construction online, a shortlist of potential puzzle concepts was constructed and justifications are then stated as to why each specific puzzle was selected or rejected for the design process. The realization then covers the implementation of the research questions as it relates to creating experiments to test enjoyment factor of the various puzzles. The results and analysis will state

the information acquired from the test and then describe the data to be analysed and conclude what was learned from the tests. The discussions will return to the state of the art and discuss what was actually learned from the test and propose recommendations for future iterations of similar tests as well as to propose potential uses for the information acquired during the research.

Context Analysis

The purpose of the educational escape room for the Hengelo museum is to cover the topic of the historical development and growth of the city and utilizing the escape room as a tool to deliver this educational content. The room aims to leverage the knowledge within the literature and in conventional escape rooms to develop the educational, engagement, teamwork, and goal oriented components of the escape rooms in order to optimize both the level of participant enjoyment and educational objectives to fulfill the requirements for both the client and the children which the escape room is to serve.

The project document here is the work of two bachelor students, including the author of this paper, in conjunction with a supervising professor. The project is created for the use by the Museum Hengelo: a small local museum in the eponymous city for the purposes of education and entertainment. The museum has placed the project under a quite short list of requirements that allows for much more creative freedom for the creation of the project. The museum's contact point would like for the room to entertain the visiting children, but also teach them something. How much they will need to be entertained, how much they are taught, and what exactly they are taught is mostly up to the designers of the room which grants a large degree of creative freedom.



Figure 1, Hengelo Escape Room

The project is being developed in conjunction with the Assortimens company, a company that specializes in manufacturing assorted pieces of equipment ranging from furniture to arcade style consoles. The Assortimens company will assist with the creation of specific and custom items to better fit the room from both a game mechanic and aesthetic perspective. Within the context of this project, the museum is the primary stakeholder as the museum is the one financing the project and shall ultimately become the operators of the escape room.

The point of this escape room is to create a gamified educational experience: one that emphasizes both fun and education. Gamification is the application of game design principles outside of the context of game design, such as in education¹. Escape rooms are almost certainly games, or at least they utilize design principles that would be considered central to the creation of any gameplay experience including teamwork [12] and information recall [11]. As such, implementing an escape room into a museum exhibit will easily fall within the borders of gamifying the experience. The Museum Hengelo is currently a very standard museum with non-interactive exhibits which usually are presented by allowing the visitors to come in, look at the artifacts, and read the texts. A formalized interactive exhibit is the first for the museum and the museum's contact point consequently granted the allowance for the developers to develop the escape room as we please as long as we loosely fulfill the requirements set by the museum. The large degree of creative freedom and low degree of client guidance makes creating an evaluation matrix for the success of the escape room something of a challenge. The goal is to meld education and entertainment into a single product and try to promote both to the highest degree possible within the context of the escape room. As enjoyment and educational content and the balance between them is the metric which the Museum Hengelo's contact point wants to evaluate the project by, this paper will treat the maximization of both enjoyment and educational content of the room without severely compromising either. Furthermore, the research hopes to find out whether or not there is even a need for a compromise between educational content and enjoyment as it pertains to escape rooms.

Escape rooms and gamified experiences in general are able to leverage mechanics which are simply not available to regular education. Gamification can be highly effective, at least when applied within an educational context, when it is able to transform and deliver the content of an education syllabus in a way that turns the task from something mundane into an appealing and even addictive experience [1]. Gamified systems has a further benefit of being able to engage with adult participants [10]. That said, I have found that educational games tends to suffer from two outstanding problems. The first issue is a matter of setup. Educational 'games' quite often just regular exercises disguised as games, exams and textbook exercises delivered within a different medium. This can be seen most evidently when covering academic escape rooms [5] where the exercises are barely disguised versions of standard textbook exercises. Such setups would, to me, be undesirable though they could still serve to be useful. Meta-studies have found that most studies regarding gamified academic experiences find that the gamified experiences tend to already function better than comparable academic exercises [2] and participants indicated that they were more engaged by the problems and more involved in group discussions in comparison to their usual experience of a classroom [13]. The fact that gamified academic products tend to perform better than their purely academic counterparts doesn't directly answer the question of whether or not the scale of gamification and the level of educational content impacts the enjoyment of users however.

¹ <https://en.wikipedia.org/wiki/Gamification>

State of the art

Commercial and academic escape room varies in their primary objectives. A commercial escape room is there to make money for the creators and to maximize the chance that the location name is spread as far as possible as a form of advertisement. Educational escape rooms on the other hand have a captive audience and have the primary goal of communicating and imbuing information as any exercise and textbook does. That said, they share similarities. An interesting and engaging escape room is a metric that successful escape rooms in both commercial and academic escape rooms would score well in. Likewise, there are various other components that escape rooms in both spheres share.

Commercial escape rooms

The precursor of escape rooms and the closest to the idea of the modern escape room is 5 Wits, arguably the first ever escape room. Though the goal of 5 wits is not to escape, it holds many of the defining elements of an escape room including an interactive storyline and an end state². The first escape room that has marketed it as such was the Real Escape Game developed by Takao Kato in 2007, an escape room that heavily utilized logical puzzles and numerical and color coding much like computer games that said room was allegedly inspired by³.



Figure 2, 'Real Escape Game' by Takao Kato

The fact that escape rooms were not initially conceived as escape rooms but as a preexisting format that has all but been absorbed makes for an interesting historical note. Escape rooms were not actually a genre in and of themselves at first. Escape rooms can be described as a very small and particular subset of amusement park, cooperative puzzle game, and theatre rolled into one. They were initially establishments built around puzzle games that have grown to encompass the set. Escape rooms was just a format that room creators and participants both took to with great enthusiasm, judging from these

² "About 5 Wits Adventures." 5 Wits, 29 Mar. 2019, 5-wits.com/what-is-5wits/.

³ Corkill, Edan. "Real Escape Game Brings Its Creator's Wonderment to Life." *The Japan Times*, The Japan Times, 20 Dec. 2009, www.japantimes.co.jp/life/2009/12/20/to-be-sorted/real-escape-game-brings-its-creators-wonderment-to-life/#.XL4QTOgzaUI.

points of data. 5 Wits in fact vehemently stated that they were not an escape room and were marketing the fact that they weren't an escape room as a selling point.

Modern escape rooms have developed defining features. Tracking down escape rooms with good scores and exposure often yields a rather numerous list of shared elements between escape rooms. From the list of best escape rooms in the world compiled by The Perfect Escape website⁴, Skurrilum from Hamburg, Germany, Sherlocked from Amsterdam, Netherlands, Mr. X Puzzle House from Shanghai, China, Escape Hunt from Paris, France, and Roomscape from Dallas, United States all carry some very notable common elements. First of all, all of these escape rooms have a very strong identity in terms of theming and the mood of the escape room. The rooms are noted to be memorable in part due to the fact that the setting of the room is such that the rooms have a very strong mood. The Mr. X Puzzle house, for example, heavily invests in props and components in order to make the room come alive. The massive investment that no doubt went into making the escape room look convincing as a piece of living media and therefore increase the immersion that the audience feels inside of the room.

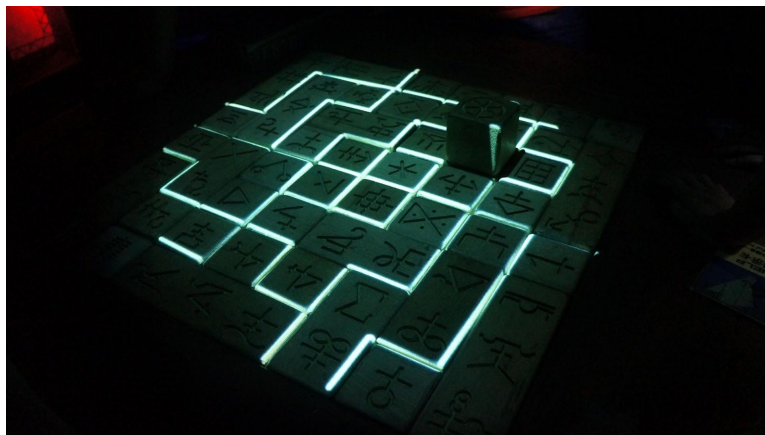


Figure 3, One of the puzzles from Mr. X

This is especially notable as a strong theme and high production values are far less of a driving factor through the design of the often cited escape rooms in academia. A lower production value in academia may be expected, the lack of a strong theme in comparison to commercial escape rooms is not. The extent to which immersion supports engagement is not studied in academia and would be difficult to gauge even if it was. That said, memorability and strength of theme is likely to be a very important factor when it comes to memorizing the actual escape room and evoking emotions that relate to the escape room experience that could be transferred over to academia where such things are severely lacking.

Escape rooms in academia

Educational escape room shows just about every cited benefit of gamified educational paradigms over non-gamified paradigms [1]. Furthermore, there is a very high level of interest and desire for escape

⁴ Tri. "Best Escape Rooms in the World | Most Popular Escape Rooms." *The Perfect Escape*, The Perfect Escape, 29 Jan. 2019, perfectescaperoom.com/famous-escape-rooms/best-escape-rooms-in-the-world/.

room educational tools and related works within the field of education [8]. When discussing student motivation and engagement, various academic escape rooms had roundly positive feedback, stating that students are more active and motivated to act in a team [5], that students reported an increased level of interest not just in learning but the topic being covered [9], and that students in general expressed interest in the escape room as a method of learning [6]. Escape rooms are rated highly by students and test subjects and is even stated to actually motivate students to engage in subjects that they otherwise wouldn't be interested in. This is incredibly promising, as it means that escape rooms can potentially have positive impact to student engagement and performance far beyond the scope of the material and topics covered inside of the escape room. Despite that, there is the undeniable fact that academic escape rooms are lacking and bland compared to their commercial contemporaries. One thing that all successful commercial escape rooms have is a strong theme: an atmosphere that entirely fills every single component of the experience. It would be best to demonstrate this by looking at a few academic escape rooms however.

Vörös [6] notes that gamification of the educational process provides certain boons citing engagement, participant interest, and tangible objectives with which the participants could navigate the room. This is a noted benefit that escape rooms have over non-gamified educational frameworks that often is unable to generate interest within students the same way that gamified education can. Pan [3] further states that the escape rooms in academia mirrors commercial escape rooms in its ability to provide a space of cooperation and communication for participants.

Dietrich [5] created an escape room that utilizes chemistry concepts inside of an escape room. The paper had a positive participant feedback, but we need to remember that escape rooms inside of academic settings operate under quite different mechanics than commercial escape rooms. Whilst discussing escape rooms by contrasting commercial and academic escape rooms, it is important to remember that the closest functional contemporary to academic escape rooms aren't their commercial kin but are instead traditional teaching methods such as lectures and exercise books. The fact that an escape room is 'interesting' in this context simply means that it compares favorably to rote memorization and repeat exercises that students probably have been participating in for close to two decades at the point where they engaged with the escape room material. Quite frankly, just about everything would compare favourably to yet another uninteresting exercise.

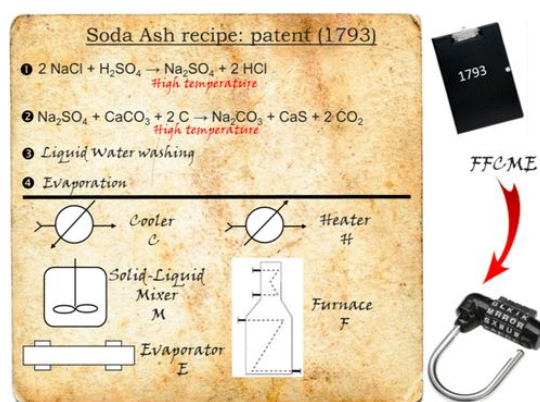


Figure 4, A simplified overview of one puzzle, document [5]

The problem with the escape rooms that the academic world offers is that it almost invariably is just a conventional question worded differently. It is academic material, ground down with more savory bits in order to make the uninteresting and unengaging parts of the subject a bit more palatable. Whilst the positive feedback from academic escape rooms is reassuring, the persistent issue with academic escape rooms do not go away. Reforming exercise questions into a new format may offer options for participants to engage in teamwork and cooperation in order to complete a tangible goal that they are offered [4], but the simple fact is that the escape room inside of academia is a rather poor showing of what is effectively just a facelift done on pre existing exercises with cited issues with student motivations.

It appears that the difference between performance metrics of educational and commercial escape rooms comes down to effort. The lower standard on display by academic escape room is likely the result of the captive audience that allows for developer complacency. If the escape room in academia is below par, students can't exactly just stand up, cross over a school district, and study at an institution with a better escape room instead. Through all of the 6 academic escape rooms listed in the references, all of which represent different subjects being implemented in the escape room format, there is not one that has put anywhere near the kind of effort seen in commercial escape rooms into the academic escape rooms. The academic escape room lacks even a theme that commercial escape rooms will not launch without. The academic escape room has content, but it has no theme. It has nothing for the audience to connect to besides the content. The state of the art of academic escape rooms seems to entirely be driven by the bare bones questions, dressed up slightly as to not be immediately recognizable as an exercise facelift. Whilst this may be perfectly fine for a one-off event, such a thin veneer is unlikely to last and the novelty that academic escape rooms all but certainly benefit from will fade to leave behind a mediocre experience that nevertheless takes up far more time and resources than traditional education of any type.

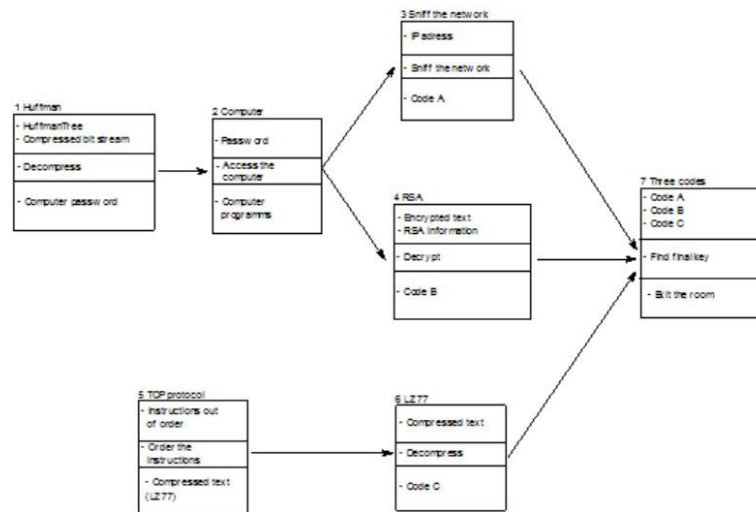


Figure 5, Puzzle component inside of escape room [4]

When analyzing the state of the art, the disparity between commercial and academic escape rooms can't be any more clear. It evokes the idea of the old turn of phrase that said that brilliance is inspired by struggle. When academic escape rooms can always get an audience, they have little need to improve. We do, however, if we want to make the Hengelo escape room a successful event then we will need to do far more than simply follow the footsteps of academic escape rooms. Academic escape rooms have provided us examples of how to work with educational content. Most of the time, the academic escape rooms are so bare-boned that they are indeed nothing more than the educational content. Expanding and developing this base into an enjoyable and engaging experience whilst serving an educational message will no doubt be challenging, but it is a challenge that we can't really avoid if we are to bring this escape room to anything approaching a good escape room product.

Specifications

The overall question that the report want to answer is how we can best balance the educational content and entertainment. Firstly, we will conduct a test with a pen and paper prototype for formative feedback in designing the underlying logic within the puzzle. Then, we can use what we have learned to create the physical product and conduct an actual test with the target audience of 8-14 year old children to investigate the presence of a negative correlation between educational content and participant enjoyment as well as to evaluate how well the project performs as an escape room. For this, the subjective experience of the children is the most important component that will be inspected. An academic paper directly addressing the relationship between education and enjoyment as it relates to a learning tool is not a topic that has seen much academic coverage, if at all and therefore information regarding the relationship between academic content and entertainment seems to be necessary and worthwhile. For the purposes of the test, the educational content will be scaled between the different puzzles as the test is meant to evaluate whether or not introducing and increasing the acquired knowledge required to solve a puzzle. Some puzzles will be entirely unsolvable whilst learning nothing, others will only be solvable through either understanding of the knowledge content within the room. The test will conclude with a questionnaire that asks the children to comparatively rate the puzzles which they participate in.

Before the physical test though, we will need to test the coherence of the escape room. When evaluating the logic and reasoning behind any type of exercise, the designers almost inevitably would gain a blind spot in regards to the design of their devices. Logical leaps and reasoning that looks entirely reasonable and obvious to them might be esoteric and confusing to others. This goes double for a project that is designed for children with ages as low as 8 years old, though it is a persistent problem with just about any audience. The initial test is meant to test the logic and reasoning behind the experiment to ensure that the reasoning behind the test is functional and sound. The real room has a lot of distracting components that also presents an interesting challenge for the test subjects. Unlike jigsaw pieces, not all of the cards provided to the test subjects actually go anywhere in the puzzle. This is also to make sure that the pieces that do not fit do not prove to be too distracting for the participants.

The test at this early phase utilizes cards in the format of a board game in order to represent the room. The board game is an instance of a paper prototype utilized in many experiments and is generally considered an accepted standard for modelling more complex experiments and products in early phases of design⁵. The initial test utilized easily accessible test subjects, in this case the other students within the vicinity of the testing chamber, for the purposes of evaluating the game logic. Whilst the end product caters to children, this initial phase of the puzzle is meant to test the logic behind the different components of the room and as such simply having students run through the room's logic is enough. The initial paper prototype will be able to reveal whether or not there is logical flow and questions regarding whether or not the educational content interferes with the enjoyment of the test subjects. They are not the target audience regardless, and so their enjoyment does not necessarily answer the question of whether or not the educational component interferes with the enjoyment. Testing the relation, if there is any, of the educational content and the enjoyment of the target audience will have to

⁵ Paper Prototyping: The Fast and Easy Way to Design and Refine User Interfaces

wait until the physical testing. Even then, the relatively low number of test subjects will unlikely allow us to form any tests with a high power or authoritative conclusions. Hopefully however, the test will inform us on how to create a better product.

Ideation & Design

The initial design phase was based upon the design of the escape room before we begin constructing things in their technicalities. As this is likely the first time that the children have experienced an escape room, that needs to be taken in as part of the design paradigm. We will be able to utilize cliched design options without inducing reflexively negative reactions from the audience. On the other hand, we needed to keep in mind that the kinds of leaps of logic that we would be able to make might not be obvious to the children. We need to keep that the kinds of things that we consider to be common knowledge and common sense might very well be esoteric and obscure for younger children. As such, we want to implement mechanics that are novel but still understandable.

The initial brainstorm yielded many results, some of which are taken from other escape rooms and others being common knowledge. Some of these were implemented, others were rejected for various reasons.

1. Every puzzle gives a digit of the final door code - An idea that was eventually incorporated. Most escape rooms ran puzzles in series. As we were hosting children who are unlikely to be able to coordinate as effectively as adults, we thought it might be better to allow them to work on each puzzle separately.
2. Jigsaw style assembly puzzle - We really liked the idea of using the jigsaw puzzle. This allows for tactile engagement and provides a chance for the children to play with spatial reasoning.
3. Overlay puzzle - This was eventually judged as technically unviable.
4. Transposition cypher puzzles - We really did like this idea, but we were unable to come up with a good way to communicate how to solve the puzzle to the children. If we just state the way to solve it, it just becomes the jigsaw puzzle without the tactile aspect.
5. Angled view puzzle - The puzzle was deemed to be too obscure to be recognizable. For children who know what the puzzle is the part will be trivial. For those who do not know, there is no effective way to figure it out.
6. Capacitive circuit puzzles - Using electricity and exposed circuitry is fun and quite safe at the relatively low voltage at which an Arduino operates, but ultimately having exposed circuitry opens up the possibility of the puzzle being worn down or damaged by repetitive use which we wanted to avoid.
7. Hidden messages illuminated by backlight - We choose to implement this because it was relatively easy to implement and, like the red reveal, allowed the puzzle to eventually be figured out even by interacting randomly with the puzzle without needing prerequisite knowledge to solve the puzzle.
8. Red reveal puzzles - fun and recognizable. Even if the children do not immediately recognize
9. Hidden doors - This was taken off the list because the confines of the room made hidden doors an unviable puzzle.
10. UV flashlight to reveal hidden messages - easily utilized and developed for, we definitely wanted to use this.
11. Riddles & worded puzzles - Whilst fun, there are implementation issues. We do not have the benefit of being able to choose an age group and spanning the intellectual development level

between the ages of 8 to 14 makes it essentially impossible to design a riddle for one age group that would be of suitable difficulty for another.

12. One-way mirror - The one way mirror is a semi-transparent mirror. If there is a difference in luminance between the two sides, then observers from the side with more light will see a mirror whereas the observer from the side with less light can see through perfectly. This allows the participants to feel the sensation of discovery once they realized the trick with the mirror.
13. Order the books into the correct order - We had to discount this due to how technically complicated this would be. We had the initial idea of using capacitive patches, RFID and barcode readers, and various other mechanisms to try to get the puzzle to function. We eventually abandoned the concept when we were able to create a significantly simpler setup that utilized similar technical formats.
14. QR, RFID, or barcode readers - We eventually ruled this out due to the technical complications that might arise due to maintenance. Having to reboot, reset, and restart arduinos or computers every single time presents far larger technical issues than we are comfortable with allowing.
15. Music plays in the background, there must be complete silence in the room for a time for the puzzle to be completed. Music needed to be disabled and talking needed to be stopped - Considering our audience we would have been unlikely to make this puzzle function.
16. Cooperative puzzle, the person operating the puzzle can't see the game state - Our room proved to be too small for this puzzle to effectively function.
17. A too small cylinder with a key inside that will need to be filled with water to make the key float to the top - We wanted to avoid using liquid in any puzzles due to the mess it might create. The room also housed historical artefacts that should not be exposed to water and circuitry that may be destroyed by contact with water.
18. Clue requiring the players to flip through to the correct page of the correct book - We really liked the idea and implemented this in our designs.
19. 'Who is it' style game to eliminate books in order to find the one needed - It stood up to specification challenge, but was eventually discounted for a similar but better puzzle.
20. Really poorly illuminated components that are only visible when the lights are turned off - This was yet another puzzle that needed to be removed due to physical constraints. The room we are in housed massive windows with no curtains which made this puzzle entirely unviable.
21. Use a magnet to manipulate an object the players can't touch - it had a cool concept but we were unable to come up with a puzzle that was suitable for this mechanic.
22. Item hidden inside books - This was easy to implement, utilizing a limited number of pieces that need to be developed. It also had the appeal of delivering a hidden treasure.
23. Look for answers hidden inside of text - We eventually discounted this idea for various reasons. First, prolonged contact with human skin would eventually damage the pages which mandates the kind of replacement that we want to avoid. We also don't think it's very entertaining and worth incorporating into any tests.
24. UV puzzle hidden on open blinds - this had to be discounted as we were unable to install blinds or curtains in the room's windows.
25. Large classical-style map of Hengelo that contains number sequence - judged to be unviable due to the limited dimensions of the room.

26. Receive clues through old-timey telephone and use the telephone to dial numbers - This was something that we were recommended through our contacts. We were of course going to implement it due to how unique of an experience getting to operate a rotary telephone is.
27. Use the two 360 views to obtain a number, the room has a 360 view on the floor which we would want to implement as a part of a puzzle - this was easy to implement and incorporate into many different puzzles.

We ended up ruling out the vast majority of the components, choosing the best options that would fit coherently within the size of the room and for the younger audience. We therefore ended up with a shortlist of the items we wanted to implement into the first stage of testing that we would do to test the room.

1. Every puzzle gives a digit of the final door code
2. Jigsaw style assembly puzzle
3. Hidden messages illuminated by backlight
4. Red reveal
5. One-way mirror
6. Clue requiring the players to flip through to the correct page of the correct book
7. Large classical-style map of Hengelo that contains number sequence
8. Receive clues through old-timey telephone and use the telephone to dial numbers
9. Use the two 360 views to obtain a number

The disparate components were assembled into a single piece with each piece contributing to a different part of the puzzle.

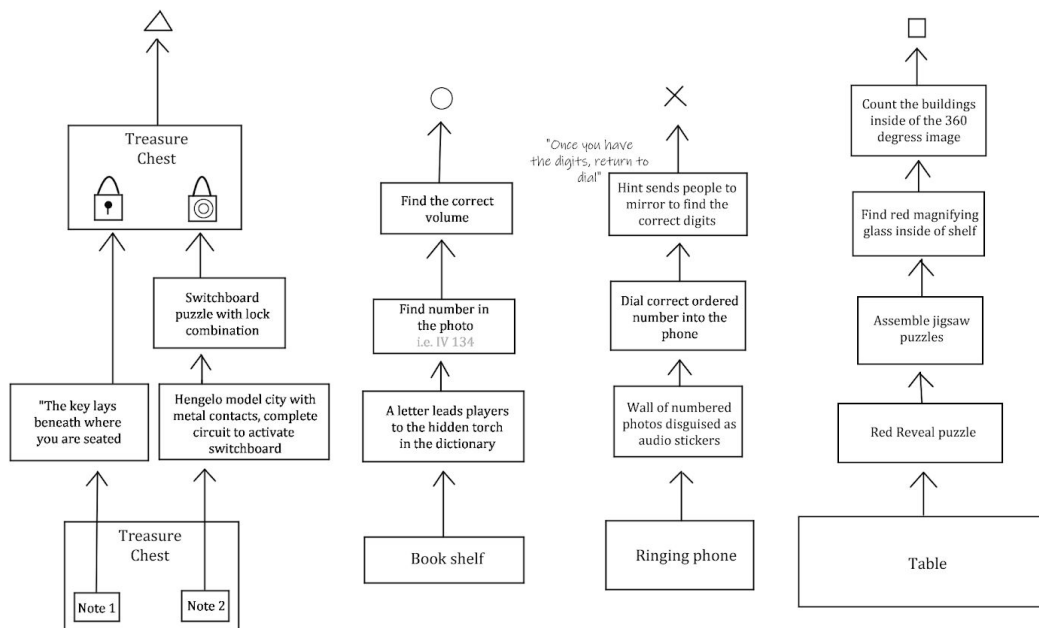


Figure 6, Finalized Initial Room Design 1

Figure 6 shows the initial paper prototype flow chart prior to the construction of the paper prototype. The designs have changed moderately little since this initial design

Personal Contributions

The development of the Hengelo Museum escape room was done in conjunction to Edwin Dertein of Assortimens and developed between two students including Chulakit Dumnoenchanvanit, this paper's author, and Jordi Argicola, the other developers within the project. The workload was divided between the two students in accordance to which of the two can either develop each segment of a project most quickly or develop it to a higher standard or some combination of those two factors.

Conceptualization

The majority of the contribution to the project during the ideation phase overlapped. During this period, both of the escape room developers leveraged past knowledge regarding escape rooms in order to construct the ideation phase in conjunction with content available online⁶ for other concepts that could be implemented within the escape room. In this early phase, the functioning of the escape room took priority over any concerns in regards to answering any overarching questions about the escape rooms. In this first phase, the construction and planning of the escape room ran in parallel and was focussed upon creating the logical skeleton of the escape room. At this phase, private work on the escape room from either of the developers were at a minimum as the various sessions composed the majority of the development time. Both developers contributed effectively identical time to the project at this phase of the creation and the work is too intertwined to parse personal contributions of each specific developer.

Paper prototyping

The paper prototype, developed to test the logic behind the 'skeleton' of the project, saw a much higher division of workload. The paper prototype required testing with live subjects and therefore the consent forms and ethical protocols as well as the creation of testing procedures. Both developers surveyed the room in order to take actual distance and size measurements of all of the disparate components of the escape room for the purposes of designing equipment that is of a suitable size for the room in question. The workload division of the project saw the author of this report taking care of the creation of the paper prototype itself by creating mockups of the escape room floor plan as well as the components in the form of playing cards to be utilized within the test. Both developers were present for the test and conducted the test in tandem with the author of this report taking notes and managing the puzzle components and with Jordi managing the verbal description of the room, managing the hinting system, and keeping time for the puzzle.

Project realization

The production of the project needed two large families of responsibilities which were the creation of the physical components of the project themselves and the accompanying paperwork that included the manual of operation for the escape room as well as the mandatory consent forms and the escape room testing questionnaires which will be necessary to answer the research questions proposed by both of the room's developers. In general, this report's author generally worked with circuit assembly, component creation, laser cutter plan creation, and assembly and cutting of components that require large amounts of detail when it comes to handwork. Jordi focussed on the creation of the necessary

⁶ <https://nowescape.com/blog/100-more-great-escape-room-puzzle-ideas/>

forms, maintaining and managing contacts with the clients, the project coordinator, and the prospective test subjects was the role primarily of Jordi. A more specific breakdown of roles is written below:

- The consent forms⁷ were mostly created by the work of Jordi Argicola and distributed by him as well.
- The creation of the jigsaw puzzle⁸ was a cooperative effort with Jordi editing and sizing the jigsaw puzzle within a photo editing program and this report's author who designed the laser cutting diagram, glued the printed images onto the puzzle, trimmed the paper down to the correct size, and varnished the printed images onto the jigsaw pieces.
- The acquisition of the various components such as the copper tape for the logo switchboard and the UV flashlight was dealt with by Jordi.
- Questionnaires⁹ were drafted by both parties and edited into Dutch by Jordi.
- The logo switchboard and the accompanying code and circuitry was designed, cut, glued together, debugged, and assembled by this report's author.
- The clue based language puzzles were dealt with by Jordi.
- The mirror puzzle¹⁰ was designed, the laser cutter diagram drafted, and the card created by the author of this report.
- The red reveal puzzle¹¹ was designed, the laser cutter diagram drafted, and the pieces assembled by the author of this report.
- Setting up and assembly of puzzles within the escape room location were done cooperatively by both developers.

Physical prototyping

Both developers were present at all three physical tests both in the initial phase and in the full product test phase. Once again however, the workload was divided depending on what each specific developer was capable of contributing. Both developers are responsible for setting up and cleaning up the room. That said, Jordi was still the primary member responsible for introducing the room and running the questionnaires and this report's author is the one who was responsible for noting down the actions of the various participants within the room in order to correspond with other methods of recording. This was especially important during the tail end of the physical prototype tests when video recordings were not viable due to the stipulations within the consent form and the necessity of acquiring actual test subjects.

⁷ Appendix for consent forms, page

⁸ Jigsaw puzzle, page 32

⁹ Questionnaire questions, page 35

¹⁰ The mirror puzzle, page 62

¹¹ The magnifying glass, page 66

Paper prototype

The paper prototype is not a test as much as in an iterative design process. As the purpose of the paper prototype is to make sure that the logic behind the puzzles are functional and sound in concept and in creation. As such, the different segments of the test are adjusted to remove any issues that the early test reveals even when the fundamentals of the procedure remains the same. Each phase of the test essentially uses a different version of the test and that is a deliberate part of this iterative design process. The paper prototype utilizes the procedures outlined above during the realization phase. The more detailed transcripts of notes is down in the appendix phase of the paper.

The purpose of the paper prototype is to test the logic of the puzzle. As such the bare minimum moving parts of the projects, the outline of the different pieces that will fit together to form the puzzle, will be needed for the test. As long as the test subjects are able to interact with the puzzle as if they were in the room, the test will serve its purpose of testing the logic of the room. We will need to make sure that the test subjects are able to reason essentially as we do. If university students are unable to reason their way around a puzzle, it is unlikely that the children target audience will fare much better. The purpose of this phase of the experiment is to test out the logic of the room and iteratively improve the setup so that once the paper phase of the prototypes concludes, the experiment will be logically sound even for those who are entirely unfamiliar with the experiment.

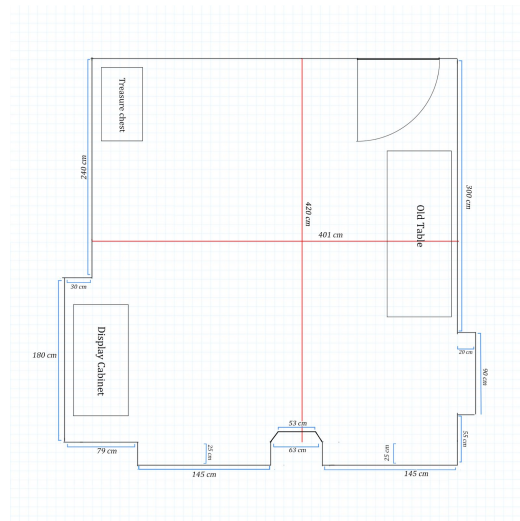


Figure 7: Room representation

The room is represented by a large printed map as seen above. For the purposes of experimentation, the test was conducted at the Proto board room inside of the Zilverling building within the University of Twente. The room's component items are represented as cards inside of the room's mockup. The room utilized the map as a representation of the physical space within the room. To set up the experiment, one researcher introduces the study and the rules within the study and takes corresponding notes. A video camera is set up overlooking the paper prototype such that the researchers can review the actions taken and difficulties faced by the test subject so that improvements could be made iteratively. The cards all represent items within the room and are sorted into five distinct piles that can be manipulated

and utilized by the test subject in order to run the test as if they were within the actual escape room. The piles of card represents 'stations' within the room where items are compiled and are as follows:

Hidden cards

- Key
- Bookshelf books (multiple)

Right cards

- Mirror
- 360 view
- Destroyer
- Metal frame

Display case cards

- Walking Cane
- Knife
- Dinner bell
- Chainmail purse
- Metal chain
- City map

North cards

- Phone
- Window images
- TV screen

Bookshelf cards

- Magnifying glass
- Switchboard
- Words
- Bookshelf
- Wooden panels

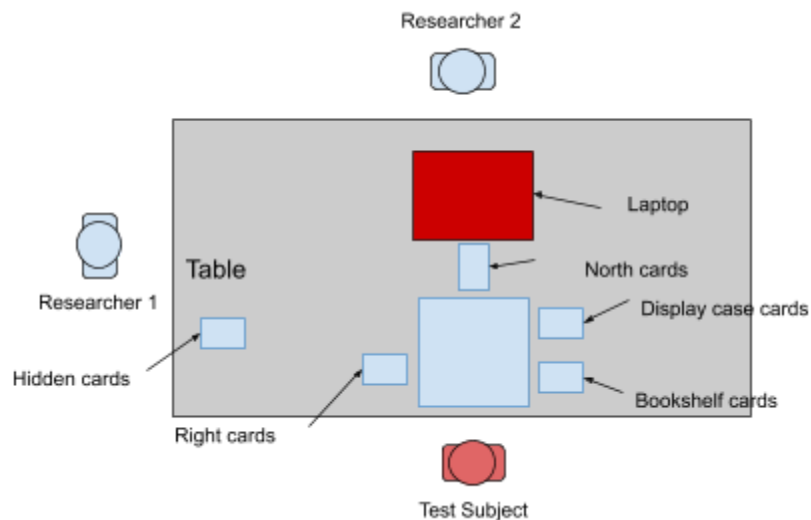


Figure 8: Experimental setup

Each of the items representing items that are already within the room or will be created and placed there for the physical prototype. Certain puzzles are much more visual however. For these specific puzzles, supporting images are provided to facilitate the test. The wall below bears component solutions to two different puzzles detailed within the methodology segment including both the phone and the

switchboard logo puzzle. These images were displayed on the screen of the laptop and placed in front of the test subject.



Figure 9: Wall of paintings

Once the test subject enters the room, researcher 2 will give them a brief description of the concept of the room and what it is meant to represent. The subject is asked to verbalize all of their thoughts in order to better illustrate the logical reasoning of the test subject. On the test subject's signal, the stopwatch is started and the experiment officially begins. The total experimentation time within this phase is variable on how long it takes the test subject to perform the task. Once one full hour has elapsed from the start of the test, the experiment is concluded and that instance of the test is considered to be unsolved.

The researchers are to maintain minimal contact with the test subject and are to only give clarifications if the subject either directly requests it or the subject's dictation has made a critical error in comprehending the flow of the puzzle or the content of one of the cards. In either case, the issue is noted by the first researcher as a flaw within the puzzle worthy of a potential fix. Once the time has entirely elapsed or the subject is able to complete the paper prototype escape room, the subject is asked several questions regarding the test. These questions are:

- Are there any parts of the test that you find to be particularly difficult or illogical?
- Are there any parts of the test that you have found too easy or trivial?
- Are there any parts of the test which you considered to have consumed too much of your time?
- Are there any parts of the test which you think was too short?

- Are there any other things you would like to see in the full escape room if you ever decided to visit?

Other questions are questions mostly regarding the answers given to clarify certain parts of the responses from the test subject. Once the test subject is finished, the test is reset in preparation for the next test subject.

Testing procedure

The participants are acquired primarily from the Educafe and the Smart XP lab of the university of Twente Zilverling buildings between 10 am to 5 pm. Each participant is briefed on the basic concept of the test, the potential risks with the test, the final product's form, and what they are expected to do during the duration of the test (solve the room). Hints were to be kept essentially as only clarifications when the test subjects makes a mistake interpreting a card's text and even then only when the mistake won't be replicated by the physical object that the card's text is meant to represent.

Test 1

Test subject volume: 1

Test period: nearly 1 hour, exact time missing

Completion status: incomplete

Subject number 1 unfortunately required that the test needed to conclude before the participant was able to solve the room in its entirety. We immediately realized that whilst we have prepared much of the material for the test, we did not have a standardized riddle hints written out. This meant that the developers had to improvise riddles on the spot which naturally affected the quality of the information that could be acquired during the test. During the test, we also saw issues with the decoy cards (covered in more detail under realization). The participant utilized any number they found in just about every single place where a number could conceivably go. Near the end of the test, the participant effectively was in a deadlock, making no progress as the test subject attempted to determine the use of the 'Destroyer' card in particular. As the test took too long, we were unable to ascertain whether or not the subject would have been able to actually ever resolve the experiment without more concrete hints.

The first test was particularly chaotic as not everything was ready and most of the notes of improvement pertained to the paper prototype itself as opposed to the logic of the puzzles. The paper prototype needed to undergo major changes as a lot of the necessary components that we didn't think of were simply not yet ready. The participant also worryingly attempted to use the numbers in just about every single point imaginable. It may be wise to add some kind of telegraphing that pertains as to how many numbers each separate puzzle will accept as to not unnecessarily waste the test subject's time on rubbing each number everywhere until they find a place that accepts the number. The cards were changed and the riddles were formally written up in preparation for the second test.

Test 2

Test subject volume: 1

Test period: 34 minutes 58 seconds

Completion status: complete

Subject 2 acted much more systematically compared to subject 1 by gathering the vast majority of the available components and placed it in one place and proceeded from there. The vast gulf between a systematic approach and a more random approach was apparent by how few wasted moves subject 2 needed whilst solving the puzzles though the locations of the wasted moves still warranted concern. The formally written riddles also showed promise as the test subject immediately managed to solve many of the word riddles without time wasted on attempting to find their way through useless avenues of thought. The primary point of delay are with the display case cards which once again served to highlight the fact that having distractions within the escape room detracts from the experience and unnecessarily increases the difficulty of the room. One of the more concerning issues was with the riddle that led to the dictionary with the clue of “some things are lost in translation” which the test subject took as indicating specifically that the dictionary had nothing whatsoever to do with the test. The last point of concern was that the stickers that indicated the numbers¹² was mistaken as just part of the image and not as an actual hint.

Changes were minimal, the image file needed modification in order to clarify its purpose. The rest of the file needed little adjustments as the adjustments made to correct the issues that arose during the first test fixed much of the issues with the skeleton of the room. The decoy components¹³ remains an issue, but will need to remain within the room. By this phase, it is at least clear that the logic behind the room’s puzzle flow is also understandable by those who had no hand in developing the room.

Test 3

Test subject volume: 1

Test period: 41 minutes 33 seconds

Completion status: complete

Subject 3 repeats much of the process as subject 2 and has shown issues in linking the images provided in figure 9 to the puzzle for which it was assigned. Whilst subject 2 was able to make the link immediately, subject 3 had issues with seeing the link utilized within the triangle line of puzzles. Subject 3 also had issues in connecting the UV flashlight with its intended use with the bookshelf as the subject attempted to use the UV flashlight on just about every other object before finally returning to the bookshelf. The third subject demonstrated some need in showing

Whilst the logic behind the room may very well be sound, allowances may need to be made to allow the room to allow participants some flexibility and allowances should be made to allow for some mistakes. The card locations were adjusted, notably the (13) mirror and the (7) magnifying glass had their locations switched to better accommodate the participants.

¹² Image inside of the Realization section

¹³ The components that are not used as a part of any of the escape room puzzles e.g. decorations.

Test 4

Test subject volume: 2

Test period: 29 minutes 22 seconds

Completion status: complete

The fourth test with two test subjects was an unparalleled success with the fastest completion time out of any of the tests. Whilst it is natural that two people would be able to function faster than one, the breath of difference in performance between the fourth test and those seen in anything apart from the second test was a point of note. This was unfortunately the only test which was possible to stage with more than one test subject but the fact that the two were able to cooperate so well is a good sign for the escape room project. There were concerns about the mirror puzzle as the test subjects immediately solved the mirror puzzle the moment that the clue from the telephone was given to them.

Some minor tweaks were made, mostly to the mirror hint as the participants as well as the developers both felt that the message provided by the telephone allowed the puzzle to be solved too easily. We adjusted the wording of the puzzle to make the puzzle more of a challenge for university test subjects. This change, notably, will not carry on to the physical prototype for use with the museum.

Test 5

Test subject volume: 1

Test period: 55 minutes 28 seconds

Completion status: complete

Test 5 was the most concerning test of all from a design perspective and not just because it was the one test that took the longest. Some of the time could be attributed to the time that this particular participant used to inspect the room's various components, but much more of the time is spent on the participant attempting to both inspect components with no real purpose and attempting to find answers in unconventional places. Many of the issues that occurred during this particular test was unique to the paper prototype, but should nevertheless serve as a template for adjustments. The puzzle introduction points were not made clear and the test subject had issues visualizing the items in the rooms using the description given on the cards. The participant had a very sharp eye for detail, but that worked to their disadvantage as they attempted to pursue logical threads that did not exist. The test subject also had issues with finding the lines of threads that leads to different puzzles and therefore struggled a lot early on when the subject did not know where in the room to start.

The modifications made during the previous test to the mirror was rolled back and a large number of clues such as "your image" as it pertains to the hand mirror. Whilst the modifications made during this phase aren't particularly pertinent to the final product due to the necessary translations that will need to be implemented, wariness in regards to making sure that the clues are understandable to the participants should be paramount. As the escape room is meant to serve participants from the ages as young as eight years old, we should err on the side of easy puzzles as opposed to difficult ones.

Test 6

Test subject volume: 1

Test period: 38 minutes 26 seconds

Completion status: complete

Many of the problems observed during the prior test is not present in the test for subject 6. The subject demonstrated issues that resembled the subject from test 5 namely that they saw an image of a castle and assumed that one of the books from the list provided¹⁴, namely one about medieval architecture, was alluded to by the painting. The subject also attempted to utilize the UV flashlight on just about every object imaginable apart from the one object closest to the origin of the flashlight suggesting that there might be issues with associating proximity with relation. The subject has a slightly longer than normal solving time, though it should be noted that this particular subject also took significant amounts of time to think through the clues. Overall however, the test at least assures us that the reasoning behind the puzzles are sound.

Final notes

The test will inevitably have certain limitations. The limited moving parts within a paper prototype will minimize the likelihood of participants going down incorrect lines of conjecture, and yet we were unable to avoid that even in the restricted scope of a paper prototype.

The test has allowed us to correct the outstanding issues with the missing components of the puzzle and furthermore better illuminates the issues that still persists inside of the design. The biggest persisting issue that will likely carry over to the physical prototypes will be that the word based puzzles may cause a difficulty spike for participant teams not capable of handling the type of challenge that riddles can provide. Stopping the participants from going down pointless tangents and incorrectly would nevertheless be incredibly important. Whilst this was not a persistent problem for all university students that served at this phase's test subjects, the fact that it was a problem at all indicates that some design components should be incorporated to minimize the amount of misunderstandings and misattributions of gained passwords or equipment.

¹⁴ Bookshelf, page 51

Physical prototype

The physical prototype took the test plan that was developed during the paper prototype phase and implemented it into the physical realm. Below is a diagram of all of the various escape room components as they are placed during the physical prototype test. Like in earlier parts of the test, the escape room is divided into four puzzles that corresponds to the four pairs of numbers needed to solve the escape room. These puzzles are all marked with the previously mentioned four symbols, namely triangle (Δ), circle (\odot), cross (X), and square (\square). These, respectively, corresponds to the logo switchboard, the bookshelf, the phone, and the jigsaw lines of puzzles respectively.

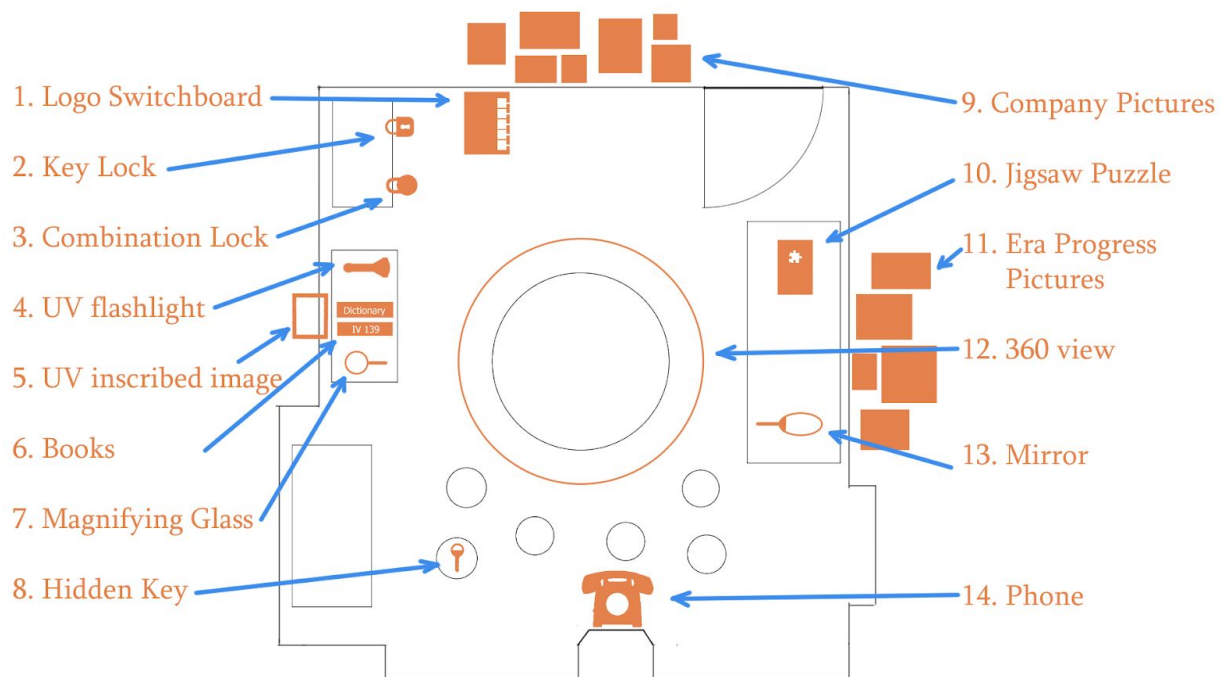


Figure 10, physical prototype room plan

1. Logo switchboard

This is a component of the triangle line of puzzles. The puzzle is constructed using various laser cut wooden boards that could then be assembled to form a slanted box. The front plate bears thin lines of copper that are designed to allow electrical flow. A control arduino sits beneath the system and once the copper circuit (indicated in red lines below) is complete it commands the arduino to begin distributing the code for the answer to be displayed.

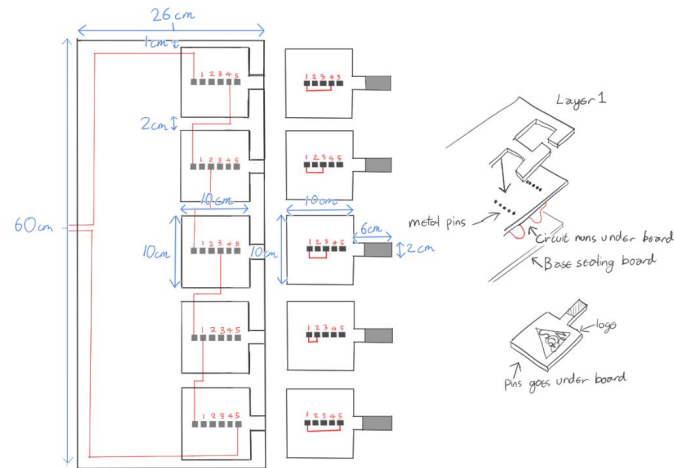


Figure 11, the switchboard circuit diagram

The board is a part of a larger whole that includes the mounting box where the Arduino can sit within to distribute the signal. The system is dormant until the logo switchboard sends it a signal, at which point it becomes active.

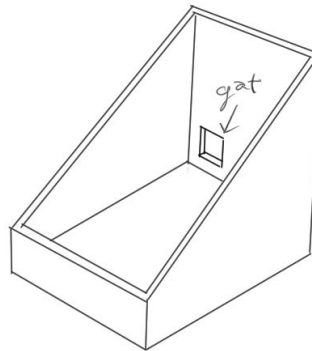


Figure 12, mount sketch

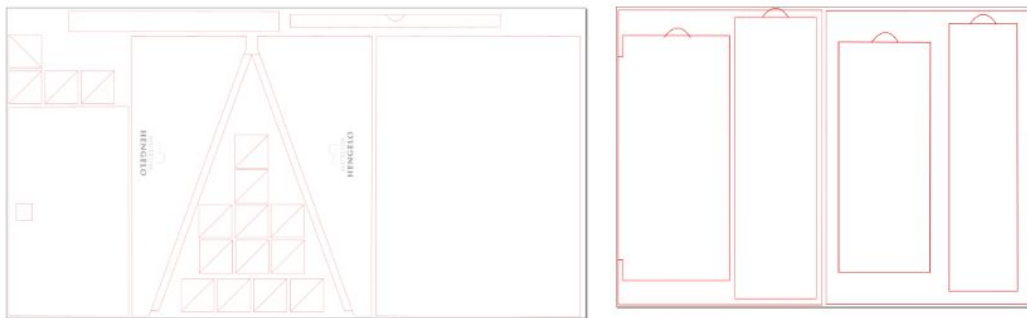


Figure 13, mount laser cutter file. Switchboard is mounted to the left and the display to the right

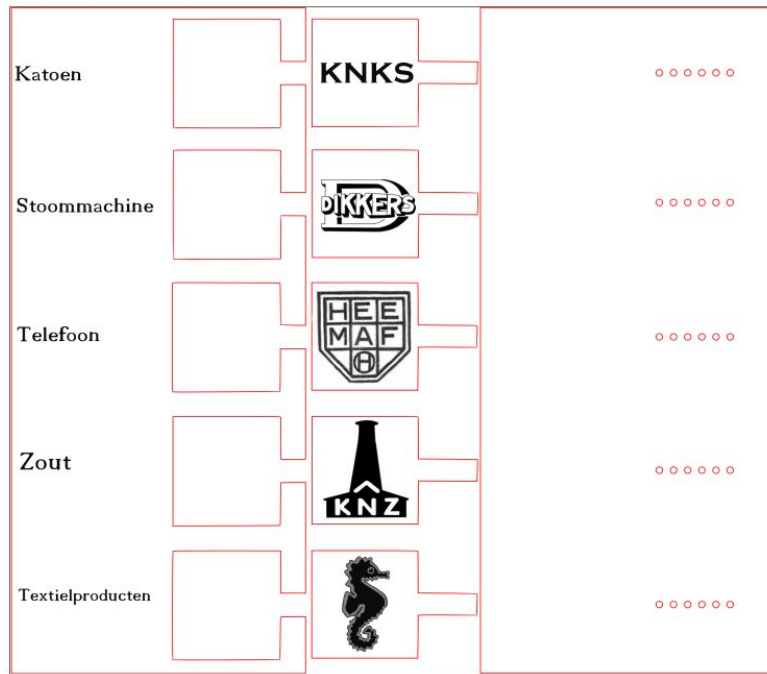


Figure 14, front face board with tabs

2. Key lock

A part of the triangle line of puzzles. The key lock was purchased for the purposes of the escape room. The lock sits on one of the two latches that keeps a wooden chest sealed.

3. Combination lock

The combination lock is a part of the triangle line of puzzles. The combination lock utilizes the code acquired during (1) the logo switchboard. The lock sits on one of the two latches that keeps a wooden chest sealed.

4. UV flashlight

The UV flashlight is placed within one of the (6) books, namely the hollow dictionary. The clue on the message about the circle line of puzzles should point the participants to the dictionary where the UV flashlight is sitting within.

5. UV inscribed image

The UV inscribed image is a part of the circle line of puzzles. The inscribed image holds the combination of "IV 139" written in invisible ink that can be revealed by (4) the UV flashlight.

6. Books

The bookshelf is filled with approximately 30 books and is for the circle line of puzzles. Most of the books functions as decoys, but two particular books are of importance for the circle line of puzzles. The first is an empty dictionary that functions as a security box with a UV flashlight inside of it. The second is

the fourth volume of a collection of encyclopedias that corresponds to the letters given by (5) inscribed image. Both are required to solve the circle line of puzzles and acquire the final combination.

7. Magnifying glass

The red magnifying glass is of the square line of puzzles. The red magnifying glass bears no lenses, instead it is replaced by a piece of plain red transparent acrylic. It can be combined with (10) the jigsaw puzzle as a part of the square line of puzzles to reveal the purpose of (12) the 360 degree view.

8. Hidden key

The hidden key is a part of the triangle line of puzzles. It is hidden beneath one of the chairs within the room and can be used to unlock (2) the key lock.

9. Company pictures

Company pictures are all a part of the triangle line of puzzles. They are all framed images of the products of different companies with their logos more or less apparent somewhere inside of the frame. Each image shows what each company produces which can be used with (1) the logo switchboard to change the logo board from the dormant to the active state.

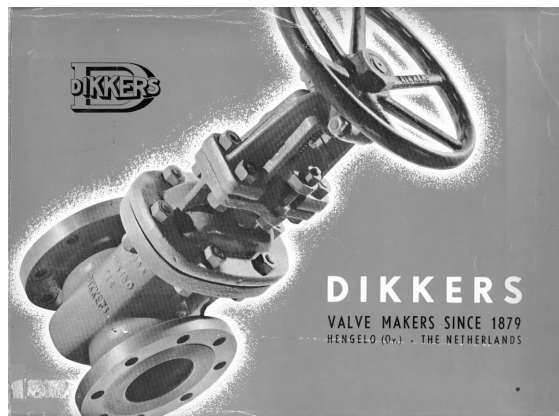


Figure 15, one of the images utilized within the room's triangle line puzzles

10. Jigsaw puzzle

Jigsaw puzzle is a part of the square puzzle line. It is a custom two-sided jigsaw puzzle with a mounting frame that can be used to enclose and flip over the jigsaw puzzle once it is fully assembled. If the jigsaw puzzle is combined with (7) the magnifying glass then the hidden message on the jigsaw puzzle can be revealed.

11. Era progress pictures

The era progress pictures are a part of the cross line of puzzles. The images details four different formative eras of the city of Hengelo through the medieval, industrial, cold war, and the modern era of the city of Hengelo. The frames of the images shown below are also numbered with a number pair combination of two unique combinations. If the pair is placed in the correct advancing order and entered into (14) the telephone then it would change the phase of the phone forwards.



Figure 16, city era images from medieval, industrial, cold war, and modern era in clockwise order

12. 360 degrees view

The 360 view is a part of the square puzzle. The puzzle is used after the (10) jigsaw puzzle is combined with the (7) red reveal magnifying glass to reveal the real location of the correct number. The number that can be used as the final combination for the square puzzle.

13. Mirror

The mirror is a part of the cross line of puzzles and is the final segment of said line. The (14) phone should send the participants to the hand mirror with a hint. If the participants combines the hand mirror with a strong light source, the final combination sequence for the cross sequence will be available.

14. Phone

The phone is a part of the cross sequence of puzzles. It is the starting point of the cross lines and sends participants looking for (11) the era progress pictures. Upon receiving the correct combination from the era sequence numbers, the phone will send the participants towards (13) the hand mirror.

Puzzle Solutions

The puzzles are divided into four puzzles with four shapes that all converge into a single one. The solutions and their uses are below.

Triangle (\triangle)

1. The chest (underneath (2) keylock and (3) combination lock on the room diagram) instructs the participants to search for a clue near where they are seated.
2. A key for the first of two locks is attached to the bottom of one of the stools (the smaller circles within the top diagram).
3. The key allows the first lock to be unlocked.
4. The chest also instructs the participants to look for the code for (3) the combination lock on the logo switchboard.

5. The (1) logo switchboard is a circuit box that will only activate once small tabs with company logos are placed next to their correct corresponding industry e.g. salt manufacturing or landline telephones.
6. The circuit, once completed, displays the combination of numbers needed to open the combination lock.
7. Once both locks are released, the chest can be opened. The combination for the triangle puzzle is within.

Circle (○)

1. On the bookshelf (beneath (4) UV flashlight, (5) UV inscribed image, (6) books, (7) magnifying glass) there is a hint "some things are lost in translation". This is a language puzzle.
2. The hint should send the participants to the hollow (6) English dictionary. There is a (4) UV flashlight within the dictionary.
3. The (4) UV flashlight can be used to reveal a message on (5) UV inscribed image that reads "IV 139".
4. IV 139 corresponds to the fourth volume and 139th page of the encyclopedia (6) book within the bookshelf. The combination for the circle puzzle is within.

Cross (X)

1. The (14) ringing phone has a message for the participants.
2. The message informs the participants that "the code runs with the passage of history".
3. The code should lead the participants to (11) era progress pictures that corresponds to different eras of the city of Hengelo through the medieval era, the industrial era, the cold war era, and the modern era. All images bears a pair of images.
4. If the numbers are dialed into the (14) phone, the message will change to "you must look past your image to see the answer"
5. The hint corresponds to object (13) the hand mirror.
6. Once the participants looks at the mirror with a strong light source behind it, they can find the combination for the cross puzzle within.

Square (□)

1. The (10) jigsaw puzzle and the mount sits on the table.
2. Once the (10) jigsaw puzzle is assembled, it shows a cityscape. It can be turned over to display nearly illegible red, yellow, and orange text with complete illegible faint blue text in the middle.
3. Once (7) magnifying glass is found, it can be used to reveal the red text. The red tint of the magnifying glass and red dominated color of the bottom of the jigsaw puzzle should provide a hint that they do go together.
4. The text instructs the participants to go to (12) the 360 view image of the city square.
5. The correct number can be found on the peak of the church. This is the combination for the square puzzle.

Puzzle resolution

1. Once all combinations are entered, the complete combination for the safe will be available.

2. Upon entering the combination, the safe can be opened and the room's alarm system can be disabled. The room concludes.

Questionnaire

The questionnaire is posed to the participants to better understand their mindset and their preferences in the escape room. The questionnaire serves as the primary node from which conclusions can be drawn.

1. What do you think of the escape room?
2. Which was your favourite puzzle?
3. Why was that your favourite puzzle?
4. Which was your least favourite puzzle?
5. Why was it your least favourite puzzle?

The Role of the Physical Prototype

The physical prototype is designed to function as both a testbed for the escape room and, assuming everything functions well, to serve as the escape room product for the Museum Hengelo. There are three primary roles that the physical prototype will need to fulfill which the paper prototype simply was not able to. First is the fact that the physical prototype would be tested on its target audience group in its intended final language, second is to ensure that the change from the paper version to the physical version has not degraded the underlying logic behind the puzzles to the point where it becomes unsolvable, and thirdly is to answer the separate research questions of the room's developers. The primary overarching point of the entire project may be to deliver the best escape room possible, but the research question still needs to be answered. The physical prototype also saw heavier involvement of Assortimens which will be the facility primarily responsible for fabricating and acquiring the necessary components for the escape room.

The first thing that will need to be tested using the physical prototype that couldn't have been tested using the paper prototype was to make sure that the puzzle was still viable in Dutch and targeted to an audience that could well be half the age of the university students who volunteered for the paper prototype. Firstly is the problem with the language difference. Certain puzzles within the escape room are language dependant and therefore the puzzles will need to be translated into its final language in such a way that it preserves the level of desired difficulty. If the puzzle were too difficult or too easy then the puzzle may take up an undue proportion of the participant's time. Secondly is the issue with the age gap. Whilst the room was designed to make sure that the minimal amount of knowledge is required to solve the room, the knowledge to recognize certain apparatus such as UV flashlights will most likely be necessary. As university students have more time to compile such 'general' knowledge than 8-14 year old children, the difference in what can be assumed to be common knowledge will fundamentally exist. The physical prototype will need to ascertain, first and foremost, that the children can still understand the room's apparatus often enough to solve the room without needing to too heavily depend on dumb luck alone.

The second thing that will need to be tested will be the adaptation of the puzzles from the paper prototype version to the physical version. By necessity, the paper prototype of the escape room Hengelo

project¹⁵ was trimmed down to the bare necessity with the moving parts minimized to only the strictly necessary with very few decoy cards with no use in solving the puzzle. Within an actual escape room, the participants may assume that clues and segments are decorations and vice versa. When the test subjects during the paper prototype phase combine the escape room's objects and link two clues together correctly, the puzzles function a hundred percent of the time. Within the actual escape room, there is a chance that the participants use the tools in the intended fashion but the tool fails to function. The best example of this would be a puzzle where the participants needed to use a UV flashlight to reveal an invisible code within one of the paintings. During the paper prototype, the test subject could just inform us that they want to use the UV flashlight on the painting and it will always reveal the message. In the actual escape room. They might not have panned the flashlight over the spot where the invisible message is hidden and therefore assume that the combination of the UV flashlight and the painting is a wrong combination despite it being the correct combination and the solution to the puzzle. As the room will need to function as a complete product, it will be necessary to repair any bugs in the system that was not revealed within the paper prototype phase.

The final purpose of the room is to actually answer the research question regarding the room's educational and functional efficacy with both developers approaching the escape room from a different developmental angle. For the purposes of this paper, the third purpose of the room is to answer the research question of whether or not educational content within escape room negatively impacts the enjoyment of participants. To answer the question, the escape room puzzles are split into distinct pairs:

- The telephone (X) puzzle and the logo (△) puzzle as the educational content puzzles
- The jigsaw (□) puzzle and the bookshelf (○) puzzle as the educational content free puzzles

The distinction is drawn between the pairs of puzzles. The telephone (X) puzzle requires the participants to use contextual tools such as technology level, city developmental levels, and the images of various Hengelo industrial products to the numbered images of the different city eras into the correct order in order to solve the puzzle. The logo (△) puzzle requires the participants to use the images on the walls with the products of various companies or use the company picture books within the room in order to correctly identify and match each company to their primary product. These two puzzles are highly reliant on earlier phases in order to function and therefore depend on knowledge learned earlier in the process. The first two puzzles are in contrast to the jigsaw and bookshelf puzzles which are very modular and more reliant on effort or logic than they do on procedure. Someone could step into the jigsaw (□) puzzle when the jigsaw is assembled but still solve it with little issue. As such, the puzzle is more geared towards quick satisfaction of solving small parts of the puzzle without an ongoing puzzle narrative for the lack of a better term. The first two therefore more heavily rely on learned information whereas the second two depend on immediate reasoning, basic problem solving ability, or just patience to search for the thread leading to the end combination.

¹⁵ Escape room Hengelo paper prototype, page 56

Results

Physical test 1

Test subject volume: 6

Test subject type: 6 children

The first physical test was our first experience in experimenting on the target audience's age group and essentially served as an extension of the paper prototype test. Unlike physical test two and three, physical test 1 had to take place without the complete room components. Physical test 1 also has an issue with the test subjects themselves. The test subjects present were a part of the museum contact chain which made their time an easy acquisition but they were already participants in the earlier test. This was problematic due to the fact that the puzzle ran by the museum and the puzzle built by us utilized a significant number of reused components. This was an immediate problem early on as the test subjects immediately searched the room for components that they recognized from prior tests, finding the fake dictionary within the first few minutes even before consulting the opening clues. The fact that a large number of the new puzzles were still under construction exacerbated the issues. Ultimately however, we were still able to make sure that the logic of the puzzle was sound. At this point, we were able to make no adjustments. We did not have the research question questionnaires prepared by this phase and so we were unable to gain any results for the questionnaire. As not all of the puzzles were ready yet, the answers to the questionnaires will also unlikely be particularly useful.

Physical test 2

Test subject volume: 5

Test subject type: 2 children, 1 teenager, 2 adults

The second physical test is the first useful test done on the escape room. Immediate problems arose however as the phone simply did not function and therefore the puzzle's integrity and full function could not be tested during the first test. Fortunately however, just about every single other component in the room did function which significantly simplified matters. There are certain issues with the room's design that has become apparent with this test.

Design Issues

Firstly is the issue with the UV flashlight. To an extent the UV flashlight issue was something that was predicted, but the difficulty of finding a hidden text using the UV flashlight was made incredibly prominent within the test. The picture frame where the hint is hidden is big and can't be covered by a single pass using the UV flashlight. This, in practical terms, meant that the participants considers a room component, namely the UV inscribed image, to have been checked even though they haven't found the hint yet. The problem with the room's decoration also persists. The participants attempted to find clues hidden inside of the glass display case, on the model radar on the glass display case, on the paperweight on the table and various other items. The clutter has been emptied to a large degree, but the remaining clutter continues to cause problems. Another unforeseen issue was with the use of the UV flashlight. There are weird white dots on the walls. They were relatively indistinct against the pale green color of the room's paint, but they glowed brightly when exposed to the UV flashlight. That and other UV reactive component confuses and distracts the participants which are results which we had hoped to

avoid. The last issue was that the participants has made attempts to brute force puzzle components like the logo board. Instead of looking around for clues or thinking about it, the participants relied on their prior knowledge and trial and error, invalidating the puzzle.

Potential Design Solutions

First thing's first, the middle table has to go and needs to be replaced with something more nondescript. The middle table is important for the room's balance and for the participants to have a central place to put all of their found or used components, but the table can't distract from the escape room. The table has three images mounted on it with dates that detracts from the puzzles and causes the participant to believe that it had something to do with the puzzles. The table needs to go. The problem with the decorations in the room has been minimized as much as we could, but it will likely always persist. Unfortunately, we have been unable to find ways to stop the participants from going down imagined avenues of logic and following threads that don't exist. There is also little that can be done about players trying to brute force their way through puzzles instead of trying to find a solution somewhere in the room. On the other hand, other issues can actually be solved. The UV panning issue can be resolved by significantly enlarging the size of the invisible writing or by duplicating the scripts over many parts of the puzzle such that there is a large chance of the participants simply stumbling across the hint. The issues with players trying to enter digits into inappropriate places could be cut down significantly by telegraphing how many digits a particular component will accept. These solutions will go some way to alleviate the persisting problems with the escape room.

Research Question Responses

	Favourite	Least favourite
X Telephone puzzle		
△ Logo puzzle	III	I
□ Jigsaw RR puzzle	I	I
⊙ Bookshelf puzzle	I	

Figure 17, physical prototype test 2 results

The idea behind the physical prototype is to gauge whether the educational content of the Hengelo escape room interferes with the enjoyment of the room's participants. From the first set, it appears that the educational content does not interfere with the participant enjoyment. If the test results are indicative of the relationship between educational content and participant enjoyment, there is essentially no relationship between the educational content and entertainment value whatsoever. The table above does not tell the whole story however.

The reasoning behind the choice of each participant is important when discussing the research question. A large number of the participants were very attracted to the logo puzzle thanks to its involvement to the city and the city's industry whilst another of the participants stated that the amount of knowledge that was required of the logo puzzle was unfair. It should be noted that the participants did not use the

images bearing the logos of the city to solve this puzzle. This point is interesting as with this group of participants, the educational content appears to have enhanced the experience for them. The reasons given as to why the jigsaw and bookshelf puzzles were satisfying was because the participants took great joy in the discovery of the hints and seeing the solution appear in front of their eyes where it was once hidden. That said, a participant noted that the jigsaw puzzle was only fun as they assembled it, because the moment the jigsaw was finished then it just became a matter of following instructions. These responses presents an obstacle to answering the research question as none of the reasons why a participant likes or does not like each specific line of puzzles doesn't significantly relate to the educational content of the room. To a large extent this was expected of a puzzle that had so many confounding variables and the strongest statement that could be made is that educational content does not necessarily interfere with the participant enjoyment of the escape room puzzles.

Physical test 3

During the testing period between the first and second test, changes were made to the room in order to immediately address the outstanding issues with the first test. A new table was acquired and moved into the room and the metal table was moved out to ensure that no future complications would arise. The UV inscribed painting was dismounted from the wall and had the code 'IV 139' added to more areas to make it more likely for the participants to stumble across the code and the telephone was disassembled, rewired, and reassembled over and over until it finally functioned once more.

Design Issues

There are now far fewer issues during this third test than the second test and the problems are mostly more easily resolved. The telephone puzzle does stand out as a particularly problematic puzzle however, something that did not arise earlier as the telephone simply did not work early on and the developers had to convey hints to the participants directly. Now that the phone could be observed functioning however, problems in the programming arose namely that the phone's programming does not allow for it to be used as a clue at all. Once the phone starts ringing, the recorded voice starts playing the moment the headset is picked up. What this means in practical terms is that once the phone is activated, the recorded hint starts playing the moment the headset is lifted off the phone. Once the participant places the phone to their ear, the message is halfway through already and the message does not repeat. This essentially makes it near impossible for anyone to get any useful information out of the telephone. Smaller issues persists as well. The participants often ended up confusing cotton, the raw product, with textiles, the processed products. The participants also saw the UV inscribed image, an image of a Heemaf train, and assumed that they were the manufacturers of the steam engines as opposed to Dijkers, the actual answer. The problem is further exacerbated by the fact that the participants interpreted the paintings as decorations unrelated to the puzzles for a good portion of the time they spent in the room.

Potential Design Solutions

The problem with the phone is the largest problem and the one that will likely take the longest to resolve. The problem with the message not being understood can be addressed in several different ways, the fastest of which might not be the most technically elegant. The technicalities of the program is not well understood by the developers of the escape room as the brunt of the work on the rotary

telephone was in the hands of Assortimens and specifically the supervising professor Edwin Dertein. The best solution would likely be to add some kind of pause before the message plays and then have the message loop over and over until the next phase of the phone is triggered. Less technically savvy solutions to this problem is available as well. The audio file could conceivably be edited such that there is a long pause or a dial tone before the voice message starts playing. Similar edits to the audio file could be made by making a 30 second message repeat over the course of four or five minutes to make sure that everyone who is interested in hearing the message will be able to get all the information they want. Which solution will be implemented will likely be a matter of how much more time it'll take to reprogram the repeat and pause functions into the phone. Fixing the issues with incorrect but sound logical threads is yet another issue altogether. The images we have provided could be replaced with others, but this process would likely end up being endless. Confusing cotton with textiles or confusing an electrical train for a steam locomotive is a mistake that people will end up making and little can be done to remove the possibility of the misunderstanding occurring altogether.

Research Question Responses

	Favourite	Least favourite
X Telephone puzzle	I	
△ Logo puzzle	I	
□ Jigsaw RR puzzle		III
⊙ Bookshelf puzzle	I	

Figure 18, physical prototype test 2 results

If the response of the third test was the only response available, then the conjecture that we as the developers would have made would be more clear cut. As it is, the combined results did not deliver a clear answer to the question of whether or not there is a relationship, positive or negative, between educational content and participant enjoyment.

The stated reasons as to why participants enjoyed certain puzzles more than others is interesting as it stands in contrast to the prior test and shows the difference in motivation for different audience groups. The least favourite puzzle, by far, was the jigsaw red reveal puzzle with the primary complaint about the puzzle being that it was far too easy. Once the jigsaw is assembled and the magnifying glass is found all that was left to do was to search for and find the church on the 360 degree view and the puzzle is solved. That particular puzzle was nothing more than just an instruction rather than being an interesting puzzle for the participants to solve which disappointed even the young participants within the room. This group of participants also had a high appreciation for tactile puzzles, citing the bookshelf as one of the highlights of the room due to the fact that there was so much to look through. This was notable as most of the actions taken by the participants at the bookshelf was almost entirely fruitless and yet it was a part that was cited as something the participants enjoyed. The logo puzzle was also cited as a

favourite, though for rather superficial reasons. No reason was given as to why the telephone puzzle was a favourite of one of the participants.

Conclusion

From the information shown in this test, the level of educational content within the puzzle does not appear to significantly diminish participant enjoyment of that segment of the escape room. Whilst the participant does not cite educational content as a positive or disadvantage, the test appears to show that the participant enjoyment is not diminished by the introduction of components that requires more understanding, knowledge, or reasoning. The question of whether or not the educational content of gamified spaces in general probably can't be answered by the results here, but it can be stated that the educational content of the Museum Hengelo escape room does not interfere with the enjoyment of the participants. The central limitation right now is with this test is that it can make no clear statement of the relationship between the volume of educational content and the enjoyment derived from the puzzle.

Discussions

Discussing the Escape Room Design

Whilst the results of the research question test is less than satisfying, the design of the escape room itself is successful. The room has received universally positive comments from participants so far and the room appears to be able to challenge and interest not just the ideal target audience but also the accompanying adults. The questionnaire responses adds to the bigger picture, showing a large variety of motivating factors that appeals to the test subjects in the physical prototype phase. That said, certain intractable issues with the design of the room and the functioning of the component still persists. The phone is effectively non-functional as a room component. The paintings will require significant adjustments. The circuitry of the logo box will need proper security to stop the children from opening it up and damaging the circuit within. The room is complete in concept, but the errant issues will still need dealing with before the room can be called complete in practice.

There persists certain issues with the room that only really arise at this point of the project. In retrospect, the room does somewhat suffer from a certain lack of focus. There was a large priority placed into incorporating different components for the participants to interact with. We, the designers, placed very heavy emphasis of making each puzzle unique and attempted to implement as many mechanics as we could. This emphasis on trying to create as many different mechanics as possible may have detracted from the flow of the room. Many of the puzzles were incredibly modular and weren't very self contained. This became a problem as once each separate segment of the puzzle was over, there was little thematic or logical thread that would necessarily lead the participants through each line of the puzzle. This was observed in both the paper prototype and the physical prototypes where participants bounced between puzzle lines instead of following the puzzle through to the end. I hypothesize that they didn't follow the puzzle through to the end because they encountered points where they are unsure of how to proceed with the puzzle. Whilst this has not diminished the enjoyment of the participants significantly enough for them to have had a negative experience because of it, I still propose that the experience could be significantly improved if each specific puzzle was more cohesive. The puzzles would likely have benefited from a single base concept that is expanded in complexity until it provided sufficient challenge for the participants instead of many smaller concepts stitched together as was the system used to formulate the puzzles utilized for the project.

Discussing the Findings & Experimental Setup

Due to the scarcity of research in the specific topic of the relationship between the level of educational content and its enjoyability, the research question could have been useful in informing the development of gamified products. As things stand however, the results of the test proved to be inconclusive even if it yielded interesting results. Looking at the results from a purely numerical perspective, it would appear that the hypothesis of the inverse relationship between educational content and participant enjoyment is not only wrong, but actually inverted. The aggregate of the two final tests with the questionnaires deposited the majority of the favourite puzzle votes on a puzzle with high educational content and the majority of the least favourite votes on the puzzle on the puzzle with low educational content. This could be due to a large number of reasons that could be proposed which really is the crux of the problem. Locating the specific problematic component is challenging due to how varied the puzzle lines are in

detail, mechanics, and difficulty. Nevertheless, there are interesting parts of the results that are worth discussing.

The issue with the wide variety of function, difficulty, and appeal between the different puzzles complicates the ability for an experiment to create any kind of useful information. Each specific puzzle requires a different skillset, a different approach, a different level of reasoning ability, and therefore each specific puzzle will inevitably appeal or repulse different participants based upon how they prefer to engage problems. As such, the prototype format is poorly suited for testing larger questions regarding the question of the relationship between educational content and participant enjoyment. Whilst the test has implied that the participants did not consider the puzzle to be problematically overburdened with educational content, there still might be a negative correlation between enjoyment and educational content that is hidden behind the base appeal of the different puzzles. The participants have cited various reasons as to why they like a certain puzzles the best such as the satisfaction of discovering a hidden clue to a more personal investment in the topic of the puzzle and more tactile interaction which many of the participants found to be extremely satisfying. The fact that there is essentially no negative consequence for adding educational content to the room at this low level is highly encouraging from the point of view of an educator. Furthermore, the participants may interpret the educational content not through the lenses of learning but rather through a lens of challenge and the kind of challenge which they crave which may very well result in the educational content being a part of the appeal of the puzzle.

Discussing Future Research

Unfortunately, the question about the relationship between education and enjoyment remains unanswered. It is a worthwhile question to pursue however, especially if gamification is to be used more prominently within educational curriculums. The question of whether or not there is any relationship between entertainment derived from a product and knowledge gained from it is one that will likely require a rather large number of test subjects to answer. A comprehensive test that utilizes puzzles that are closer to each other in design to control for confounding variables and emphasizes the educational content of each instance of interaction with the product would be able to better test for the relationship between education and entertainment and would be able to better optimize the balance. We were able to deliver a product that did not compromise the participant enjoyment for educational content. That said, I believe that the educational content could be pushed a lot further before we see any noticeable drop in enjoyment.

Escape rooms have shown success when used to educate, but there are also other systems adjacent to escape rooms that might also be worth researching. One of the primary uses of escape rooms are as tools of team building and cooperative acting.

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Appendix

Paper prototype results

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

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

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 > inspects magnifying glass
9. Reads clue > identifies dictionary > finds UV flashlight
10. Inspects painting with flashlight > finds roman numerals
11. Inspects distracting display cabinet
12. Inspects table > assembles jigsaw
13. Immediately understands RR connection
14. Goes to 360 view
15. **Solves O**
16. Goes back to table > finds mirror
17. Phone rings > picks up phone
18. Instantly makes connection > goes to painting wall > dials 813
19. Goes to inspect metal frame
20. Returns to bookshelf > uses UV torch > finds IV 139
21. **Solves □**
22. Inspects mirror > understands phone hint
23. Holds up mirror to sun > gets message
24. **Finds △**
25. Dials number into phone

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 \square 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 \square**
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, test terminated early.

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

Physical prototype 1 results transcripts

Physical prototype 2 results transcripts

Results have been modified and redacted for the purposes of

Test 1

1. Approached the jigsaw > whole group attempted assembly
2. Did not immediately realize what RR was
3. Tried to brute-force RR
4. Approached logo board
5. Found mag glass
6. Figured out RR
7. Noticed numbers on floor > solve square
8. Figured out dictionary clue > understood the use of the UV flashlight
9. Inspected the picture frame > did not find the invisible hint on it
10. Looks at safe, understands that the sequence needs to be combined and then placed into the lock
11. Attempts to use the UV flashlight on various items in the room
12. Attempted to use the broken phone
13. Central pictures distracted players > ugly table strikes again.
14. Books may cause problems > confusing
15. Users added up the numbers on the ugly table
16. Figures out the order of the era hint from the phone puzzle
17. Players were confused by the hint that says that they are already sitting near the key
18. The players find IV 139
19. All hints found, puzzle resolved

Issues

- The UV flashlight pan quite often missed the hidden clue
- As expected, the various items in the room remain distracting
- Participants attempted to find the answer within the text of the book
- The safe that is used in the room requires an A to be dialed into the number pad to open, which the participants interpreted as a hint to a puzzle
- Participants attempted to bruteforce the logo puzzle
- It should be clear how many digits each specific puzzle takes

- Make it clear that the flashlight has more than just one use

What do you think of the escape room?

Liked it, it was very fun but it was a bit short.

Which was your favourite puzzle?

The bookshelf puzzle

The logo puzzle (x3)

The Jigsaw puzzle

Why was that puzzle your favourite puzzle?

The logo puzzle was quite cool and had a lot to do with the city and the industry

Seeing the text with the RR magnification glass was really satisfying

The UV flashlight took a while to find, but finally seeing it was very cool

Which was your least favourite puzzle?

The Jigsaw RR puzzle

The logo puzzle

Why was that your least favourite puzzle?

The jigsaw puzzle was not very satisfying, building the puzzle was the only really fun part of the puzzle

The logo puzzle was very confusing and [one of the participants] did all the work

Were there elements of the escape room that were too difficult or easy?

The logo puzzle was too difficult, [one of the participants] had to do all of the work

Test 2

1. Children went to the jigsaw first
2. Went as a group to the logo board
3. The participants assembled the logo board essentially at random > continued to attempt to brute-force the logo board
4. Found red magnifying glass
5. Telephone rings
6. Tries to use the red magnifying glass on the mirror
7. Assembled jigsaw puzzle
8. Flipped over the jigsaw puzzle to display the RR side
9. Attempted to use the fan's power sequence on the safe
10. Uses the magnifying glass on the jigsaw puzzle
11. Continues to try to brute force the logo puzzle
12. Managed to get square

13. Attempted to brute force books by flipping through them to try to find information > assumed that the price tags on the books was part of the code for the phone
14. Continues to try to brute force the logo puzzle
15. Finally managed to find the thread of logic for the logo puzzle
16. Attempted to place another code into the safe
17. Used the UV flashlight on everything
18. Found IV 139 > went to the encyclopedias
19. Recognizes the importance of the number but sees no pattern
20. Finally notices the last image & uses UV flashlight
21. Finds mirror number > finds triangle
22. Assumes that the sitting riddle requires them to simply sit down
23. Searching the chair > found the safe key
24. Finds X
25. Clears room

Issues

- The pictures on the walls might be assumed to be nothing more than decorations
- The telephone text moved too quickly, required the text to be spoken by the developer again
- Confuses cotton with textiles
- The photo of the Heemaf train might be misinterpreted as a steam engine

What do you think of the escape room?

It was cool and enjoyable

Which was your favourite puzzle?

The telephone puzzle

The logo puzzle

The bookshelf puzzle

Why was that puzzle your favourite puzzle?

The logo puzzle lit up and had all of the cool things inside of it

The bookshelf puzzle has all kinds of things to look through

Which was your least favourite puzzle?

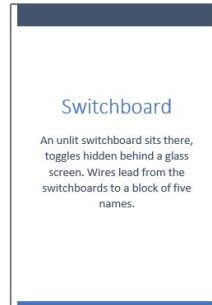
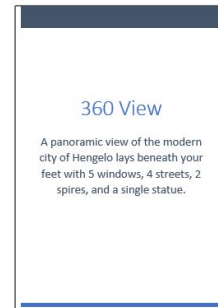
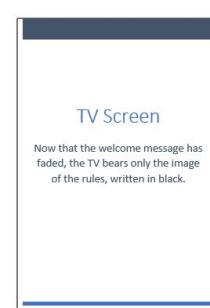
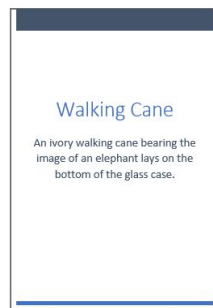
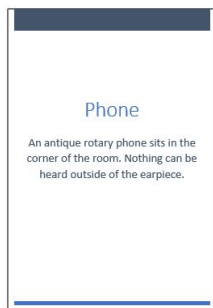
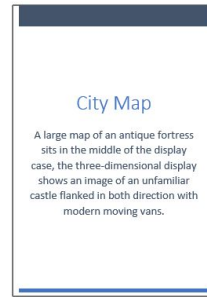
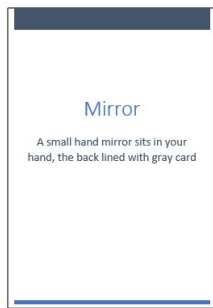
The jigsaw red reveal puzzle

Why was that your least favourite puzzle?

The jigsaw puzzle was really boring, the hint of 'just look for the number on the church' was very boring and didn't need any thinking.

Were there elements of the escape room that were too difficult or easy?
The jigsaw puzzle's hint was too easy, didn't take any thought.

Paper prototype cards



Paper Prototype Bookshelf

The bookshelf bears the following books

Book name	Estimated inspection time
Staircases – the architecture of Ascent	30 seconds
Wildflowers of Britain Month by Month	30 seconds
The Social Industrialization of Eastern Netherlands	30 seconds
Fifty Shades of Gray	30 seconds
Mr. Penumbra's 24-Hour Bookstore	30 seconds
To Kill a Mockingbird	30 seconds
Still Stripping After 25 Years	30 seconds
H185-LLK Lawnmower operational manual	30 seconds
War and Peace	5 minutes
On the development of the King Tiger	30 seconds
Freshwater fly-fishing	30 seconds
The Birds of Eastern Netherlands	30 seconds
The Girl Who Would be Queen	30 seconds
The Lake of Spires	30 seconds
Eating People Is Wrong	30 seconds
How to Make Money in Your Spare Time	30 seconds
How to Avoid Huge Ships	30 seconds
Stones for Abigail	30 seconds
Why Cats Paint	30 seconds
How to Succeed in Business Without a Penis	30 seconds
The Manly Art of Knitting	30 seconds
Everything I Know About Women I Learnt From My Tractor	1 minute
Everything I Want To Do Is Illegal	30 seconds
Mommy Drinks Because You're Bad	30 seconds
A Passion For Donkeys	30 seconds
Old Tractors and Men Who Love Them	30 seconds
The Practical Pyromaniac	30 seconds
How to Raise Your IQ By Eating Gifted Children	30 seconds
Anybody Can Be Cool...But Being Awesome Takes Practice	30 seconds
English dictionary	30 seconds
Encyclopedia volume I	1 minute
Encyclopedia volume II	1 minute
Encyclopedia volume III	1 minute
Encyclopedia volume IV	1 minute
Encyclopedia volume V	1 minute
Encyclopedia volume VI	1 minute
Encyclopedia volume VII	1 minute
Encyclopedia volume VIII	1 minute
Encyclopedia volume IX	1 minute
Encyclopedia volume X	1 minute
Itinerary of Hematt products	1 minute
Observations of local birds in the Hengelo region	30 seconds
Seas of Ashes	30 seconds
The potato parade	30 seconds
Victorian Architecture Designs	30 seconds
Does God Speak Through Cats	1 minute
Who Cares About Elderly People	30 seconds

Final Escape Room Procedure

Square puzzle - Table / Jigsaw

1. Find jigsaw pieces on table
2. Assemble jigsaw
3. Find the red magnifying glass that sits inside one of the cupboards
4. Flip over jigsaw
5. Use magnifying glass to see hint: [square] is the number on the church
6. Find church on 360 view and observe: [square] = 48

Circle puzzle - Bookshelf

1. Paper sits on the shelf with the hint "[In Dutch]: some things are lost in translation" → Soms raken er dingen verloren bij het vertalen.
2. Dictionary holds the UV flashlight
3. An image on top of the bookshelf has the series IV 139
4. The encyclopedia volume 4 (IV) page 139 has a piece of paper with a number on it
5. Observe: [circle] = 17

Triangle puzzle - Phone

1. After 5 minutes in the escape room, the rotary phone rings
2. Receive hint through phone [in Dutch]: "The order of history of Hengelo holds a code. Return here when you have found it." → De volgorde van de geschiedenis van Hengelo vormt een code. Kom hier terug als je deze code gevonden hebt.
3. Photos on the wall yield the sequence 74, 52, 68, 21
4. When sequence is dialed into the phone, the hint changes to [Dutch] "To find the solution, hold your image to the light" → Gebruik de spiegel, en zie het licht.
5. Find the hand mirror
6. View the mirror with a bright light behind it, revealing [triangle] = 31

Cross puzzle - Treasure Chest

1. Observe treasure chest in corner of the room. See hints [Dutch] "Find the key. You're (sitting) close!" → Vind de sleutel. Je zit dichtbij! and "Match the companies to their industry to proceed" → Maak de juiste combinatie van Hengelose bedrijven en hun producten om de code te vinden.
2. Find ways to open the two locks:
 - a. Padlock:
 - i. Find key underneath one of the stools
 - b. Code lock:
 - i. Observe photos on the walls to figure out what company operated in what industry

- ii. Place logos in the correct order to light up the switchboard
 - iii. put switchboard sequence into the code lock to open it
 - iv. Code is 1868
3. Inside treasure chest, find a little paper that says [Cross] = 87

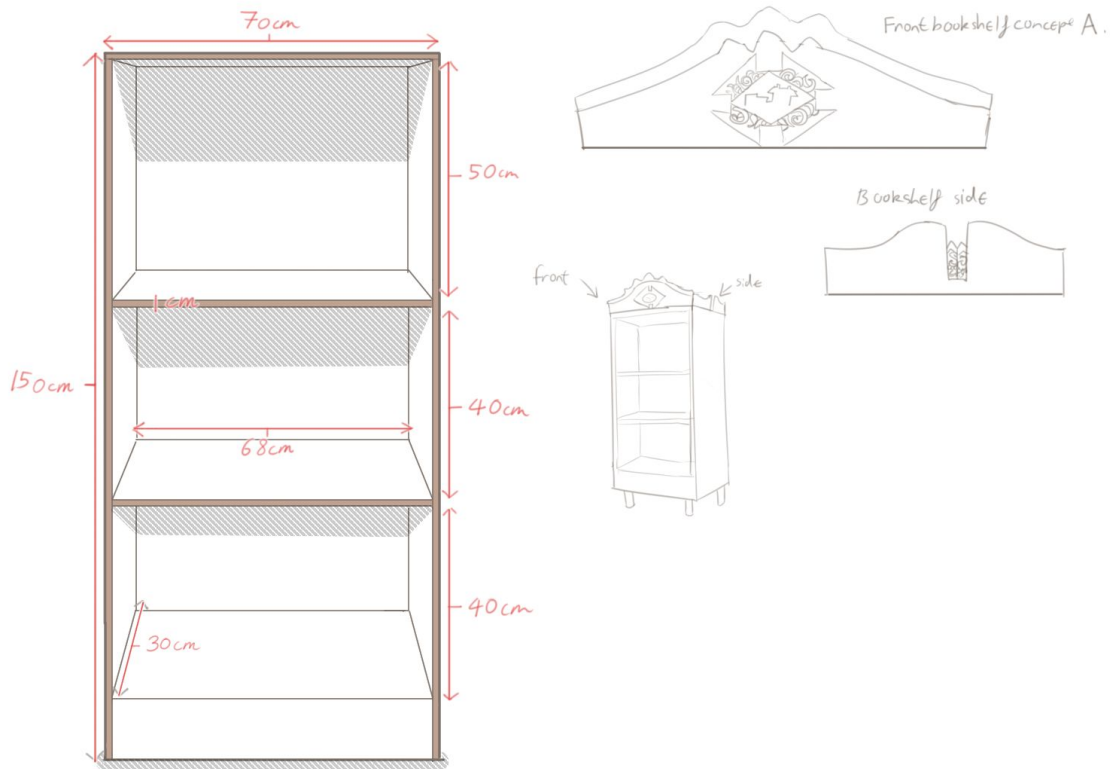
Ending

1. The end sequence will be 48 17 31 87 A
2. The laminated sequence indicates in which order the numbers should be placed in order to
3. The candy rewards are in the safe with the remote to disable the alarms and the stopwatch to time the progress
4. The safe's combination is the sequence of all escape digits plus A
5. The players will need to stop the stopwatch to freeze their precise time.
6. The players then can use the remote to disable the alarms
7. The room concludes

Assortiments Assignments

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 uit ziet, 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

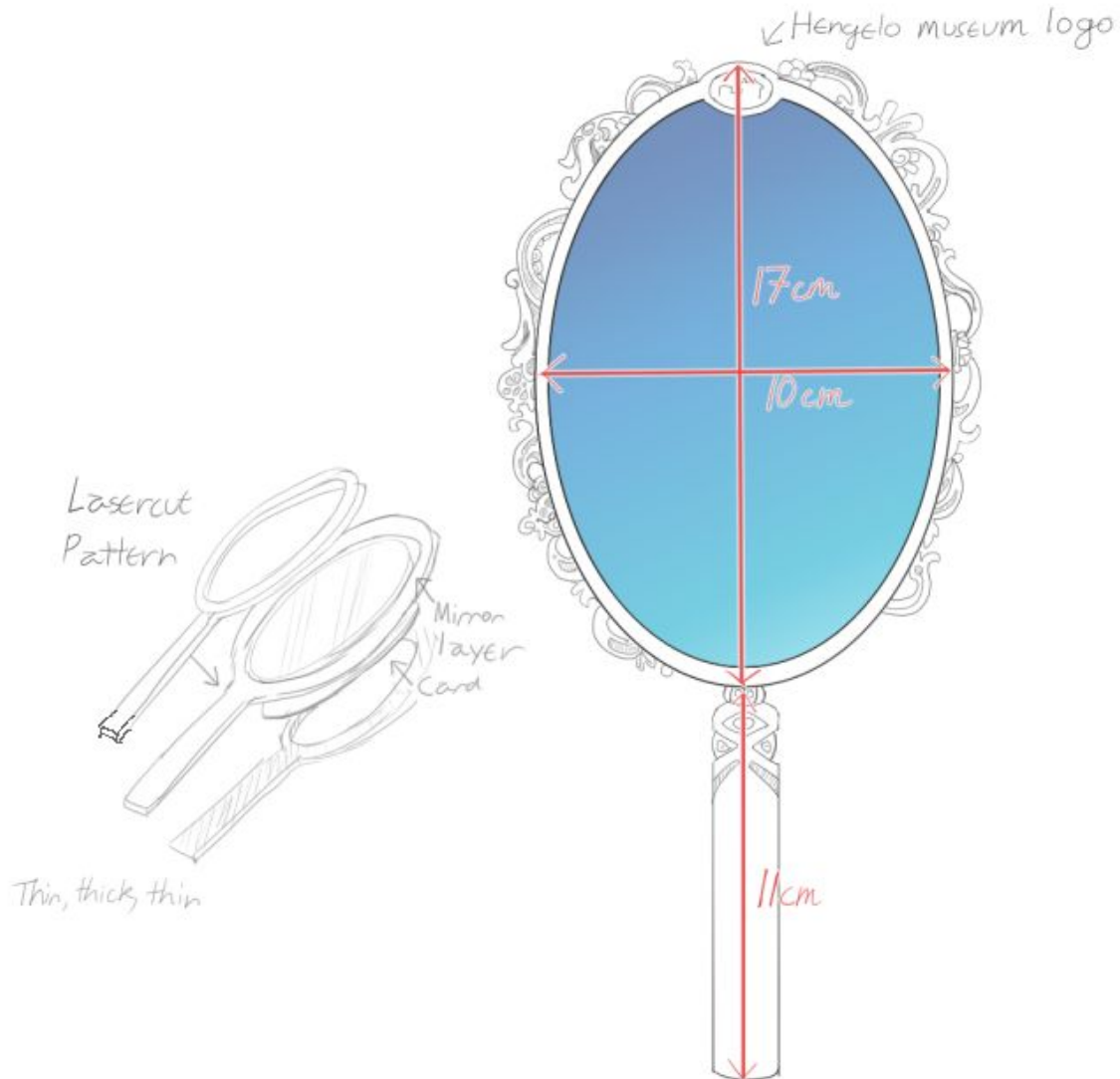
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur

E-mail: jordi.agricola@gmail.com

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 slijk 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

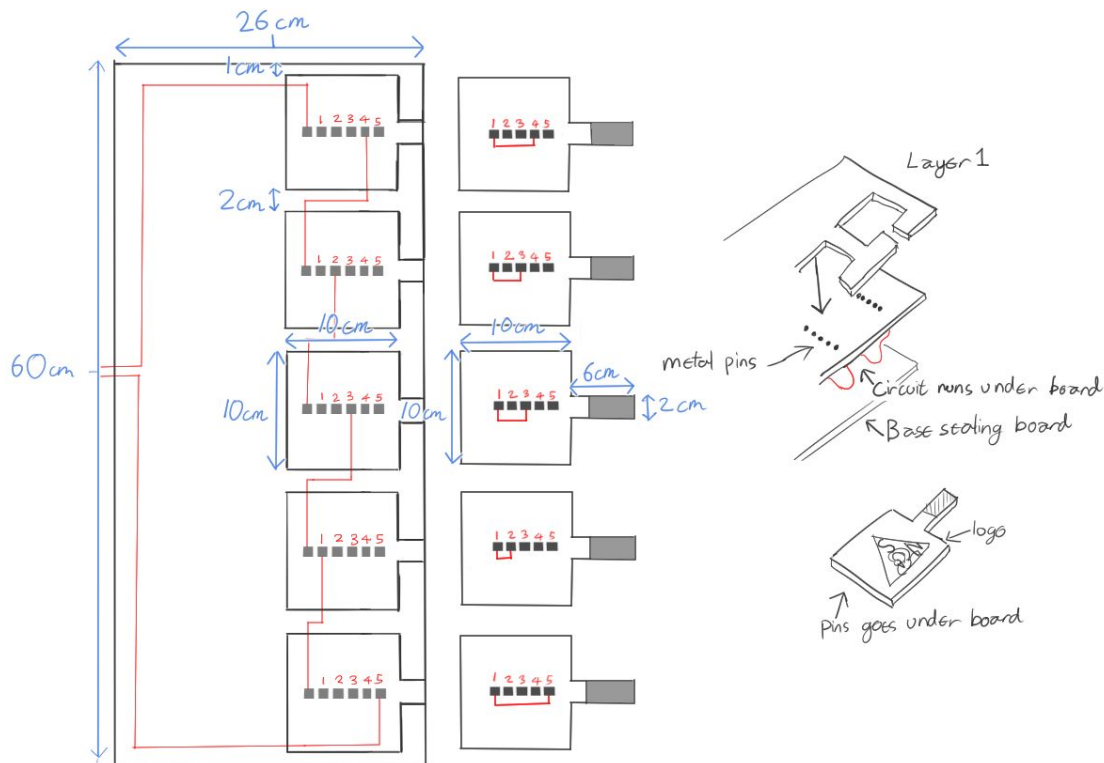
E-mail: jordi.agricola@gmail.com

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.

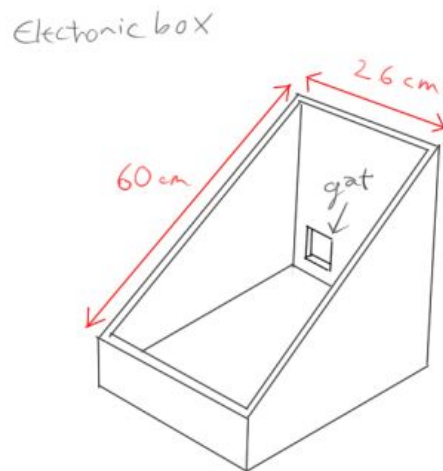
Het is belangrijk om de contactpunten (en stroomdraden) in de blokken en vakken zo te plaatsen dat er maar één combinatie is waarin de stroomkring compleet is.

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

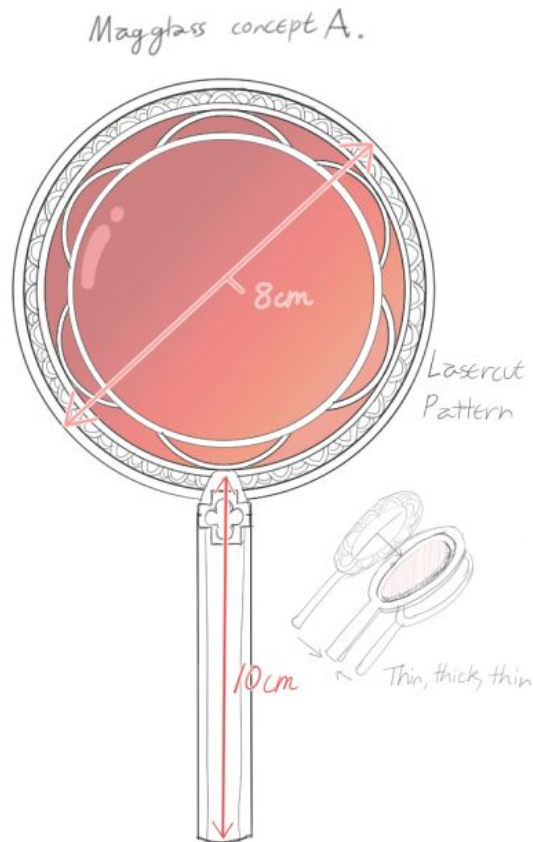
Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur

E-mail: jordi.agricola@gmail.com

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 vergrootglas 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!

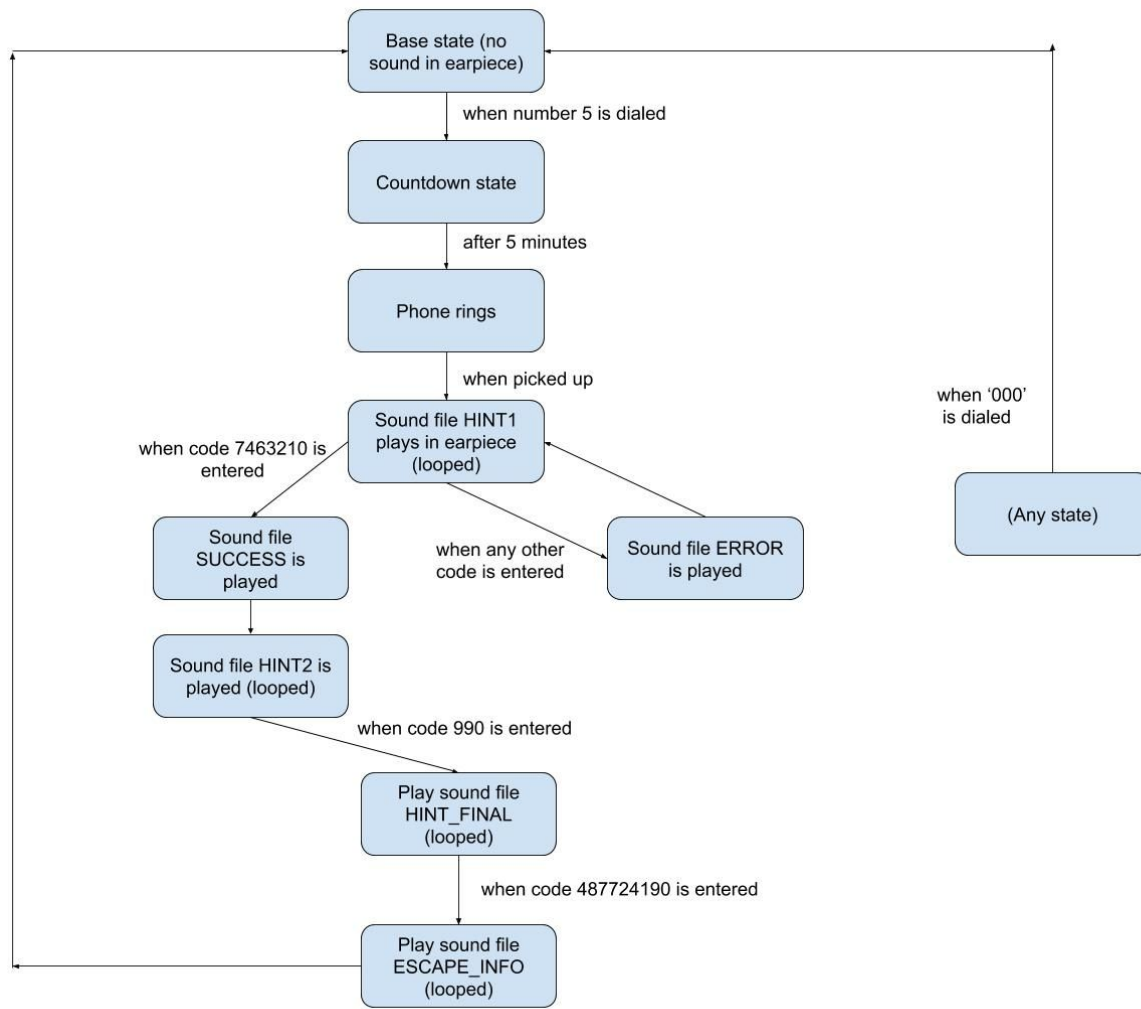
Contactgegevens

Jordi & Chulakit, bezig met de Escape Room voor Museum Hengelo

Op vrijdagen op AssortiMens vanaf ongeveer 10:00 uur

E-mail: jordi.agricola@gmail.com

Telephone flowchart



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.

☐ ☐

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

Enschede, gemaakt 16/05/2019

Toestemmingsformulier EWI: Escape Room Hengelo

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 na het onderzoek een chocolaatje krijgt als dank. ☐

**In tweevoud getekend op
(datum)**

**Voornaam en leeftijd van
kind(eren)**

Naam van ouder / verzorger

Handtekening

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