The Impact of Character Style in Narrative Medical Visualization

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October 18, 2025

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Faculty of Computer Science
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Master's Thesis

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Abstract

In the digital age, effectively communicating complex medical information to diverse audiences poses a significant challenge. Medical narrative visualization seeks to address this by combining storytelling and visual design to enhance comprehension, engagement, and memorability. A key component of this approach is the use of visual characters, which shape emotional connection, trust, and understanding. However, inconsistencies in character style raise questions about their impact on audience perception. This thesis investigates how different visual character styles influence emotional engagement, memorability, and the accuracy of medical information communication. Through a quantitative user study, three distinct character styles will be developed and integrated into medical narratives, followed by a structured three-part questionnaire assessing emotional response, knowledge recall, and comprehension. The findings aim to establish design guidelines for character creation in medical storytelling, define reusable abstraction parameters for consistent style generation, and identify advantages and limitations associated with various character styles.

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1 Introduction

In the age of technology we encounter a lot of information daily. Some information we consume out of interest, some out of necessity, some might even be vital to our survival, such as medical knowledge. Be it patients of all ages, relatives or anyone with an interest, medicine needs to be communicated by specialists to foster awareness and support decision-making. Considering how complex medical data and healthcare information can be, the challenge is to convey it in a comprehensible way. This may become particularly difficult as the target audience includes people of different age groups, with a wide spectrum of knowledge and interests, as well as varying cultural, geographical and educational backgrounds. It is referred to as a *broad audience* [Böt+20].

The field of *medical narrative visualization* aims to tackle this challenge by integrating storytelling techniques with visual representations of medical content [Meu+22]. By structuring information in a narrative format, this approach enhances engagement, comprehension, and memorability, making critical healthcare topics more accessible and meaningful [Mit+23c].
A key element of narrative medical visualization is the use of *characters*. Characters serve multiple functions: they provide a human-centered perspective, guide viewers through medical processes, and evoke emotional connections that aid in understanding [Bud+23]. Whether designed as realistic patient avatars, stylized illustrations, or abstract representations, characters help contextualize medical information by illustrating symptoms, treatments, and health outcomes in a way that resonates with audiences.
The style of visual characters can significantly influence how effectively medical information is communicated. The choice of visual character style does not only impact the emotional engagement of the audience but also their trust in the presented information. For instance, characters that closely resemble real people can foster a sense of trust and credibility [Luo+06], while stylized or abstract characters may resonate more widely and encourage broader engagement [Mit+23b].

1.1 Motivation and Problem Statement

Within the Visualization Group at the University of Magdeburg, we have been investigating medical narrative visualization and have produced several stories designed to educate a broad audience, including narratives on liver cancer, cerebral small vessel disease, and the bicuspid aortic valve. When examining these stories a lack of consistency in visual style becomes apparent: characters are often selected according to individual authors' preferences rather than a unified design framework. These inconsistencies are particularly evident in the representation of the main characters. For example, the character Emma (fig. 1.1c) is depicted using photographic imagery, whereas the character Alex (fig. 1.1a) is represented as an abstract, hand-drawn figure. Despite the clear differences in visual style, the effects of these choices on audience comprehension, engagement, and perception remain unexplored.

(a) Alex [Stu+22] **(b)** Thomas [Meu+22] **(c)** Emma [Mit+23c]

Fig. 1.1: Previous Story Characters

The characters shown in figure 1.1, utilized before the AI boom of the 2020s, were either stock photos or handmade graphics. Following the wide spread introduction of AI and image generation, character generation became even more accessible [Mit+24]. But what type of character should be generated for disease stories? Which effects do different character styles have? Should they be constructed in a more abstract way, like Alex (fig. 1.1a), or should they be realistic, similar to Thomas (fig. 1.1b) or Emma (fig. 1.1c)?

To address this research gap, it is necessary to investigate how character style influences the aspects of the narrative and audience experience that characters most directly impact, such as memorability, comprehension and emotional response.

1.2 Aim and Contributions

This thesis aims to investigate how different visual character styles influence emotional engagement, memorability, and the accuracy of medical information communication in medical storytelling.
The research is guided by the following questions:

RQ1 *Which visual character style leads to the strongest emotional connection and identification with the audience?*

RQ2 *How does visual character style influence the memorability of key medical information and character memorability?*

RQ3 *How accurately can underlying medical data be communicated through different visual character styles in medical storytelling?*

This thesis contributes to the growing field of medical narrative visualization by:

- Identifying guidelines for selecting appropriate visual character styles in medical storytelling
- Developing a three-part questionnaire framework combining affective evaluation, knowledge recall, and symptom recognition as a replicable method for future character studies
- Establishing reusable character style definitions based on clearly defined abstraction parameters, enabling reproducibility for medical storytelling, as well as consistency and comparability in future research
- Compiling a list of potential advantages and limitations associated with the usage of different character styles

To address these research questions, a quantitative user study will be conducted. Three distinct visual character styles will be defined, from which six individual characters will be created using AI image generation tools, followed by manual adjustments. The set will include three female and three male characters. Each character style will then be implemented into an existing story to ensure consistency and to keep the project within its time constraints.
Each study participant will view the three character stories and undergo a compact three-part questionnaire for each for each of the stories.

1.3 Thesis Structure

In the following an overview of the thesis chapters will be provided:

Chapter 2 presents a literature review, discussing previous research on narrative visualization, AI-centred character design, emotional engagement, memorability, and the communication of medical information.

Chapter 3 details the methodology, including the character design, story preparation, and the three-part questionnaire used to evaluate emotional connection, memorability, and symptom recognition.

Chapter 4 focuses on implementation, describing the global study structure, adaptation of the three character stories and the questionnaire.

Chapter 5 will focus on the evaluation methods, as well as providing detailed insight into the study results, followed by a discussion.

Chapter 6 provides a brief summary of essential thesis details. Additionally, limitations and future work are discussed, to show in which direction the research can progress.

2 Literature Review

2.1 Theoretical Background

Visualization for Broad Audiences

When addressing a broad audience, communicators must consider that many viewers lack specialized background knowledge and differ widely in age and cultural experience [Böt+20]. To reach such groups effectively, visual and narrative choices should prioritize clarity, engagement, and accessibility [Gar+21]. Non-expert audiences respond more positively to data when it is embedded within a story [Ma+11] or when the visualization invites an appropriate level of interaction [Böt+20; Mli+25]. With this insight, scientific material intended for broad audiences should be broken down to its central information and presented through straightforward and simple visuals [Böt+20].

Narrative Structure

As storytelling has has been established as a reliable and favorable method for relaying complex relationships and insights to broad audiences, it has been integrated in visualization research. This research area is called *narrative visualization* and it uses storytelling techniques, as well as data-based visuals to make scientific information accessible [SH10]. Segel and Heer [SH10] split narrative visualizations into two core aspects: data representation and narrative structure. This integration allows users to not only see data but to understand it within a coherent storyline. A typical narrative visualization consists of content, characters, conflict, and structure [Dyk19].

The story structure can be essential to communicate a meaningful message. Typically, the structure consists of an introduction, a climax and a denouement, which is inspired by Aristotle's tension arc [Mad08]. Narrative design patterns for data-driven storytelling are helpful tools for researchers to build a well-structures story [Bac+18].

The sequencing and transitions within the story need to be treated carefully, particularly in slide based stories [Hul+13]. Story elements such as labels, arrows, motion, audio and text can aid in the implementation and in highlighting important aspects [KM13; HD11]. Additionally, when addressing a broad audience, essential facts should be communicated with real data, to support the trust in the story at hand [Lee+15].

Narrative Visualization in Medicine

When it comes to medical topics, there can be some additional obstacles. Medical data is sensitive by nature and needs to be handled confidentially [Meu+22]. However, due to the wide applications and large broad audience in medicine, narrative visualization can be a good method for public communication. The research in narrative medical visualization is multifaceted and currently ongoing [Gar+23; Ma+24]. Apart from useful application of visualizations to motivate treatment [GJ21], the focus falls on generating data based-medical stories.

Meuschke et al. [Meu+21] discussed narrative visualization in medicine and proposed a template for the narrative visualization of disease data. Building on this work, we designed a case study employing structure, personalization, characters, and metaphors to explore the differences between slideshow-based stories and scrollytelling [Stu+22]. Mittenentzwei et al. studied the effects of these variants on usability and aesthetics [Mit+23a]. They also found that using stories in data visualizations helps share disease-related information in a way that audiences can understand. Additionally, they explored how likely the readers are to follow a call-to-action after viewing a story [Mit+22]. Fogwill et al. [FM24] further demonstrate that interactive data comics increase engagement and comprehension compared to purely textual communication.

Mittenentzwei et al. [MPM24] examined the conceptual and methodological challenges of visually communicating health information. Their analysis of the purpose, content, and form of medical storytelling provides a framework for designing visual narratives that combine medical accuracy with emotional impact. Building on this, Mlitzke et al. [Mli+25] investigate how interaction influences narrative flow and comprehension in tumor-related visualizations. The authors also focused their efforts on investigating the fundamental dimensions of the narrative design space, such as conflict, content, character, and structure, and providing a general overview of the design process based on their experience with multiple data-based story designs [Mit+25b].

Characters in data-driven Storytelling

Characters enhance a story's narrative, not only in narrative medical visualization [Mit+23c], but in other sectors like gaming, which is leading character driven storytelling research. Cavazza et al. [CCM02] examined dynamic interactions among autonomous characters, laying early groundwork for this research direction. Later, other authors advanced the concept of character-driven narratives by showing how well-developed characters with distinct traits and backstories enhance immersion and audience engagement [MC19; She22].

Game character designs were also analyzed through a psychological lens, highlighting the emotional depth and social dynamics involved. The design of non-player characters (NPCs) offers useful parallels to data-driven storytelling, where characters also represent information rather than interact directly with users. In both cases,

empathetic engagement is central: characters are crafted to evoke emotional connection rather than functional control [Isb22]. In their work the author emphasizes the significance of the characters emotions, as they can become "contagious" to the viewer. This shows the importance of conveying emotion through facial expression and body language. Similarly, Chen et al. [CBT17] found that strong identification with a protagonist can prompt self-referencing, encouraging users to relate story content to their personal experiences.

2.2 Related Work

Characters in narrative visualization can be an essential asset to communicate medical data [Mit+23c]. Therefore, a number of research studies have been conducted to automate their design process. Budich et al. created an AI-assisted semi-automated character design pipeline, which includes four steps: character extraction from data, character naming, character appearance definition and character animation [Bud+23].
Building on this pipeline Mittenentzwei et al. [Mit+24] created a male and a female character, both in different versions with variables such as weight and age. They evaluated the characters according to their authenticity to the underlying data and resemblance across different time steps. Additionally, animations for the characters were created and compared to static images.
Recently, they expanded on their work. This included the creation of comic-style characters based on pre-existing ones. Using these characters they performed a qualitative evaluation with design experts, asking if they preferred the comic-style or the photorealism in certain aspects [Mit+25a].

In a study on animated characters (avatars) as online sales assistants the authors explored the effect of different characters and the absence of one on the customer shopping experience. Conclusions included the preference of the majority of participants to shop with an avatar due to the perceived personal connection and elevated level of trust. [KMB10]
In a similar setting, Luo et al. compared human-like characters to cartoon-like characters in a study focusing on consumer trust. The results implied that, generally, human-like characters are observed to have greater efficacy. However, cartoon-like characters have an overall more positive effect on the persuasiveness of the interface. Additionally, they seem to be perceived as more trustworthy, than their human-like counterparts. [Luo+06]

Park et al. examined the effect of visual character styles on audience empathy and sympathy responses. They created three-dimensional animated characters in three

distinct stylizations. Participants were shown various character emotions and were asked to evaluate their response. The results showed no significant effect of the character style on empathy or sympathy. [PAP19]
The differences between visually realistic, fantasy and no character when examining their influence on user engagement were evaluated by van Vugt et al. with middle school children. The results indicate that perceived aesthetic appeal vastly influences user engagement. However, the task performance was not impacted by the persona changes. [Vug+07]

A user experience study in Virtual Reality (VR) evaluated how different character types influence user preferences and emotional engagement. Participants interacted with three virtual characters: a realistic human modeled after a real person, a fictional human, and a fictional cartoon animal. Results showed that the realistic human and the cartoon-like animal were both positively associated with trust and engagement, while the unfamiliar fictional human produced the opposite effect. The authors conclude that careful character design and opportunities for personalization are key to fostering trust and strengthening emotional connection in immersive VR environments. [DL23]

An empirical study explored how character realism and background detail affect readers' identification with illustrated characters [Yan+24]. The results showed that stylized, less realistic characters reduced racial disparities in identification, indicating their potential for engaging more diverse audiences. Additionally, simplified backgrounds enhanced character identification across all realism levels, contradicting McCloud's *masking effect* hypothesis [MM93], which predicted that abstract characters would benefit most from detailed settings to support immersion.

Characters can not only be utilized in story-based applications, but also in serious games designed for learning. To evaluate the effect a character has on engagement and information retention, Gamage et al. created a study focusing on customizable character delivering a lesson. Results show that the visual character has a positive effect on engagement and knowledge retention. However, the customization of the character lead to reduced engagement. [GE18]

3 Methodology

This chapter is focused on the theoretical preparations retaining to the project. Here, the character designs, medical stories and study design will be discussed.

3.1 Character Design

To be able to explore the answers to the projects research questions, a set of characters needs to be created. Inspired by previous papers on the AI character generation pipeline [Mit+24; Bud+23] it was decided to create the character using an AI image generator. This choice would also ensure low-threshold implementation in the event of reproduction in future story creation.
Three character styles were chosen to appear in this study. This selection was based on previously implemented characters, such as *Alex* [Stu+22] or *Emma* [Mit+23c]. Additionally, based on findings in Related Work a multitude of stories, such as the one in the study by Yang et al. [Yan+24], are designed with illustrated characters. By comparing different styles in media, it becomes evident that a continuum ranging from abstract to realistic character representations can be established.

3.1.1 Style Definition

In a first attempt to capture the sentiment of the characters and create a preview for the thesis proposal, three versions of one sample character were generated. The first version 3.1a was based on the character *Alex* [Stu+22], with simplistic black outlines and simple shapes. The second version 3.1b was intended to have more details, colors and finer shapes, like a semi-detailed illustration. The realistic style 3.1c did not quite turn out as intended, as it should be a photorealistic image, similar to a stock photo.

(a) Minimalist Character (b) Illustrated Character (c) Realistic Character

Fig. 3.1: First draft of possible character style implementation

With these initial outlines in mind, the abstraction parameters of the character styles were considered. In the first round of deliberation, the identified parameters included form, level of detail, shading, and color. However, after further reflection, color was excluded, as establishing an appropriate middle ground between colored and non-colored representations proved challenging.

With this last change, three abstraction parameters were set. Each character style then was assigned a certain value for each parameter. An overview of the character style definitions by the abstraction parameters can be found in table 3.1.
As summarized in the table below, the **abstract** style is characterized by geometric or pictogram-like forms, minimal features, and flat colors without gradients. The **illustrated** style adopts simplified yet human-like proportions, moderate detailing with visible expressions, and soft, painterly shading. In contrast, the **realistic** style employs anatomically proportional forms, fine detail with realistic textures, and photorealistic lighting and shadows.

	Abstract	**Illustrated**	**Realistic**
Form	geometric forms, pictogram shapes	simplified human shape, stylized proportions	proportional human anatomy
Details	minimal features, focus on silhouette	moderate detail, visible expressions	fine details, realistic textures
Shading	flat colors, no gradients	soft shading, painterly look	photorealistic lighting and shadows

Tab. 3.1: Comparison of visual styles used in the study.

3.1.2 Character Generation

Each character will be distinct, varying in age, hair and skin colour, clothing, medical history, and name. This differentiation ensures that participants can clearly distinguish between the characters, as each story will feature only one of them.
In media, a character's gender can significantly influence audience identification, particularly among male viewers [Hof20]. To enhance personal identification, both male and female versions of each character will be created and presented to participants based on their demographic information.
Facial expressions also play a crucial role in shaping emotional responses and empathy [Buc07]. To strengthen these effects, each character will be depicted in two emotional states: happy and worried, which will be applied within the story where contextually appropriate.

According to Budich et al. character names be memorable, pronounceable, and harmonious with their personality [Bud+23]. As the characters will be viewed in German and English context, this additional consideration had to be taken into account. Therefore multilingual common names for the represented age groups were selected:

Abstract:	***Simone*** (f) and ***Simon*** (m)	(age:30, brown hair)
Illustrated:	***Andrea*** (f) and ***Andrew/Andreas*** (m)	(age: 53, blonde hair)
Realistic:	***Martha*** (f) and ***George*** (m)	(age: 62, grayish black hair)

AI Models

Recent advances in artificial intelligence have enabled the generation of high-quality visual content through text-to-image diffusion models. These models, such as Stable Diffusion [AI24], DALL·E [Ope24] and Leonardo AI [SFB24], translate textual prompts into coherent images by iteratively refining random noise into structured visuals that align with the input description [Rom+22]. Such models are increasingly used in design, storytelling, and visualization research to rapidly prototype and explore stylistic variations.

Similar projects have used Leonardo AI [Bud+23] and Stable Diffusion [Mit+24]. In this project, Stable Diffusion (tested across multiple model variants) was initially employed to ensure reproducibility and open-source accessibility. However, while the model produced realistic character styles with satisfactory results, it struggled with illustrated and especially abstract representations. The generated outputs frequently deviated from style-specific prompts and failed to follow visual abstraction instructions consistently.
As a result, the OpenAI image generation tool was selected for subsequent development. Although this approach offers lower reproducibility due to its closed model

architecture, it provides a more intuitive and accessible workflow for character creation. Compared to Stable Diffusion, which requires substantial parameter tuning and technical expertise, the OpenAI tool integrates seamlessly with conversational interfaces, making it particularly suitable for pilot procedures and future user-oriented design applications.

Prompt (Structure)

To generate the six character version, a overarching prompt structure was set up. The necessary information for each character version was then included and sent. In some instances, small adjustments had to be made to the prompt to get the desired outcome.

Prompt:

↦ Full-body <gender> character,
↪ <age> years old,
↪ <hair color and length> hair,
↪ shown with <emotion> expression,
↪ visualized in the <style name> style: <style description>
↪ The character is <pose/gesture description>
↪ wearing <clothing description>
↪ <background definition>
↪ <aspect ratio, framing, other technical detail>

Example: "Full-body female character, 52 years old, medium-length blonde hair, shown with happy expression, visualized in the illustrated style: modern semi-realistic illustration style with realistic anatomy, expressive facial features, subtle shading, and visible signs of age. The character is standing slightly angled to the viewer with a relaxed, natural pose, arms gently at her sides, wearing a casual blouse and trousers in warm colors. Transparent background, 16:9 aspect ratio, full-body framing, high resolution"

Negative prompt:

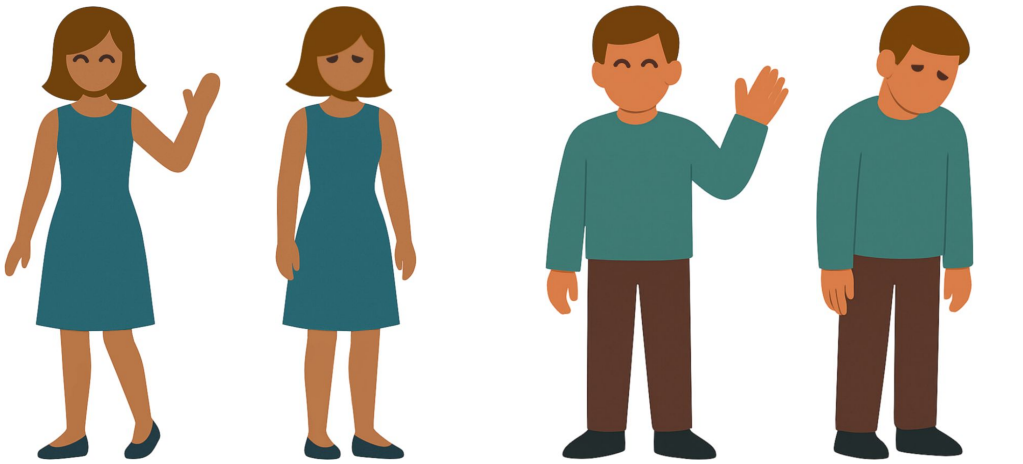
NSFW, text, deformed, ugly, blurry, unrealistic, 3d, anime, text, watermark, extra limbs, mutated hands, bad proportions, long neck, worst quality, low quality

Regular and negative prompts were used to generate the characters. Each style description was constructed using the abstraction parameters, which worked well. Apart from the realistic images, the characters were generated without a background, so they would blend into the story better. However, generating a photorealistic image

and cropping out the background would seem unnatural and break the immersion. For this reason a neutral background was selected. The results are as follows.

3.1.3 Results

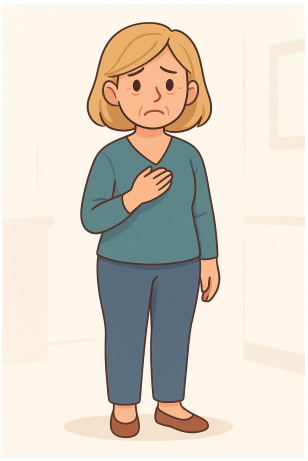
The abstract characters seen in figure 3.2 are the end results which satisfy the requirements. The generated images had some unwanted shading and some irregular facial expressions, which had to be removed or adjusted. As there are a female and male version for all characters, it is essential, that they have few differences apart from the required ones.



(a) Simone, happy **(b)** Simone, worried **(c)** Simon, happy **(d)** Simon, worried

Fig. 3.2: Abstract Characters (Age: 30, brown hair)

Creating the illustrated characters, which can be viewed in figure 3.4, took a few more tries than the abstract. One decision which was posed during this process is how to align the illustrated style in the middle between the abstract and realistic. Figure 3.3 shows some alternative image results. However, they were not selected, as they leaned too far in one direction or the other. This decision is subjective, so someone else could have selected differently.
The male version (see fig. 3.4c and 3.4d) was generated through image-to-image translation, to minimize the differences between both character versions.



(a) Illustrated - more simplified

(b) Illustrated (more realistic)

Fig. 3.3: Illustrated other options

(a) Andrea, happy

(b) Andrea, worried

(c) Andrew, happy

(d) Andrew, worried

Fig. 3.4: Illustrated Characters (Age: 53, blonde hair)

As with Stable Diffusion, generating photorealistic characters posed no difficulty. The prompts were followed precisely, and the results were highly satisfactory. Since the happy and concerned expressions were created separately, it took a few attempts to select a concerned version that closely resembled the original face. Nonetheless, the final outcome, which can be viewed in figure 3.5, was successful.

(a) Martha, happy (b) Martha, worried (c) George, happy (d) George, worried

Fig. 3.5: Realistic Characters (Age: 62, grayish black hair)

3.2 Medical Stories

In order to examine the character effects, medical stories need to be used. Creating three completely new medical stories including research, expert feedback and visual setup, would extend past the scope of this project. For this reason it was decided to reuse three already existing stories.
These stories were developed as part of the work by the Visualization Group at the University of Magdeburg and can be accessed here. In the following section these stories and necessary changes for the project at hand will be discussed.

3.2.1 Original Stories

There have been a variety of different versions of these stories, which have been utilized in certain forms for other studies. The reworked stories were based on the version that was provided by each main author. To avoid confusion on which version was used, each story will be shortly outlined in this paragraph.

Bicuspid Aortic Valve (BAV) [Stu+22]

The first story covers the experience of the character Alex, who suffers from one of the most common heart defects: a bicuspid aortic valve. It follows the structure of Dykes' *Data Storytelling Arc* [Dyk19]. The character is sent to undergo an MRI scan. The story employs clever use of a tornado metaphor to show the effects of vortices in the blood. Real 4D PC-MRI data is used, to show healthy and unhealthy bloodflow. The reader then gets the chance to diagnose Alex themselves. BAV is explained, using medical illustrations and a four step procedure to replace the irregular valve with a new valve is shown. There is an open end, inspired by the martini glass structure [SH10], for the readers to explore any other interesting information.

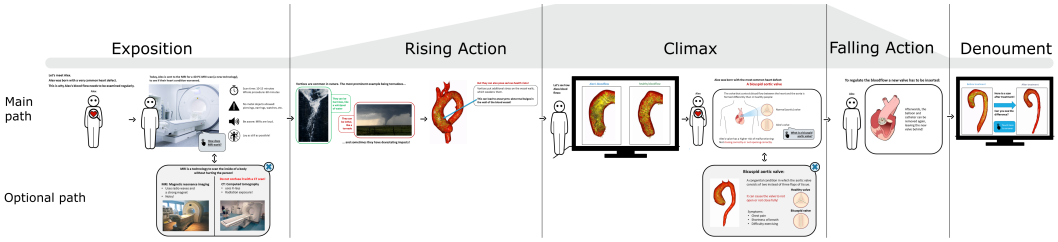


Fig. 3.6: Bicuspid Aortic Valve - original story overview

Liver Cancer (LC) [Meu+22]

This story revolves around the character Thomas who gets a liver cancer diagnosis. As this is an early implementation, the structure is not based around the character, but is more focused on the disease with the character taking a less essential role. The story follows the Seven-stage template for narrative medical visualization of disease data, which can be seen in figure 3.7.

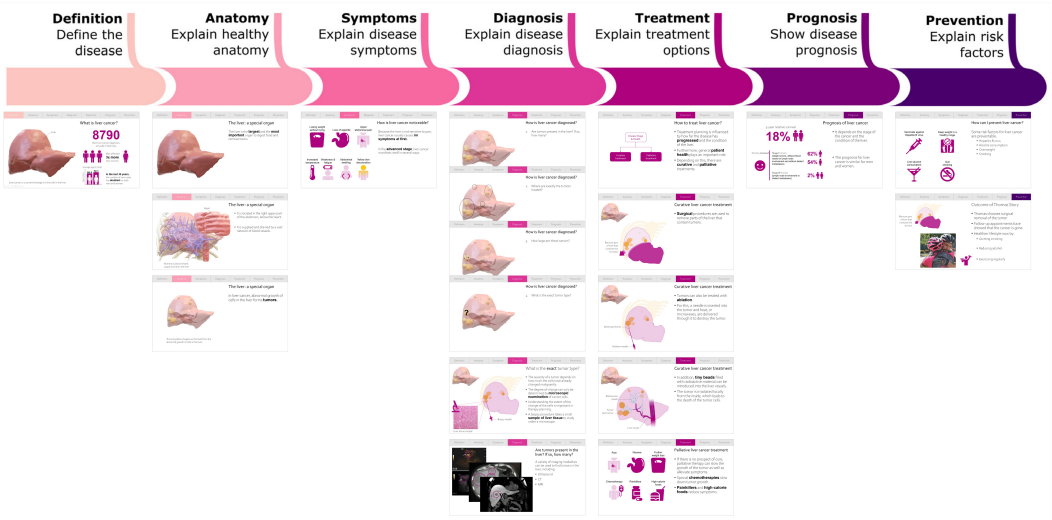


Fig. 3.7: Liver Cancer - original story overview

Cerebral Small Vessel Disease (CSVD) [Mit+23c]

This story has many variations. To support the goal of creating an updated character centered version, the patient-focused implementation was selected as a reference. In this version, Emma, a 59-year-old patient, serves as the main character. The narrative unfolds chronologically, illustrating the typical stages a patient goes through following a disease diagnosis. The structure follows the Patient-centered disease journey [Mit+23c], which will be discussed in the next section.

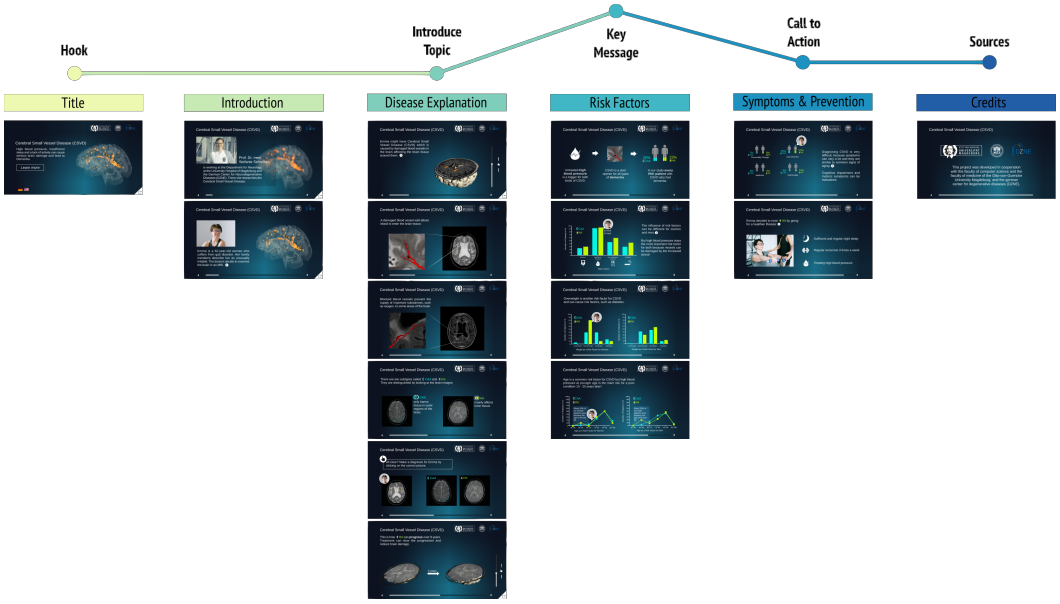


Fig. 3.8: Cerebral Small Vessel Disease - original story overview

3.2.2 Story Adjustments

The three chosen original stories have a substantial length. Additionally, they all exhibit slightly varying structures and attributes. In order to make the characters comparable in their respective environments, the stories have to be adjusted.

Story Structure

After examining the original stories, it becomes clear that they show vastly different underlying structures. Since each disease topic necessitates the inclusion of specific medical explanations to ensure the story's clarity and educational value, a complete unification of the narrative structure across all stories is not possible. However, to ensure consistency while maintaining flexibility, an overarching narrative structure can be established. This structure provides a common framework into which all stories can fit, while still allowing variation to accommodate the specific informational requirements of each disease topic.

To achieve this, the patient centered disease journey, which is an adaptation from Campbell's Hero's Journey [Cam08], by Mittenentzwei et al. is introduced as a global structure for reference [Mit+23c]. The disease journey has two variations: patient-centered and physician-centered. As the goal is to conduct a character study on the patient, the choice falls on the patient centered journey, which can be viewed in figure 3.9.
The story begins in the known world, where events from the patient's everyday life are depicted. During the departure phase, the onset of symptoms disrupts this

normal life, leading the patient to seek medical help and meet the physician. In the initiation phase, the patient enters the unknown world, undergoing various diagnostic examinations and tests in pursuit of a diagnosis and suitable treatment. Finally, in the return phase, the patient re-enters the known world and integrates the required lifestyle changes. Over time, the outcomes of the adherence can be evaluated. Ultimately, the goal is to return to normal life as best the patient can.
With this detailed structure, the stories can fill multiple stages and skip others. While different stories' emphasis will not always be on similar phases, they are still coherently arranged and provide room for overlap and dissimilarities.

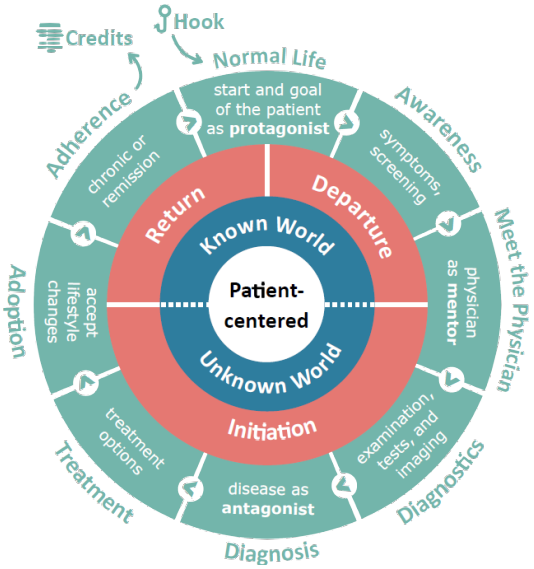
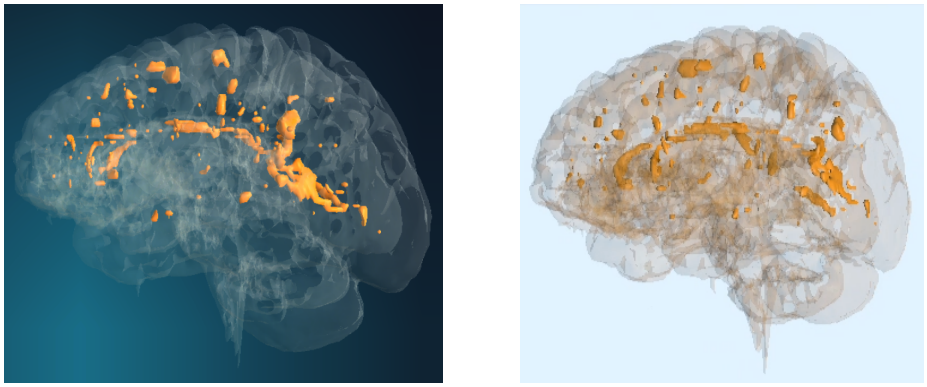


Fig. 3.9: Patient-centered disease journey [Mit+23c]

Additional differences in structure will be explained in more detail in some of the following paragraphs.

Style related Asset Changes

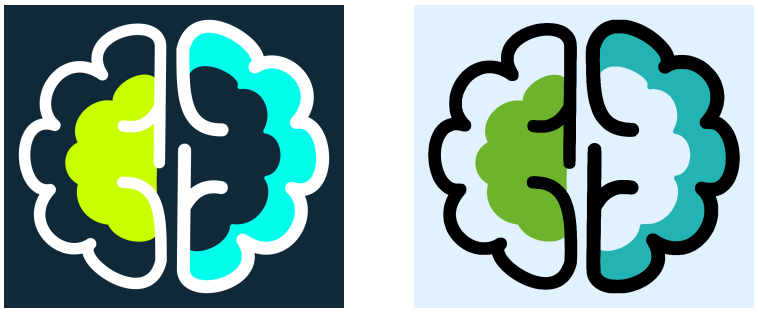
To accommodate the changed colour scheme and other related visual elements, certain assets needed to be changed to increase visibility. This was particularly necessary in the case of the CSVD story, as the background image in the original story was dark blue which made light and bright assets stand out. However, the reworked stories are all united under a light blue colour scheme, so the assets needed to be adjusted accordingly. The first change was made to the mesh of the lesioned brain. he base map colour #FFC366 was selected to provide sufficient contrast against the light blue background, while complementing the lesion colour #FF9F00. This adjustment can be seen in the comparison between the original and updated versions in figure 3.10.



(a) Old 3D brain model (b) Updated 3D brain model

Fig. 3.10: Old and new versions: CSVD 3D brain model

Additionally, the original story employed colored icons to symbolize the subtypes HA and CAA of Cerebral Small Vessel Disease. The original icons used #99FF33 for HA and #01FEEC for CAA, as well as a white outline to contrast the dark background. These icons were not readable on the light background. Therefore, the white outline was changed to black and the colors were darkened by a few shades using the html color picker [Moe25]. to #6EB32C and #23B3B2. The original and resulting icons can be seen in fig. 3.11.



(a) Old Icons for HA and CAA (b) Updated Icons for HA and CAA

Fig. 3.11: Old and new versions: CSVD subtype HA and CAA icons

For the liver story some color changes were adapted, as well. Figure 3.12a shows the icons used for symptom for symptom and palliative treatment visualization. Here, the color scheme is magenta, as it was part of the original story design. To fit the new blue scheme, the color was adjusted to a blue as can be observed in figure 3.12b.

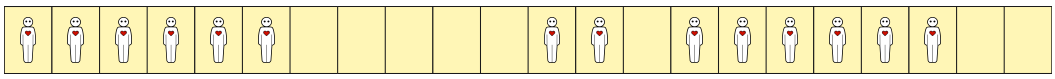
(a) Original Liver Story Icons

(b) Updated Liver Story Icons

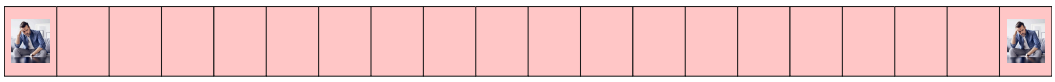
Fig. 3.12: Optional Information Path Buttons

Character Inclusion

As the stories are the vehicle to examining the properties of the character visualization, there needs to be a consistent focus across all of them. As it stands in the original stories, this is not the case. When examining the main stories, the character Alex appears a lot more often than the characters in the remaining stories, as seen in figure 3.13d. During the story development, the focus was on assuring that the characters are visible the same amount of times. The result was, that the character was visible on 5 out of the 11 pages of each story.



(a) Character occurrence in ***BAV story***



(b) Character occurrence in ***LC story***

(c) Character occurrence in ***CSVD story***

(d) Intended character occurrence in ***reworked stories***

Fig. 3.13: Occurrence of the characters in their respective stories

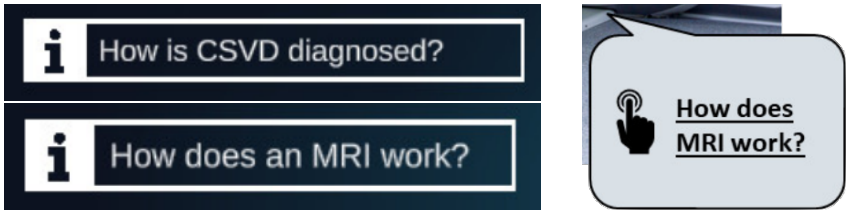
Additionally, to increase the emotional connection between reader and character, the character's name was included whenever the context allowed. Lastly, it should be remembered that there are two versions of the character: the worried and the happy. The happy version is present during the character introduction on the first page and the adherence explanation on the last page. While the character is in the unknown world phase of the story structure, the worried character version is displayed.

Interactivity

Interaction design is an essential aspect of narrative visualization [SH10]. It allows

the reader to explore the provided data and has a positive effect on user engagement [Kro+17]. The three stories exhibit varying levels of interactivity. Apart from navigation options, three different types of interaction can be found in the stories:

- **Optional information path**
  For readers with additional interests, optional paths are offered to access further information. Readers may or may not activate this path by clicking on a button such as shown in figure 3.14. This will show them further context or explain a side detail, without skipping any of the main story. Such paths are implemented in the BAV story, as well as in the CSVD story. The liver story does not include such elements.

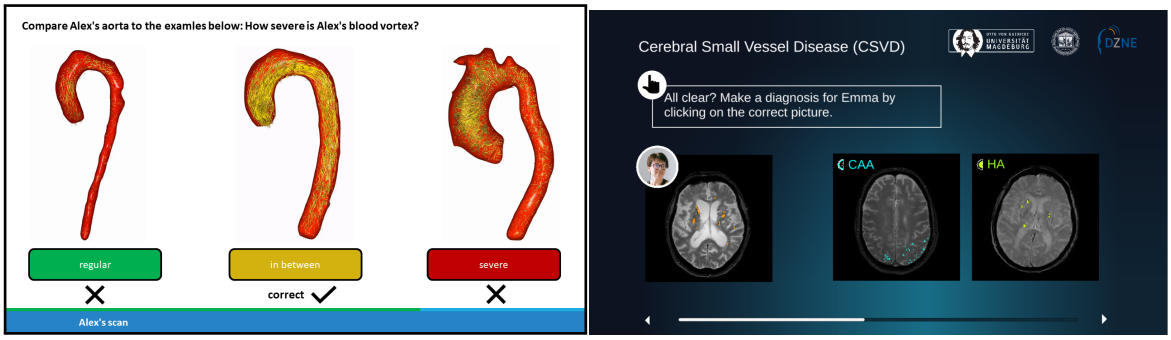


(a) Explaining specific diagnosis techniques and how MRI works in CSVD story

(b) Explaining MRI in BAV story

Fig. 3.14: Optional Information Path Buttons

- **Quiz**
  To test the readers knowledge and achieve a learning effect, small quizzes can be integrated into the story. This has been implemented in the CSVD story, as seen in figure 3.15b, where the reader is asked to identify the subtype of disease the main character has. A similar quiz can be found in the BAV story, as seen in figure 3.15a. Here, the reader needs to identify how severe the patients blood vortex is.



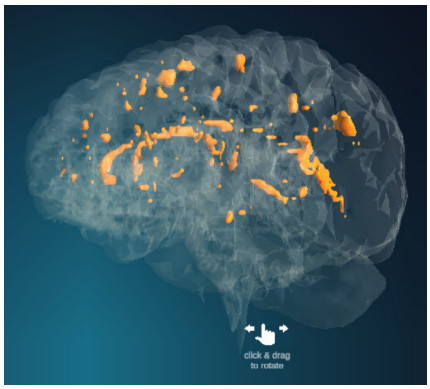
(a) BAV quiz: How severe is the vortex?

(b) CSVD quiz: Which subtype does Emma have?

Fig. 3.15: Interactive quiz question slides

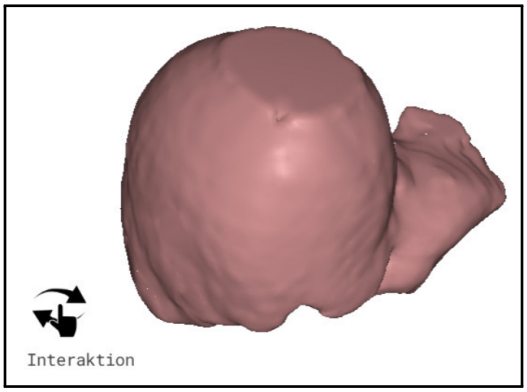
- **3D model interaction**
  Direct interaction with the data by including 3D model interaction can be

implemented. This allows the user to explore the data as freely as previously determined by the author. Options include model rotation, as was implemented in the liver cancer story seen in figure 3.16c. This was also utilized in the CSVD story multiple times. Figure 3.16a shows an invitation to model rotation. While figure 3.16b shows a different kind of interaction, where the reader can explore varying slices of the patients brain scan.



(a) CSVD story: rotate brain

(b) CSVD story: scroll through brain layers



(c) Liver Cancer story: rotate liver

Fig. 3.16: Interactive 3D models

An early story concept included an interactive question regarding patient symptoms on the opening page, intended to serve as both a hook and a diagnostic test. However, as will become evident, not all stories feature symptoms that could be directly observed, making this approach impractical. Consequently, interactivity was removed entirely to maintain focus on the characters. In cases where interactivity had originally offered valuable insight into a 3D model, animation was used instead. For example, in the CSVD brain model, the brain could originally be rotated to reveal affected areas more clearly. Here the brain was instead set to slowly rotate in the new story version, to preserve the insight. Due to the removal of optional paths, the story structures become linear.

Auditory Support

The liver cancer story includes a voice-over which reads each paragraph aloud. This in combination with animated visual information is considered to be the best way to communicate health data to readers with limited medical knowledge [Mep+15]. However, due to the lack of this feature in the remaining two stories, it had to be excluded in the reworked implementation of the cancer story.

With these story adjustments, the characters can be compared based on their attributes and not based on the story context. However, it is noteworthy that even with the adjustments, due to the varying original content of the stories, it would not be possible to adjust the stories to be completely the same. Additionally, although the stories do form a full storytelling arc and are coherent, some information had to be omitted. The main goal of the presented changes was comparability and personal connection of the reader to the character. Details which did not contribute to these goals and were non-essential information, were removed.

One major decision in regards to the story placement in the study is to combine each character style with only one of the stories:

- Abstract → Bicuspid Aortic Valve
- Illustrated → Liver Cancer
- Realistic → Cerebral Small Vessel Disease

This is necessary to make effective use of participant responses. A very limited amount of potential participants can be reached within the confines of a master thesis study timeline. To not divide the participants into unrepresentative small sample groups, it was decided to accept this limitation and proceed as intended. Any possible limitations are discussed further in section 6.2.

The reworked stories will be presented in chapter 4.

3.3 Study Design

To uncover credible answers to the research questions, the questionnaire section of the study was divided into three parts according to the questions. In the following section the concepts and setup for the interactive aspects of the study will be elaborated.

3.3.1 Emotional Connection

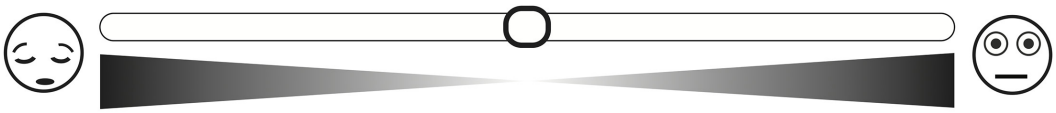
Leaning on familiar research, the first draft of this section consisted of a set of questions which were to be answered by the readers based on a Likert scale [Lik32]. The selected questions were extracted from a catalog provided by the Visualization Group at the University of Magdeburg as part of the supplementary material of a research paper in development. In this work the authors evaluated a series of studies and the catalog provides an assortment or relevant questions grouped by intent and similarity. To examine the emotional connection the readers of each story developed, the following questions were selected:

- *Identification*
  How strongly do you feel a personal connection to the narrative conveyed by the story?
- *Empathy*
  To what extent does the narrative technique help you understand the perspectives or experiences of others?
- *Emotion*
  How strongly does the technique evoke emotional reactions or responses?
- *Impression*
  To what extent did ***name***'s story leave a lasting impression on you?

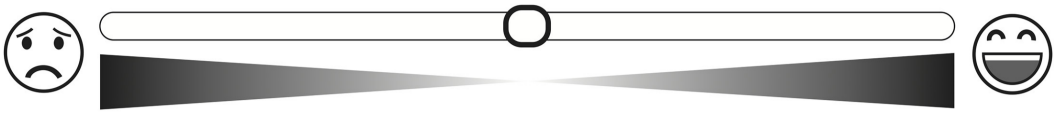
The catalog offered a selection of questions from relevant studies, as well as a range of questions the research group included based on their own experience in narrative visualization. Coincidentally, each of the selected question was an inclusion from the authors experience. As of the submission date, this paper remains a work in progress and is therefore not yet suitable for citation.

The answers to these questions could yield valuable insights into the issue at hand. However, after careful consideration and thoughtful advice, the concept was adjusted. Opting for a visual and less leading approach, the *Affective Slider (AS)* [BV16] was selected as a replacement. This method is an adaptation of the legacy method *Self-Assessment Manikin (SAM)* [BL94], which directly measures a person's affective reaction using abstract graphic characters arranged along a scale. The *Affective Slider* is a modern interpretation designed with digital user interfaces in mind. It employs two sliders, which most participants are familiar with and know how to use intuitively, to subjectively rate their pleasure- and arousal-based reactions. With these ratings an effective emotional mapping can be constructed and evaluated. [BV16]
The AS has been proven to be an effective measuring tool for subjective affective ratings. It has many advantages such as requiring no text based instructions and

relying solely on visual stimuli [BV16]. The expressions on either side of the slider guide the viewer to a reflective response and make the meaning intuitively clear. The arousal slider shows a sleepy face on the left and a wide awake face on the right, as can be observed in figure 3.17a. The pleasure shows similar faces with the right showing a frown and the left a wide smile, as seen in figure 3.17b.
Another advantage of the AS is the continuous nature of the slider. With this, researchers were able to achieve data of much higher resolution [BV16]. As this is not one of the vocal points of this study, the continuous nature of the slider was reduced to a 5-point discrete selection, to ease data evaluation later on.



(a) Affective Slider: Arousal



(b) Affective Slider: Pleasure

Fig. 3.17: Affective Slider for measuring emotional reactions

Another dominant aspect of the slider design quickly becomes apparent, when examining figure 3.17: two isosceles triangles mirrored in the middle of the slider. These serve as a visual cue for intensity of the selection. This is a crucial visual guide especially with a continuous slider scale. [BV16]

3.3.2 Memorability

When considering memorability, two key aspects emerge. The first is the memorability of the medical data itself, as conveyed through the character-focused story and as potentially influenced by the character's design. The second is the memorability of the character visual.

Medical Information Memorability

To test how accurately the readers remember the information from each story, knowledge checks were implemented. For each story three questions, themed after main aspects conveyed in the narrative, were posed. For each question the participants received a multiple choice selection out of three possible answers. The wrong answers were chosen to sound plausible to an unprepared reader but to be

Version	1	2	3	4	5	6	7	8
Face	A	A	A	A	B	B	B	B
Clothes	A	A	B	B	A	A	B	B
Hair	A	B	A	B	A	B	A	B

Tab. 3.2: Combination of traits across eight character versions

completely inaccurate if the intended message of the story was absorbed. A full list of all questions and multiple choice answers is provided in Knowledge Questions.

Character Memorability

Similarly to information memorability, the memorability of the characters themselves is also examined using multiple choice questions. However, here the multiple choices are different variations of the original character. Three main character characteristics were identified which add to their visual memorability: face, hair and clothing. To create the character versions, a second version of each characteristic dissimilar from the original was created. Then all variations of these characteristics were combined to seven new character versions. The possible variations can be observed in table 3.2 with **A** being the original characteristic and **B** being the newly added version of the trait.

The changes were adapted manually, as they require precision and consistency. This would be hard to achieve using an AI image tool. For the abstract versions, as seen in figure 3.18 and 3.19, the hair color was darkened, the color of the legwear was changed and for the face, which is minimal to begin with, a simple line was added to indicate a smile, similar to the style of the character's eyes. Special attention was paid to the color choices as the new variant needed to be distinctly differ from the original.

(a) Original **(b)** Version 2 **(c)** Version 3 **(d)** Version 4 **(e)** Version 5 **(f)** Version 6 **(g)** Version 7 **(h)** Version 8

Fig. 3.18: Abstract: Female Character Versions

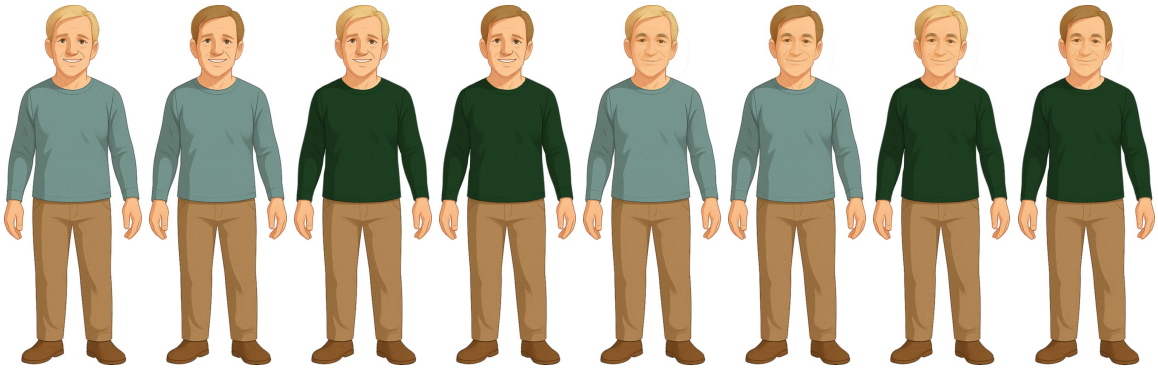
(a) Original (b) Version 2 (c) Version 3 (d) Version 4 (e) Version 5 (f) Version 6 (g) Version 7 (h) Version 8

Fig. 3.19: Abstract: Male Character Versions

For the illustrated variations, one male and one female alternative character were created, reusing the original prompts explained in 3.1.2. These were used as alternate faces on the characters. As with the abstract characters, changes to hair, clothing, as well as the face changes were executed and adjusted by hand. A filter was applied to the second hair version, to make it darker and similarly a filter was used on the shirt to make it green. The female versions of the illustrated character can be seen in figure 3.20 and the male characters in figure 3.21.

(a) Original (b) Version 2 (c) Version 3 (d) Version 4 (e) Version 5 (f) Version 6 (g) Version 7 (h) Version 8

Fig. 3.20: Illustrated: Female Character Versions



(a) Original (b) Version 2 (c) Version 3 (d) Version 4 (e) Version 5 (f) Version 6 (g) Version 7 (h) Version 8

Fig. 3.21: Illustrated: Male Character Versions

As with the illustrated changes, additional characters needed to be generated for the required changes. However, new male and female characters were not only created for a face swap, but also additional characters needed to be created to change the hair as a filter would not look natural on the realistic image. These changes were the most effort intensive, as the realistic aspects of the image needed a lot more attention to detail to look natural. All changes were done by hand in these images as well to assure that no additional changes were made besides the color of the clothing, color of the hair and the face. For every version the original image was used as the base and changes were applied from there. The resulting female versions are shown in figure 3.22 and the male versions are shown in figure 3.23.

(a) Original **(b)** Version 2 **(c)** Version 3 **(d)** Version 4 **(e)** Version 5 **(f)** Version 6 **(g)** Version 7 **(h)** Version 8

Fig. 3.22: Realistic: Female Character Versions

(a) Original **(b)** Version 2 **(c)** Version 3 **(d)** Version 4 **(e)** Version 5 **(f)** Version 6 **(g)** Version 7 **(h)** Version 8

Fig. 3.23: Realistic: Male Character Versions

All characters were examined using a color blindness simulator [Col25] to make sure the changes are visually distinct for any possible viewing viewing experience. The resulting character versions will be offered to the participants of the study, where they will be asked to identify the original character. If uncertainty arises, they will have the option to select up to three versions and rank their selection from most to least likely.

3.3.3 Medical Data Communication

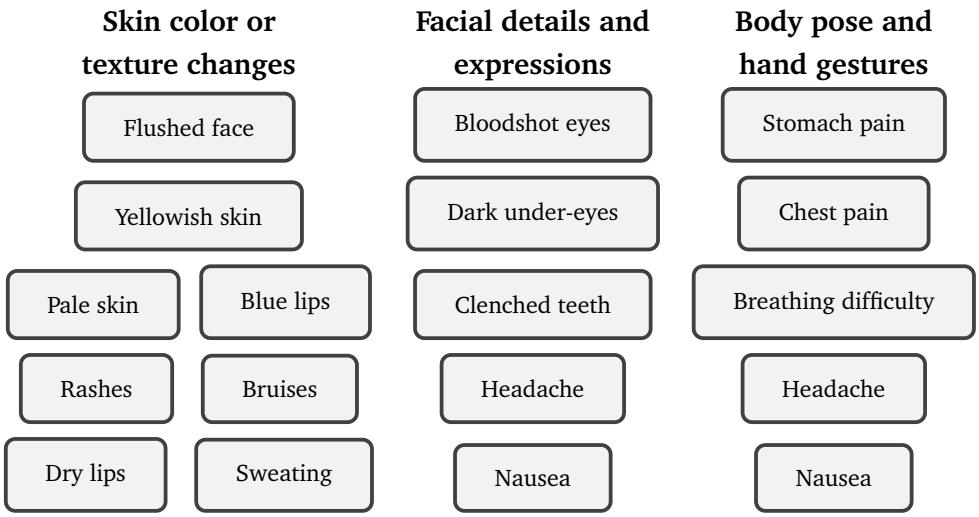
In this portion of the study the ability of each style to communicate medical data visually was to be examined. This was inspired to function similarly to the work „Ai-assisted character design in medical storytelling with stable diffusion“ by Mittenentzwei et al. When examining the authenticity of the AI generated character

outcome, participants were asked to select any keywords they considered fitting for the image from a range of categories [Mit+24].

To examine the communication of medical data through the characters, first, three categories of possible visual communication were identified:

- Skin colour or texture changes
- Facial details and expressions
- Body pose and hand gestures

These three categories were then filled with potential symptoms, that could be communicated through the means of that category. Some symptoms were fitting for both categories, as well.

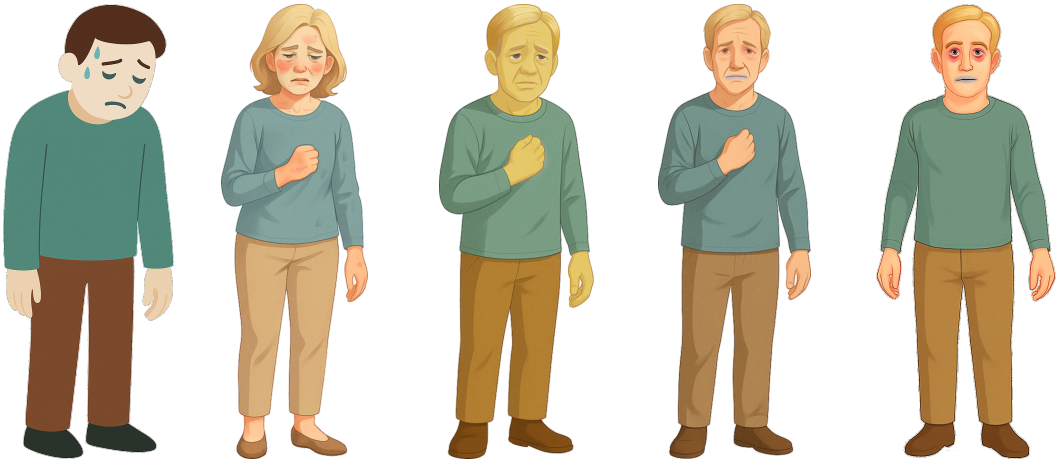


While paying close attention to the facial expression, skin color, gestures and body language and using the original characters, new character versions were created. Each character style were to have two male and two female characters with symptoms. Two characters were to have one and two were to have two symptoms in one, to see if participants would recognize multiple aspects in one visual. With this, characters were created similarly to the original character versions. Therefore the AI generator was provided with the original character version, as well as the intended symptoms and their category. Using this input the image-to-image generation was conducted.

As with most AI interactions, the generated results were rarely exactly as intended and often required multiple adjustments or re-generations. However, the primary objective of this work was to assess how effectively the styles conveyed the symptoms, rather than to evaluate the performance of the AI itself. Therefore, imperfect or unsatisfactory AI outputs were not allowed to hinder the investigation. Examples of earlier or unusable character versions are shown in figure 3.24.

The first example (fig. 3.24a) is an attempt at the abstract character who is pale

and sweating. This version had to be adjusted, as it did not fully satisfy the style definition as discussed in section 3.1.1. Figures 3.24b and 3.24c have an unnecessary pose, which does not contribute to the symptom communication. This is to be avoided, thus the designs were discarded. Figures 3.24d and 3.24e are both attempts to create the male illustrated character with blue lips and bloodshot eyes. One version is created by hand and one was made by AI. Figure 3.24e is one of the multiple attempts make by the AI image generator. This attempt, as well as any other, does not represent the bloodshot eyes in a realistic way. Additionally, similar to the handmade attempts, it was criticizes by a medical artist to look like a clown because of the representation of the blue lips.



(a) Sweating, Pale skin (old)

(b) Rashes (old)

(c) Yellowish skin (old)

(d) Blue Lips, Bloodshot eyes (old,handmade)

(e) Blue Lips, Bloodshot eyes (old, AI)

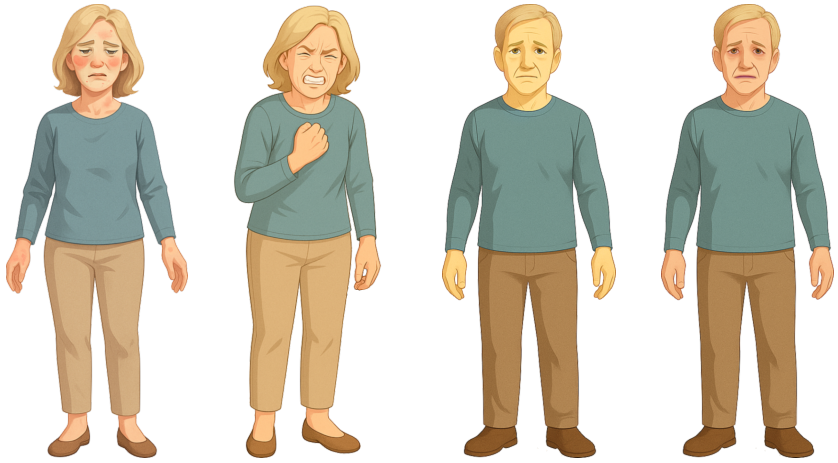
Fig. 3.24: Unused character versions with symptoms

The characters selected or made for the abstract style can be seen in figure 3.25. Figure 3.25a, as well as 3.25c were generated by AI in this version without any changes. Figure 3.25b was created by hand with the guidance of a medical artist, as previous versions were considered unrepresentative of the symptoms. Figure 3.25d is the final version of the previously viewed image 3.24a. To adapt to the chosen abstract character style, the facial features were reduced here.

(a) Stomach pain (b) Flushed face, Dark under-eyes (c) Headache (d) Sweating, Pale skin

Fig. 3.25: Abstract: Characters with symptoms

As previously discussed, almost all illustrated characters were adjusted by hand. Figure 3.26a is a combination of the original character version and figure 3.24b. The original version was used, to keep the body pose neutral, as it does not pertain to the “rashes” conveyed by this patient. A number of different versions was generated, until figure 3.26b was the result. However, it was deemed fitting for the keywords “clenched teeth” and "chest pain” showing both in expression and body pose. Characters 3.26c and 3.26d were created from scratch based on discussions with a medical artist. Both are an adjusted version of the original character. This had to be achieved by hand, as the AI results were very unrealistic as agreed on with the medical visualization expert. The yellowish skin was achieved using a filter on the character skin and selecting a color based on a reference image of this condition. Blue lips and bloodshot eyes were achieved by layering semi-transparent color shapes on the characters face based on a real reference, as well. These references were picked in collaboration with the medical artist.



(a) Rashes (b) Clenched teeth, Chest Pain (c) Yellowish skin (d) Blue Lips, Bloodshot eyes

Fig. 3.26: Illustrated: Characters with symptoms

Apart from minimal adjustments on the dry lips in figure 3.27d by adding white flakes as discussed with the medical artist, the realistic images seen in figure 3.27 are entirely AI generated without any alterations. Each image needed multiple passes, to portray the required symptom to an acceptable degree but ultimately the results were satisfying.

(a) Headache (b) Sweating, Pale Skin (c) Stomach pain (d) Dry Lips, Rashes

Fig. 3.27: Realistic: Characters with symptoms

To complete the task, the participants will be provided with each of the character visualizations and the previously presented symptom keywords. They will be asked to select any keyword they think might apply to the given character.

4 Implementation

The study was implemented using the game engine Unity [Tec25] (version 2022.3.17f1). Functionality was implemented Unity scripts written in C#.
The study was adapted in German and English to increase the number of potential participants using the Unity localization feature. It was then exported as a WebGL application and hosted on GitHub Pages [Git25]. The data was collected in a Firebase Realtime Database [Fir25].

4.1 Global Structure

For the implementation in Unity a few global navigation and context options were implemented. Back and forth navigation buttons, as well as a progress are present throughout the study. For the questionnaire portion of the study, the “Back” button was removed to prevent participants from changing their answers after seeing possible solutions on subsequent pages. Additionally, the “Next” button remains not intractable until a selection is made, to ensure participants do not miss any essential data collection steps.

The general structure of the study can be seen in figure 4.1. After a brief introduction, the participants are asked to provide some personal data. Depending on the input, they are then guided to the male or female version of the study. Each version from that point onward is constructed in the exact same way. The first entry point is the menu screen, see section 3 in figure 4.1. The menu will be explored further in section . From the menu the participants select a story they want to view first. Each story will be detailed in section 4.2. The participants read the chosen story, as in section 4 of figure 4.1. Following the individual story, the questionnaire part associated with the specific story, which has just been read, begins. The questionnaire implementation will be elaborated in paragraph 4.3.3. Once the questionnaire is complete, the readers return to the main menu screen as in section 3 of figure 4.1. The process repeats until the participant has reached the last page of the questionnaire of their last story. Following this, they are prompted to provide some additional information about the choice of the order they viewed the stories in, which will be explored in section 4.3.4. After this they can do a final submission and finish the study.

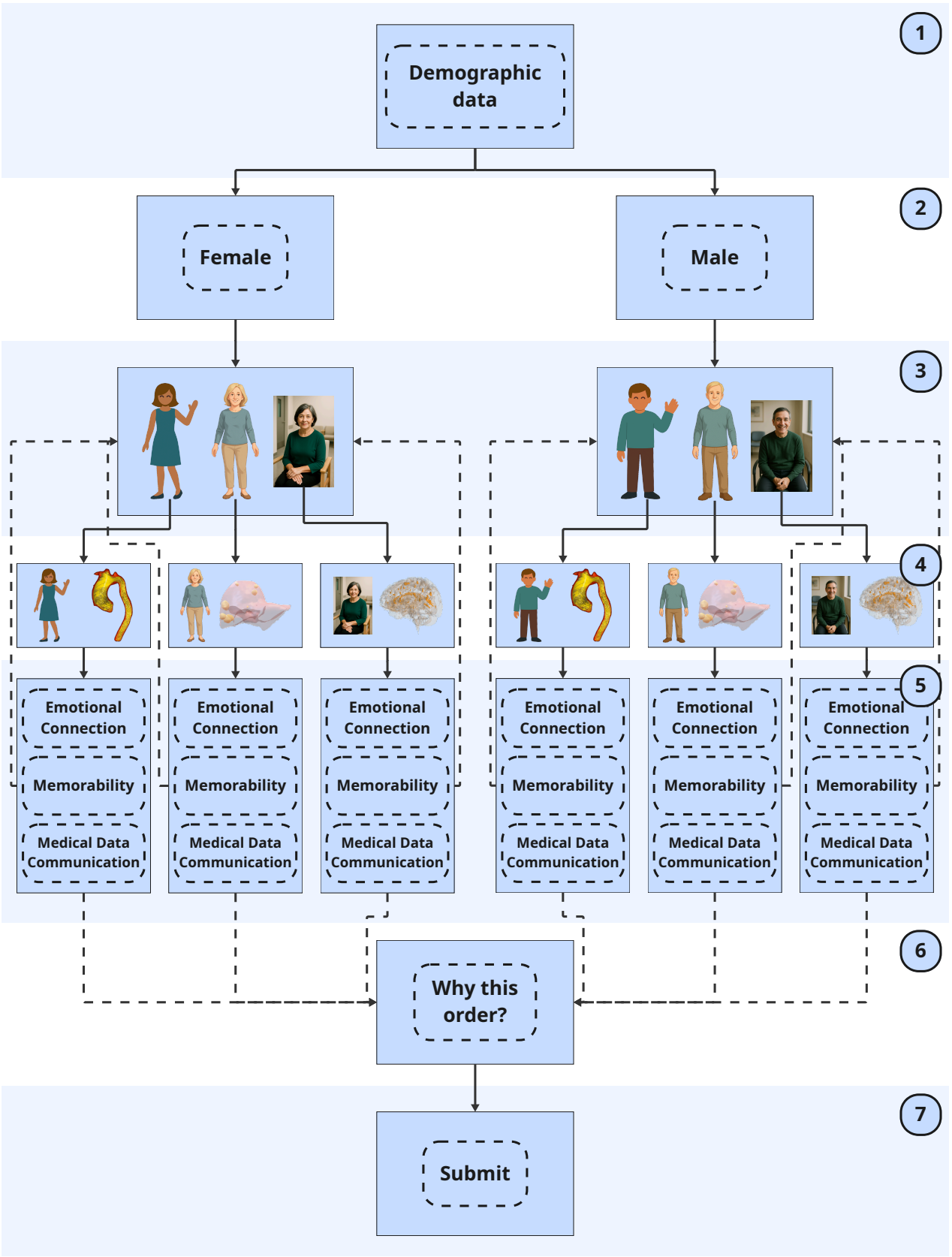


Fig. 4.1: Global structure of the Character Study

4.2 Medical Stories

In the following sections, all three story implementations will be shown and elaborated. This will include the male and female versions of story pages, wherever these versions differ. Each story follows the structure and adjustments outlined in section 3.2.2 as closely as possible with the provided content of the original stories. To ensure keep the attention of the participants throughout the whole study, each story was designed to be read in no more than 3 minutes.

4.2.1 Abstract - Bicuspid Aortic Valve

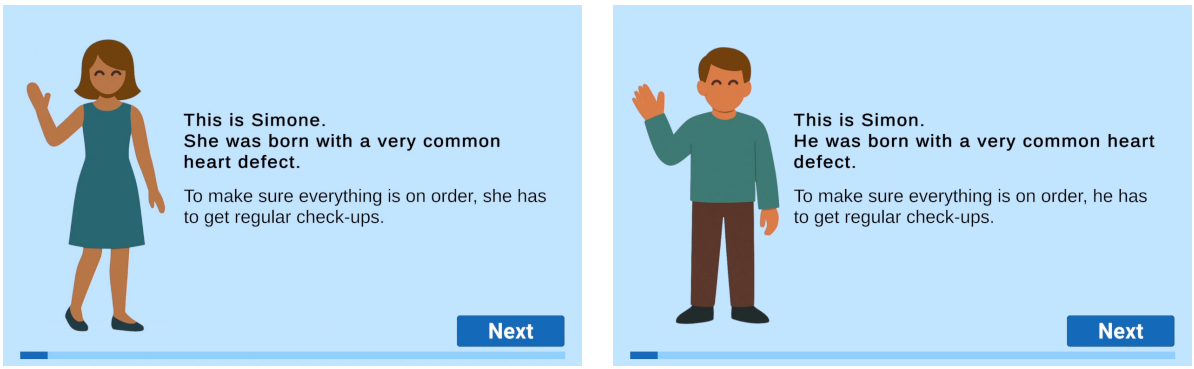


Fig. 4.2: Abstract: Character introduction

The first page is a character introduction, where the readers learn the characters name, as well as a short hook, to keep them interested. Here, the female character Simone and the male character Simon are said to have a common heart defect: a bicuspid aortic valve. To provide an introduction to the next steps, the page explains, that the character will undergo a check-up.

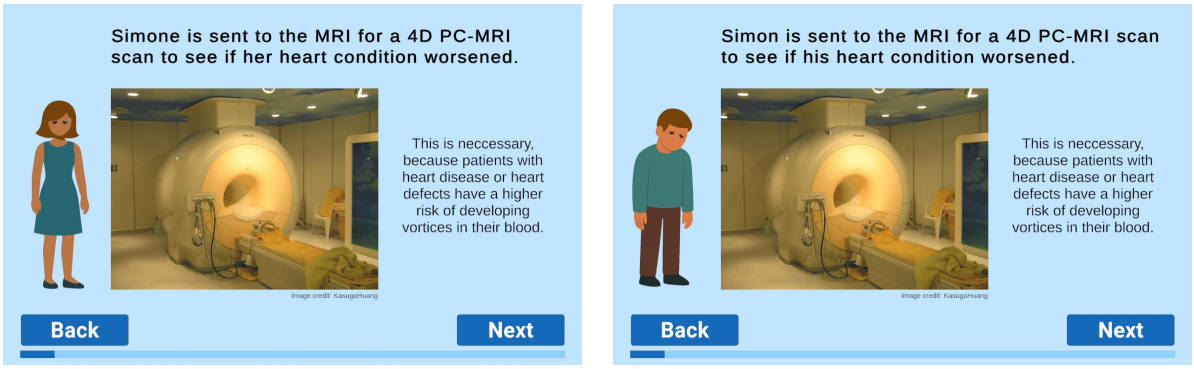


Fig. 4.3: Abstract: Diagnostics with 4D PC-MRI

The concerned character versions appear for the first time. Although a diagnosis has not been made, yet, this version should evoke worry for the character in their story. The characters are sent to a a 4D PC-MRI, to examine their condition and see if it worsened or they have worrying vortices in their bloodflow.

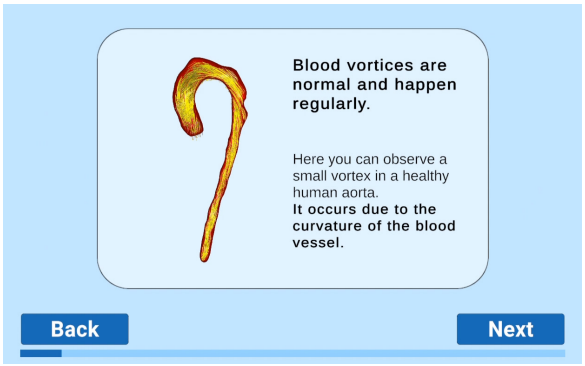


Fig. 4.4: **Abstract:** Condition - harmless

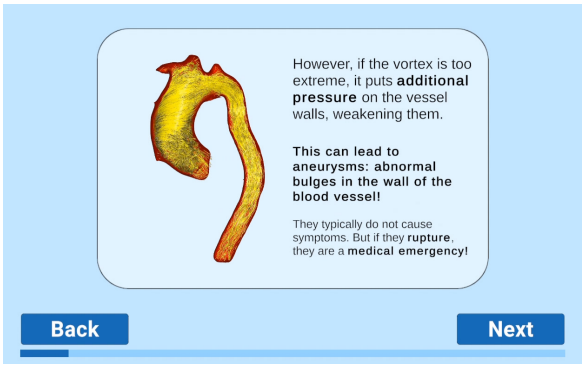
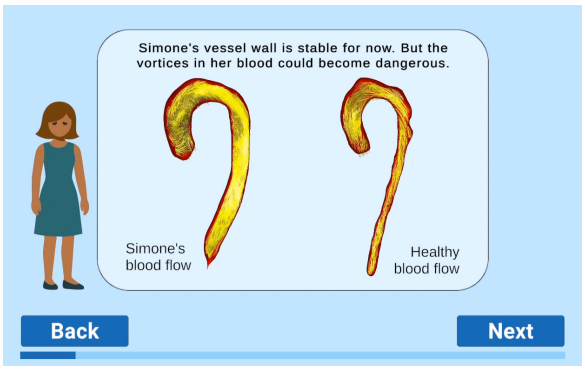


Fig. 4.5: **Abstract:** Condition - possibly harmful

To provide some additional context, blood vortices are explained further. A visual example of regular bloodflow with harmless vortices is shown to explain that they are a regular occurrence due to the curvature of the aorta.

Expanding on the context of blood vortices, a harmful vortex in the aorta is presented. In this case the vortex weakens the vessel wall and a aneurysm forms. This is supported by a visual representation of an extreme vortex inside a widened aorta vessel. An aneurysm can rupture, which constitutes a medical emergency.



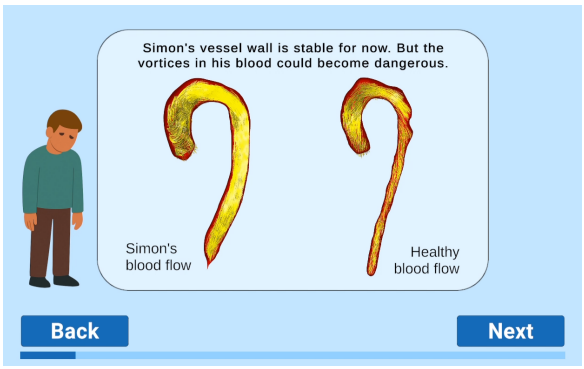
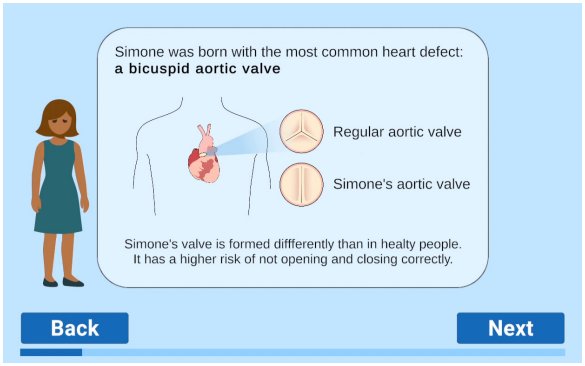


Fig. 4.6: **Abstract:** Condition diagnosis

The readers receive a side by side view of the aorta and bloodflow of the character, as well as a healthy version. This reveals that there might be a risk of vessel wall weakening due to a moderately strong vortex.



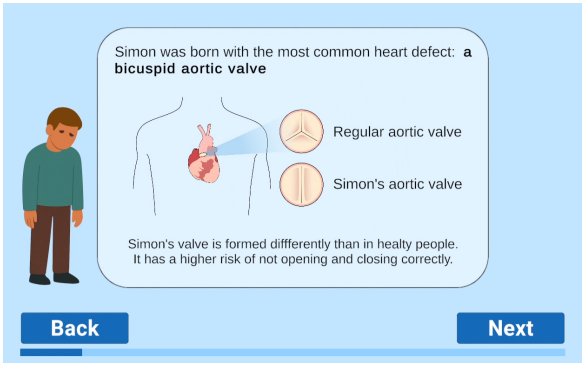


Fig. 4.7: **Abstract:** Condition explained

Going a step back to provide some information about the teased condition the characters have, the bicuspid aortic valve is explained. Utilizing a custom visualization prepared by a medical artist, the irregular valve formation is shown. Due to the abnormal construction of the valve, it has a risk of not functioning properly.

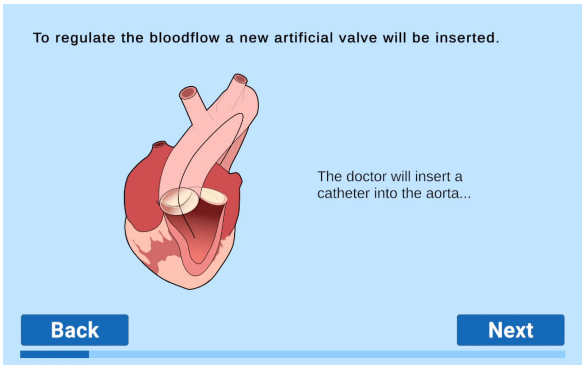


Fig. 4.8: **Abstract:** Treatment - first step

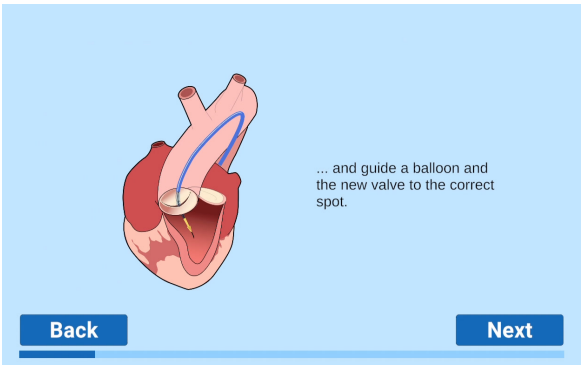


Fig. 4.9: **Abstract:** Treatment - second step

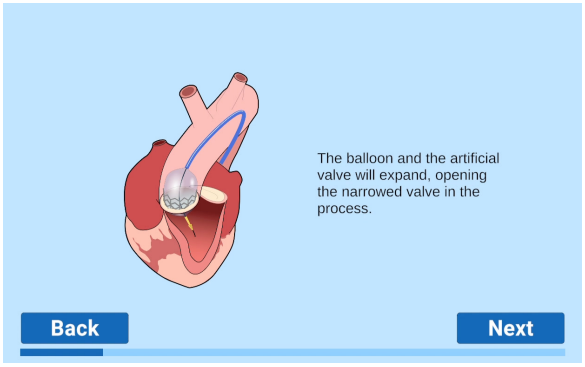


Fig. 4.10: **Abstract:** Treatment - third step

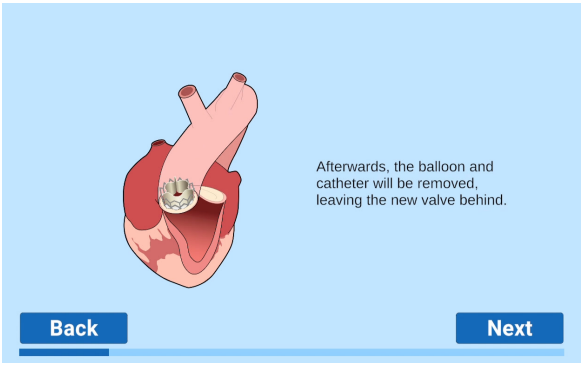
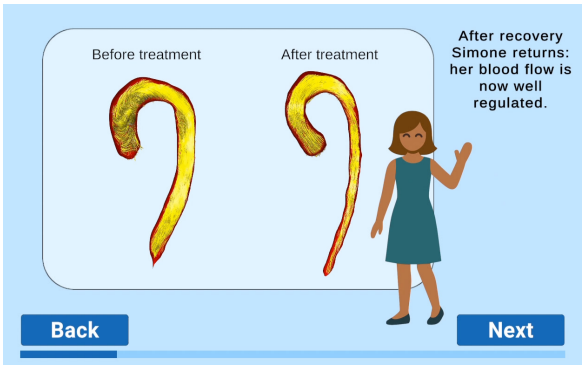


Fig. 4.11: **Abstract:** Treatment - fourth step

Figures 4.8 through 4.11 show the subsequent treatment procedures for the condition. The visualizations were produced by the medical artist, as well. As shown on the pages, the treatment, which consists of the insertion of a new artificial valve, involves four steps. First, a catheter is inserted into the aorta (fig. 4.8). This catheter is there to guide a balloon and new valve to the correct placement (fig. 4.9). Then, the balloon is inflated, expanding the new valve in place of the pre-existing one (fig. 4.10). Lastly, the balloon and the catheter are removed (fig. 4.11).



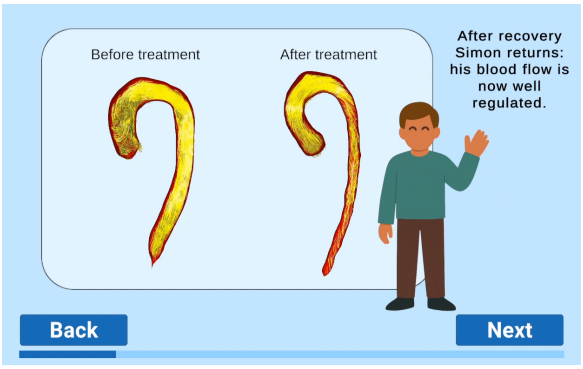


Fig. 4.12: **Abstract:** Treatment - outcome

After treatment the bloodflow in the aorta is regulated. Similarly to figure **Abstract:** Condition diagnosis, the last page in figure 4.12 shows a side by side of the characters' bloodflow before and after treatment. The vortex is regulated and the aorta is not in danger of developing an aneurysm. Here, the happy versions of the characters are presented again.

4.2.2 Illustrated - Liver Cancer

Fig. 4.13: Illustrated: Character introduction

As previously, the characters are introduced on the first page. Andrea and Andrew are 52 years old. They do not have any concerns, but are coming in for a scheduled check-up.

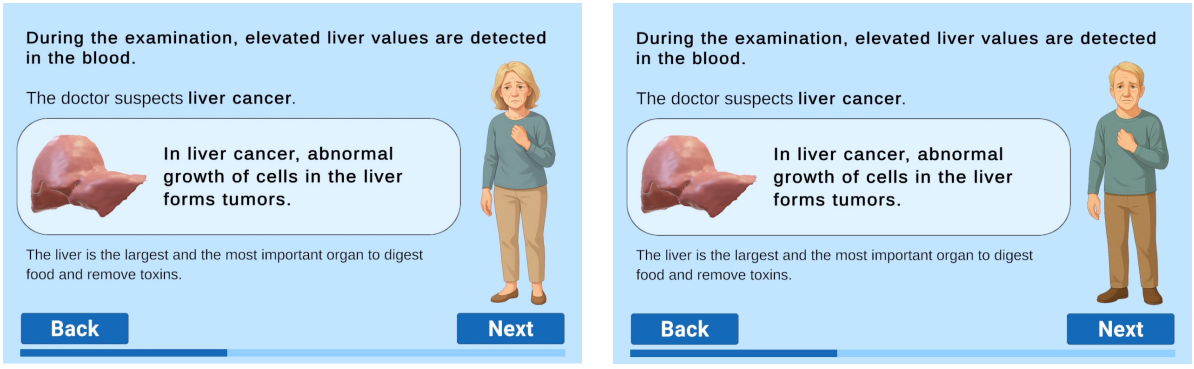


Fig. 4.14: Illustrated: Initial Screening

The concerned character version is placed starting at the second page, as seen in figure 4.14. During the check-up some irregularities stand out and need to be examined. The liver values are elevated and the medical team suspects liver cancer. The disease is also briefly explained, to provide additional information.

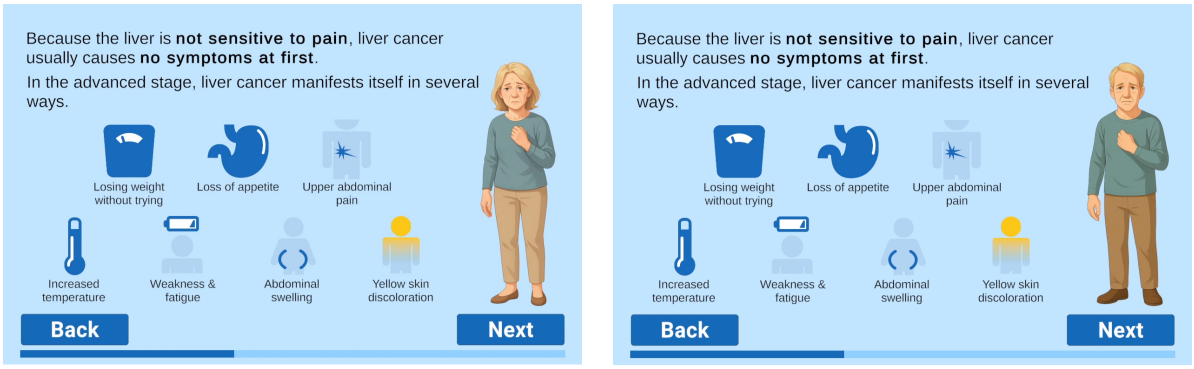


Fig. 4.15: Illustrated: Potential Symptoms

Following the story structure discussed in section 3.2.2, possible symptoms of liver cancer are presented. To support understanding icon representations of each symptom are included, which can be observed in figure 4.15. It is explained, that due to the livers insensitivity to pain the patient will not experience any symptoms in the beginning stages of the disease. The is the reason the character was not showing any signs of liver cancer prior to the appointment.

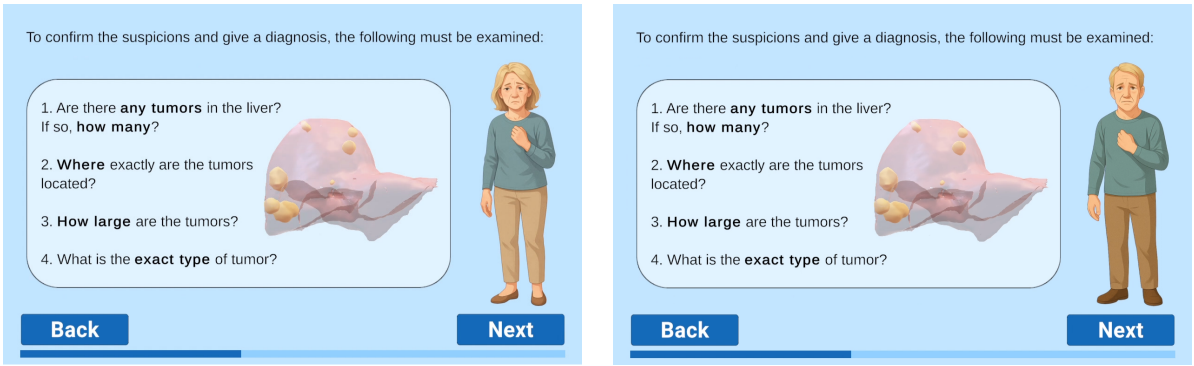


Fig. 4.16: Illustrated: Preliminary diagnostic information

The next step, as can be observed in figure 4.16, is to inform the patient of the procedure for the upcoming examination. To confirm the liver cancer diagnosis, the liver has to be checked for tumors and their quantity. The location and size have to be investigated. Lastly, the type of the tumor has to be determined.

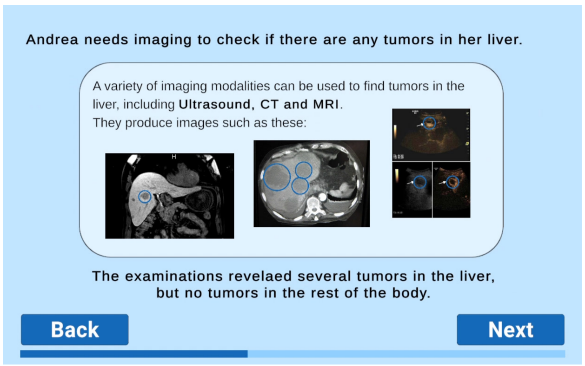


Fig. 4.17: Illustrated: Liver Cancer Diagnosis

The variety of techniques for tumor examination is presented. Ultrasound, CT and MRI can be used to detect tumors. To make the readers more familiar with the imaging, examples are shown including blue markers to spot the tumors in the images. These can be seen in figure 4.17. The character is found to have tumors in the liver but not in the rest of the body.

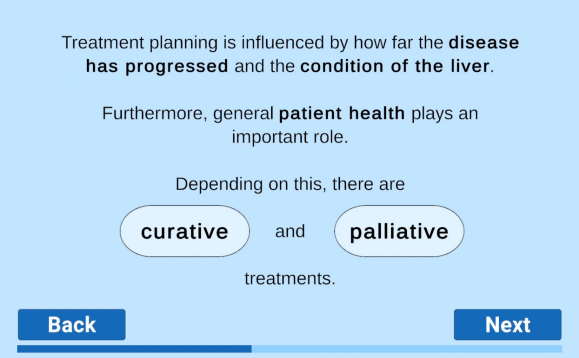


Fig. 4.18: **Illustrated:** Treatment Options

Initiating the treatment section is a small introduction into the two treatment types. Depending on the disease progression, the condition of the liver and the patients' overall health, either curative or palliative treatment methods will be employed.

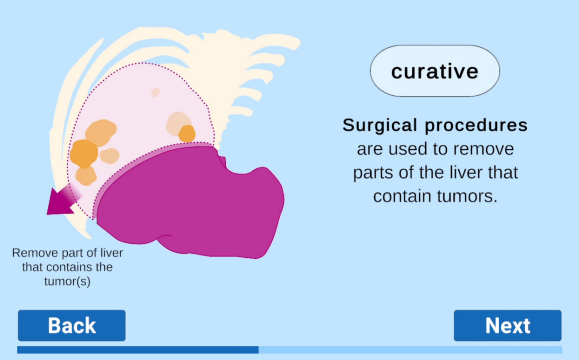


Fig. 4.19: **Illustrated:** Curative Treatment - surgery

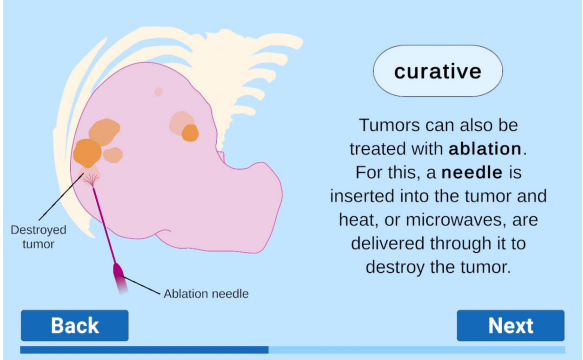


Fig. 4.20: **Illustrated:** Curative Treatment - ablation

The first treatment method is surgery. As seen in the medical illustration in figure 4.19, the parts of the liver containing the tumors are removed.
Another curative option is ablation. Shown in figure 4.20, this procedure uses a needle to insert heat or microwaves into the tumor to destroy it.

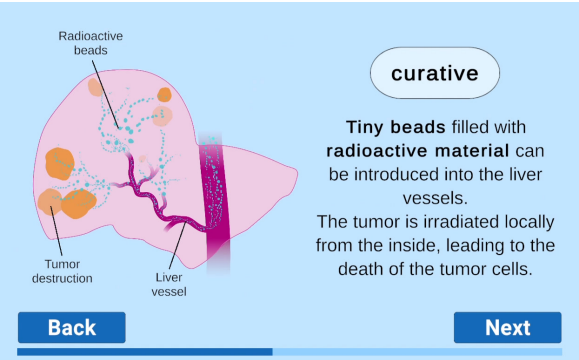


Fig. 4.21: **Illustrated:** Curative Treatment - radioactive beads

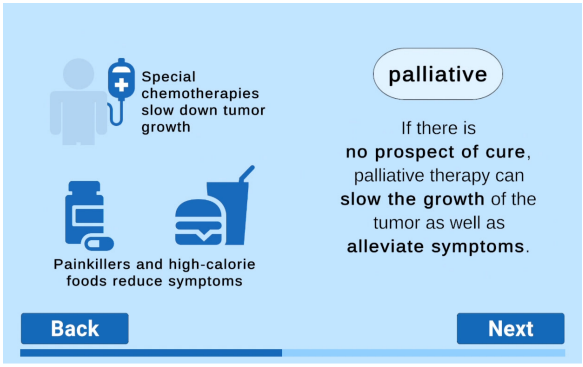


Fig. 4.22: **Illustrated:** Palliative Treatments

Additionally, tiny beads can be introduced through the liver vessel. These beads contain radioactive material, causing the tumors to be irradiated locally and being destroyed. The visual of this process can be observed in figure 4.21.
If the cancer has progressed too far and there is no prospect of cure, palliative

methods are employed. The page in figure 4.22 shows an overview of these. Palliative therapy is intended to slow the growth of the tumors and alleviate symptoms. This can be achieved with chemotherapy, painkillers and high-calorie foods.

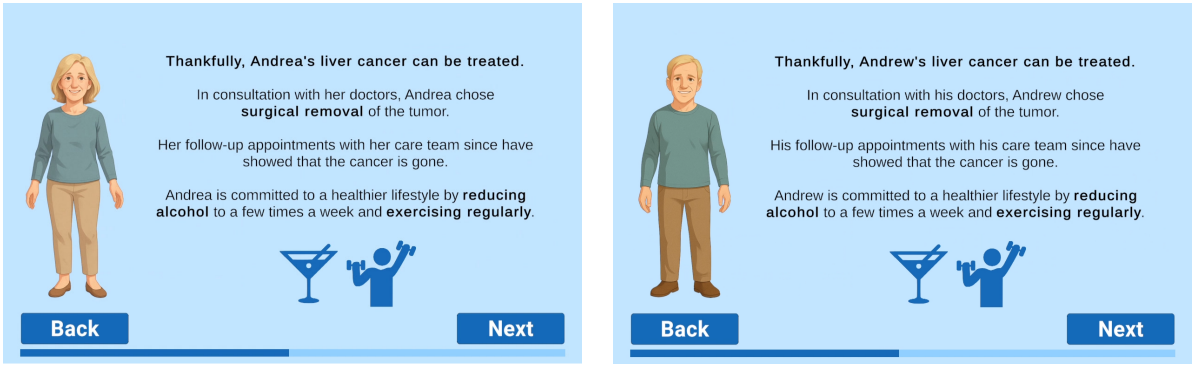


Fig. 4.23: Illustrated: Adoption and Adherence

After the treatment explanations, the narrative returns to the character's journey. When tumors were discovered in the liver, the characters consulted their doctors and decided to have them surgically removed. Follow-up appointments revealed no further signs of liver cancer. From then on, the characters committed to maintaining a healthier lifestyle to preserve their well-being.

4.2.3 Realistic - Cerebral Small Vessel Disease

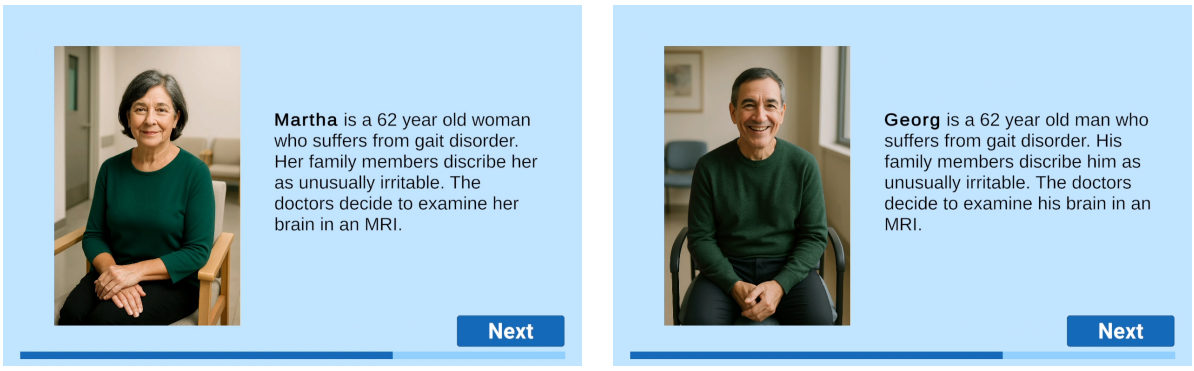


Fig. 4.24: Realistic: Character introduction

As in the previous stories the characters are introduced on the first page. They are 62 year old Martha or George. They suffer from gait disorder and their family members have some concerns, so the doctor wants to examine their brain using an MRI.

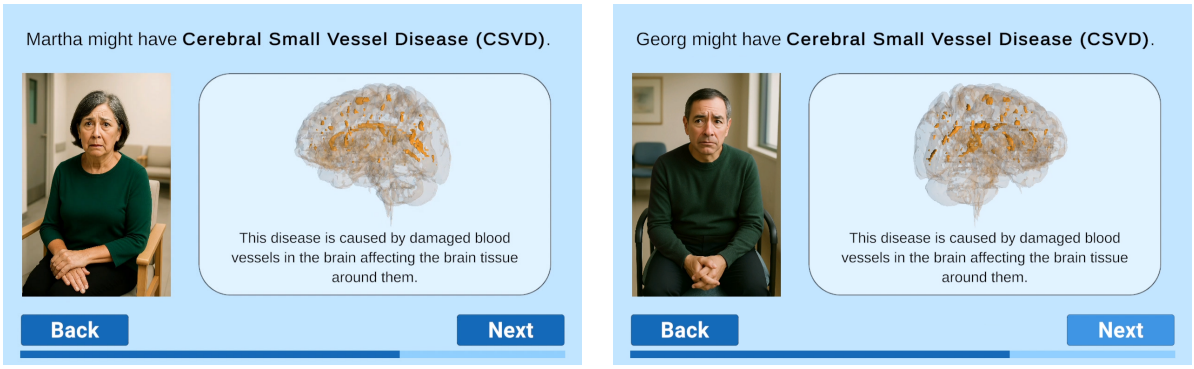


Fig. 4.25: Realistic: Screening

The visual shown in figure 4.25 is a rotating brain which was adapted from the original story in a different way, to bypass the interaction options. Here, the possibility of Cerebral Small Vessel Disease (CSVD) is introduced. And the disease is briefly explained.

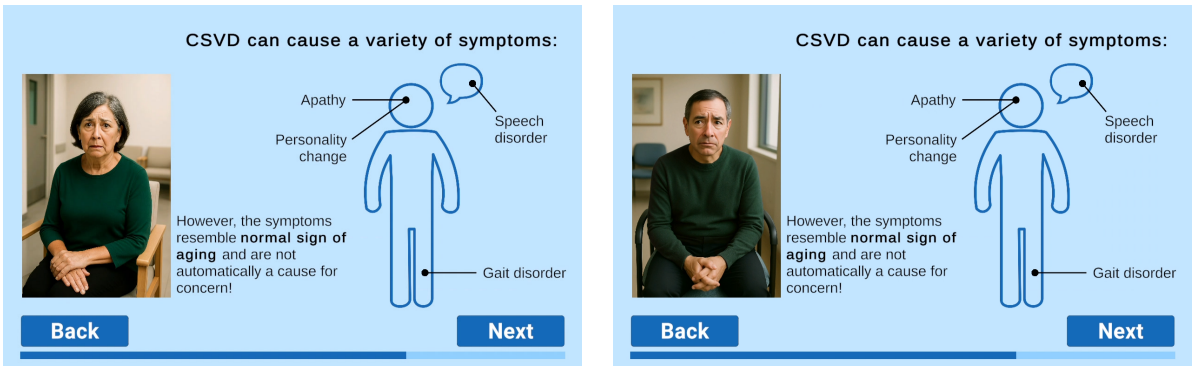


Fig. 4.26: Realistic: Potential Symptoms

To visualize the possible symptoms of CSVD, as seen in figure 4.26, a human icon is used, as they can affect a variety of aspects. Additionally, a disclaimer is added. This is necessary, as any of the symptoms of CSVD can also be signs or regular aging.

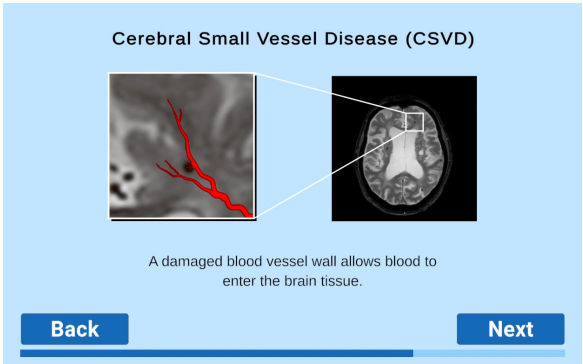


Fig. 4.27: Realistic: Micro-bleeds

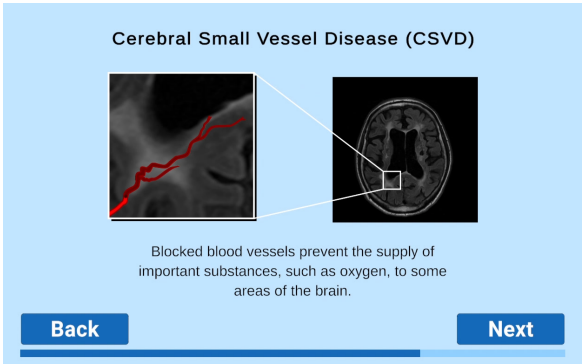
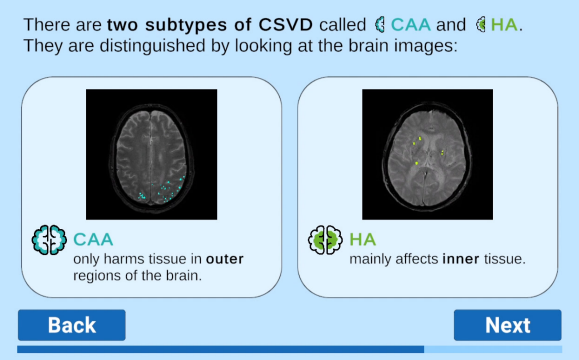


Fig. 4.28: Realistic: Lesion

Figure 4.27 and 4.28 include more detailed visualizations in regards to the disease explanation, showing micro-bleeds



After the general disease explanation, page 4.29 shows and visually explains the two subtypes visually. To help the readers categorize and memorize the subtypes better, small icon are employed. CAA is the subtype which affects the outer regions of the brain and HA mainly affects the inner tissue.

Fig. 4.29: Realistic: Preliminary diagnostic information

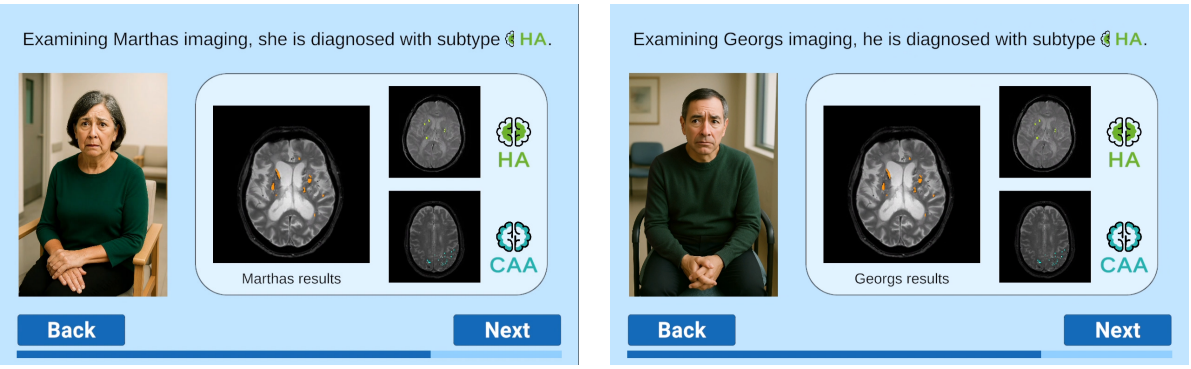
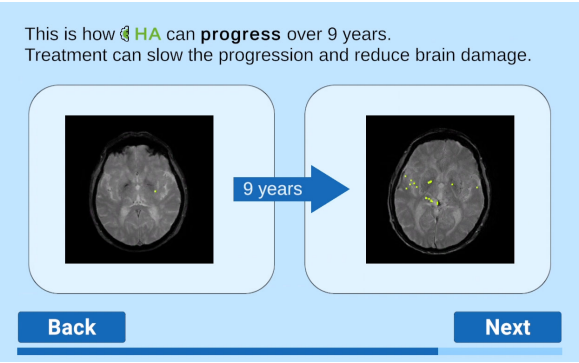


Fig. 4.30: Realistic: Diagnosis

After the subtype explanation, the patients imaging is compared to the subtypes in figure 4.30. By comparing the patients imaging to the subtypes, they can be diagnosed with subtype HA, as the disease mainly affects the inner tissue of the brain.



To show the potential severity of the condition, imaging of the progression after 9 years without intervention is shown. Imaging from the original story is used and they show further emergence of lesions.

Fig. 4.31: Realistic: Long-term Disease Impact

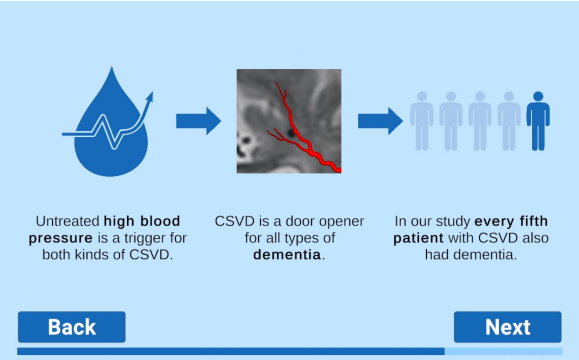


Fig. 4.32: Realistic: CSVD, Hypertension and Dementia

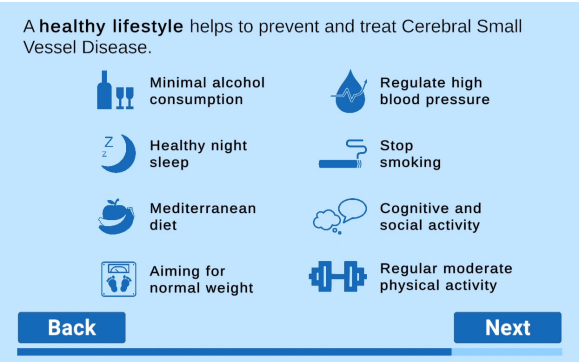


Fig. 4.33: Realistic: Treatment Options

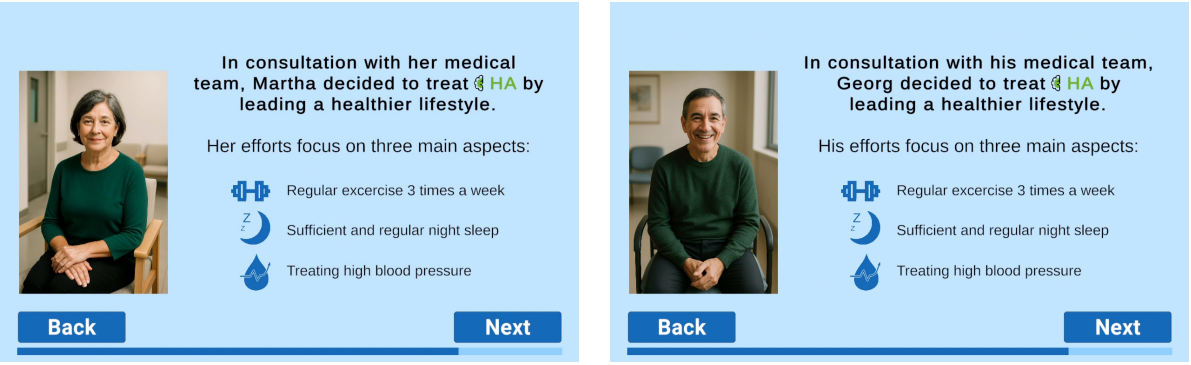


Fig. 4.34: Realistic: Adoption and Adherence

To treat the disease, the character decides to lead a healthier life, by focusing on sleep, exercise and regulating their blood pressure.

4.3 Study Sequence

In this section, each interactive aspect of the study will be presented. This includes the questionnaire, as well as general data collection required for the evaluation.

Although the page in figure 4.32 is not quite fitting for the predetermined structure, it was included in this story version. According to the World Health Organisation 33% of adults aged 30 to 79 suffer from high blood pressure and a large quantity does not have it under control [Wor25]. This page is an important information to anyone who might be affected. To spread awareness that high blood pressure can lead to CSVD which opens the door for dementia, this information was not adjusted to the structure.

In comparison to the other stories, there is no medical treatment method for CSVD. The patients are encouraged to lead a healthy lifestyle: minimize alcohol consumption, get enough sleep, watch their diet, regulate their weight and blood pressure, not smoke, exercise and engage in cognitively stimulating social interactions.

4.3.1 Demographic Data Collection

At the start of each study cycle demographic data is collected, for additional context required to evaluate the results. The following categories are surveyed.

Gender

To determine, which character version the reader will be shown and to understand differences in perception, participants are asked to specify their gender. The provided options are:

Female | Male | Non-binary | No answer

Age group

Establishing an age range for each participant is essential to examine potential age-related variations in the results. The age ranges available for choice are:

Under 18 | 18 - 25 | 26 - 35 | 36 - 45 | 46 - 55

56 - 65 | 66 - 75 | 76 - 85 | Over 85 | No answer

Level of education

Differences in general educational background can potentially affect the processing and interpretation of information communicated by the stories in medical narrative visualization. To judge the influence of this variable on the results, each participant is asked to provide their information. The following selections are offered:

School pupil | No school diploma | Lower / Intermediate secondary education

Upper secondary education | Vocational training | Higher education | No answer

Visualization familiarity

The frequency in which the participant engage with visualization techniques can greatly impact their understanding of them. In order to evaluate the understanding and memorability of the medical data, which is largely communicated visually, this information need to be taken into consideration. The following question and answer options are given in this section:

How often do you engage with visualization techniques?

Never | Rarely | Sometimes | Often | Daily

Medical Knowledge

Similar to visualization, when it comes to medical narrative visualization, medical knowledge and experience with medical topics can influence the understanding of the content substantially. In order to take this into account during the evaluation, the level of medical experience is inquired about. In comparison to the previous question, which is simply a frequency assessment, for readers it might be a little more difficult to estimate their medical experience accurately. To guide their decision, each of the five options includes a small clarification.

How would you rate your experience with medical topics?

None	*(I have no experience)*
Low	*(I have some personal exposure but no deeper understanding)*
Moderate	*(I understand basic medical concepts or regularly encounter them)*
High	*(I work with or study medical topics occasionally)*
Very high	*(I work professionally or study medical topics extensively)*

Character Preference

The story only exists in a male and a female version. As previously stated, the gender of the participant determines the story version they get to see, to increase empathy and personal connection. Participants, who either chose not to indicate their gender or specified ***non-binary***, are additionally asked which story version they would prefer to view.

Which character version would you feel more comfortable viewing?

No preference | Female character | Male character

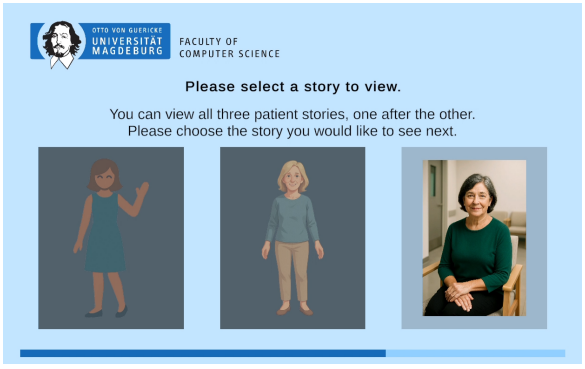
4.3.2 Menu

As seen in the Global structure of the Character Study, the menu is visited multiple times throughout the study. It serves as a central junction for navigation. As with the remaining study, the menu has a male version, seen in figure 4.35b, and a female version, as in figure 4.35a. This feature allows participants to select the order in which to view the stories. They are provided no other context then the visualization of the three main characters, assuring that the decision is based on visual appeal or curiosity. After a story has been viewed, the selection in the menu is no longer possible. This is signaled by a dark overlay over the button and no reaction during a

mouse-over hover. In figure 4.35c this can be observed for the abstract and illustrated stories. The viewing order of the stories is part of the collected data. Section 4.3.4 further elaborates on the evaluation of this data.

(a) Menu screen: female version

(b) Menu screen: male ersion



(c) Menu screen: previously read stories not selectable

Fig. 4.35: Different states and versions of the menu screen

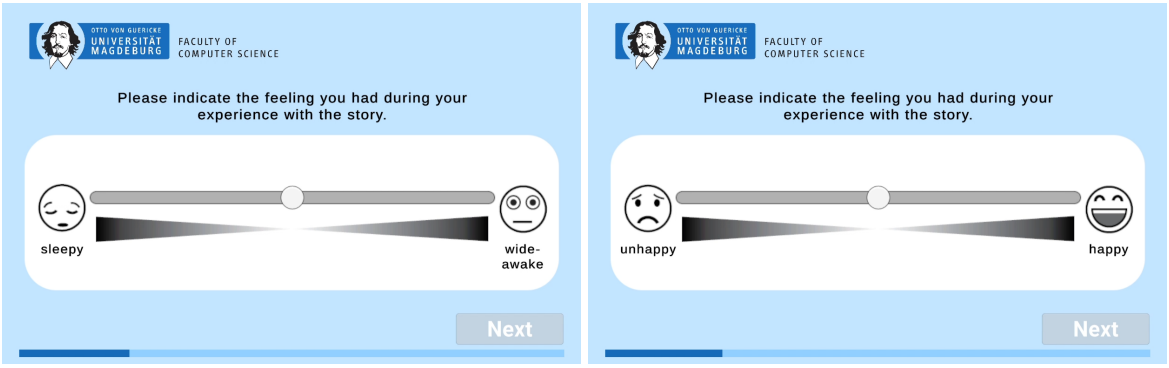
4.3.3 Questionnaire

Emotional Connection

The implementation of the *Affective Slider* was completed in adherence to the guidelines presented in the source paper [BV16]. These guidelines can be summarizes as follows:

- Both sliders must be horizontal and the initial state of the handle is in the middle.
- Spacing and size must be proportional to the screen to ensure easy value selection.
- Each slider must include intensity cues with emoticons at both ends.
- All elements must use a grayscale palette.
- Each slider represents a continuous value from 0–1.
- Slider thumbs must be circular or square (optionally rounded) and at least 10% larger than the track height for easy manipulation.

For the implementation of the slider, the standard Unity asset was used and slightly adjusted, to follow the guidelines. The original emoticons were inserted on both sides of the slider. They are publicly available under a Creative Commons license via a GitHub repository [Bet16]. The same repository holds the asset for the intensity indicator, which was also included. To ensure the gray color scale for the sliders, a white background block was added, so the blue design of the study does not influence the slider interaction. The resulting visuals can be seen in figure 4.36.



(a) Affective Slider: arousal **(b)** Affective Slider: pleasure

Fig. 4.36: Affective Slider implementation in accordance with the original author's guidelines

After landing in this section of the study a small delay of 1.5 seconds is implemented until the activation of the "Next" button. This helps to minimize accidental forward skipping as this is the first page after a story without interaction and the slider's neutral state is already considered an input. It is essential to implement a number of contingencies to avoid accidental skipping in the questionnaire, as explained previously in section 4.1.

Memorability

This two-parted section is implemented using multiple choice toggle groups in Unity. For the knowledge check, as seen in figure 4.37, the question is posed, followed the three answer options only one of which can be selected simultaneously. Once an option is selected, the "Next" button is activated.

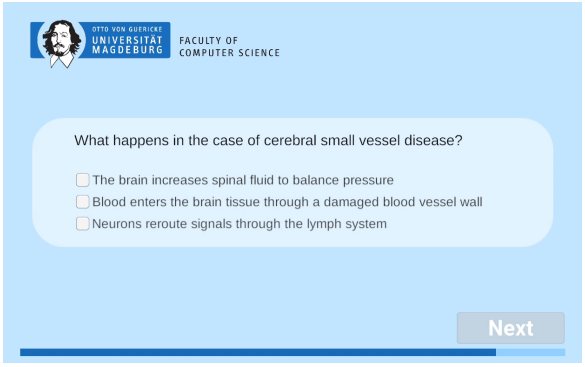


Fig. 4.37: Knowledge check implementation

The character memorability check is conducted in a similar way to the knowledge check. For this, the eight character versions, which were previously detailed in section 3.3.2, are included on the page. Each character version is placed over a toggle and at least one character must be selected to continue the questionnaire. This version can be seen in figure 4.38a. However, if the participants are unsure, they have the option to select up to three character versions. If they choose to select multiple versions, drop-down menus appear, which allow the selections to be ranked. After each selection has been assigned to a unique rank from 1 to 3, the "Next" button becomes active. An example of this ranked character selection can be observed in figure 4.38b. To affirm the personal connection the reader might have build with the character during the storytelling process, the task phrasing is set around the characters name: *Can you find **[name]**?*

(a) Character memorability: single selection **(b)** Character memorability: multi-selection and ranking

Fig. 4.38: Character memorability page examples with single and multiple selections

Medical Data Communication

To collect the symptom key words, the visualizations presented in section 3.3.3 are shown one after the other. Additionally, the 16 keywords are presented for selection. The participants are free to chose one or more symptom keywords they think relate to the image. The layout can be viewed in figure 4.39.

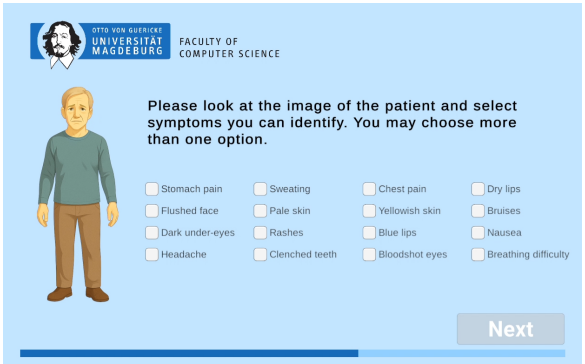


Fig. 4.39: Keyword selection implemented

4.3.4 Submission

After the questionnaire for the third story is completed, the study is almost finished. There is only one more question needed for evaluation. As explained in the previous paragraph 4.3.2, the participants are free to choose the order in which they view the stories. This can be used as additional context for evaluation. However, without any additional information, the reason for their choice is unclear. Therefore, the readers are requested to provide their internal motivation for choosing the view order. They are given a multiple choice of three options and the ability to provide an individual answer, if needed.
The multiple choice options consist of:

- ***I viewed the stories from left to right.***
  Since the typical reading direction in Western countries is from left to right, it is very likely some participants followed this instinct to view the stories.
- ***I chose the order because of the visual appeal of the characters.***
  Participants, who may have examined the characters a little closer on the menu screen, could have likely chosen a character based on visual appeal.
- ***I viewed the stories in a random order.***
  A number of readers might choose without a thought attached to their decision.

Before the final submission, the readers are asked to provide any additional comments. This is an important inclusion, as open-ended questions can provide valuable insight and context for later analysis [RCL13].

Lastly, when the data is submitted, the participants are directed to the farewell page with animated characters Simon and Simone wave them goodbye. The readers are thanked for their participation and reassured, that they may at this point close the application safely, as seen in figure 4.40.

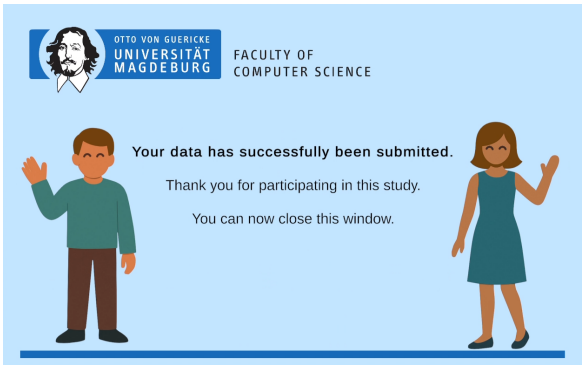


Fig. 4.40: Farewell Page

4.4 Data Collection

The user input was collected a data logger, which was implemented and adjusted in a previous project, allowing easy reuse. Each interactive element was connected to the data logger and the data collection worked without issue. The data logger collects the number and name of buttons clicked, inactive and inactive toggles, drop-down selections and free-form text inputs. Additionally, the time spent in each individual scene is captured. This feature is not essential for the current project but has been retained as a legacy component from previous studies. It was kept to provide additional flexibility in assessing dataset quality. For example, if timing data reveal that each page was viewed for less than a second, it can indicate that participants did not actually read the instructions, helping determine whether the dataset is usable.

4.5 Database Connection and Deployment

To collect the data, a Firebase Realtime Database was set up and connected to the Unity build. After resolving a few initial bugs, data transmission to the database was successfully established. At database connection each user is assigned a randomly generated ID to ensure anonymity.

For deployment, the project was uploaded to a public GitHub repository, and a GitHub Pages site was created to host the study directly from the selected root directory. An invitation text, which can be viewed in Knowledge Questions, was prepared in both German and English, containing the following key details about the study:

- Duration
- Hardware requirements
- Data anonymity
- Language availability

Finally, the study page link was embedded in the invitation text and distributed to participants, with a request to share it further among potential participants.

5 Evaluation

5.1 Method

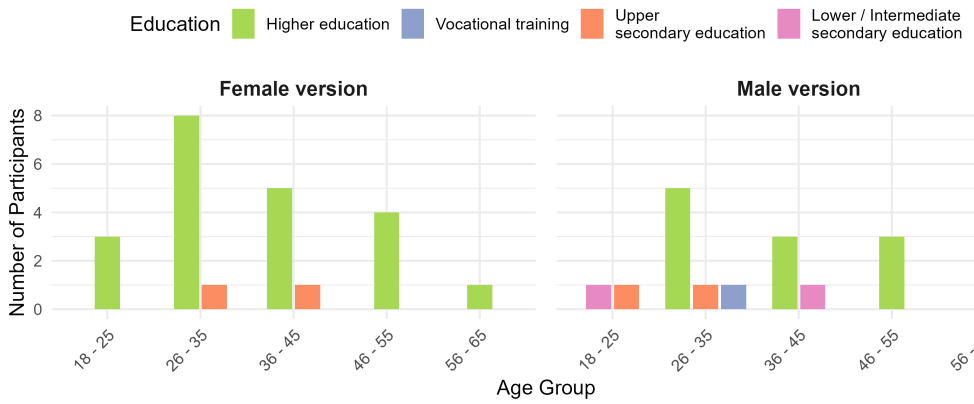
The study was conducted as a web-based online experiment implemented in Unity using OpenGL for rendering. Participants accessed the study through their computer browsers. The application window was fixed to a resolution of 1000 × 625 px to ensure consistent viewing conditions across devices.
A within-subjects design was employed to reduce inter-individual variance and ensure that all participants were exposed to each experimental condition. The independent variable was the visual character style, represented by three distinct levels of abstraction: realistic, semi-stylized, and abstract. The dependent variables were emotional engagement, memorability, and comprehension accuracy of the presented medical information.

5.2 Results

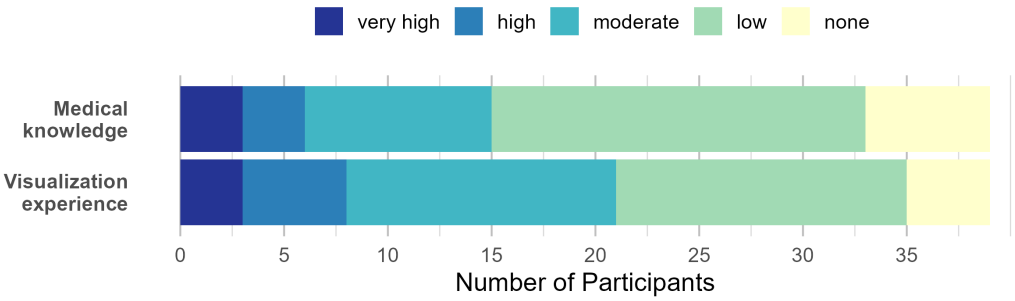
5.2.1 Demographic Data

A number of entries needed to be removed due to incomplete data. In total 39 participants fully completed the study. Out of these 22 were female, 16 were male and one non-binary. The non-binary person chose to view the female version of story. To simplify the evaluation process, this person will be included in the “female” section as per the story version they viewed. Participant ages ranged from “18 - 25” to “56 - 65”. The study was available to view in German and English. Here, the split was quite even, with 18 participants completing the study in English and 21 completing the study in German.
As shown in figure 5.1a, most participants had a higher education, 32 in total. One participant completed vocational training, 4 with upper secondary education and two with lower or intermediate secondary education.
Due to the largely uneven group sizes across education levels, even a single error could substantially alter percentage-based comparisons. To avoid introducing bias from these uneven dimensions, analyses will not be conducted based on education level.

The medical knowledge and visualization experience distributions can be seen in figure 5.1b. All levels are represented, with moderate and low being the most prevalent in both categories.



(a) Personal data



(b) Medical knowledge and visualization experience

Fig. 5.1: Demographic data on participants

5.2.2 Emotional Connection

When examining the emotional connection the participants used the *Affective Slider* to measure their arousal, or how "awake" they were during the story, as well as their pleasure, or if they experienced positive or negative emotions during the story. The participants ranked both for each story separately.
The results can be viewed in figures 5.2, 5.3 and 5.4. The arousal meter is on the x-axis and the pleasure is visualized on the y-axis. The answer options ranged from 1 to 5 with 1 being low arousal and pleasure and 5 being high arousal and pleasure. To spot patterns easily, the data for each story is presented in gender-divided heatmaps. The color represents the amount of selections attributed to each square, meaning each combination of pleasure and arousal levels. Due to the lower number of male participants, when compared to the female, the selections are presented in percent. This was implemented so the color of each square is not misleading in comparison. If further clarification on the data should be needed, alternate visualizations in form of scatterplots can be found in Evaluation: Additional Plots.

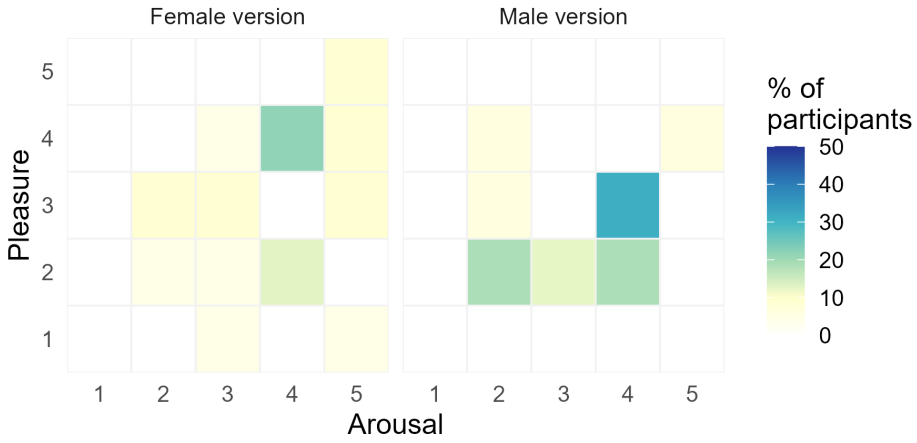


Fig. 5.2: Abstract: Emotional Connection - discrete heatmap with participant responses

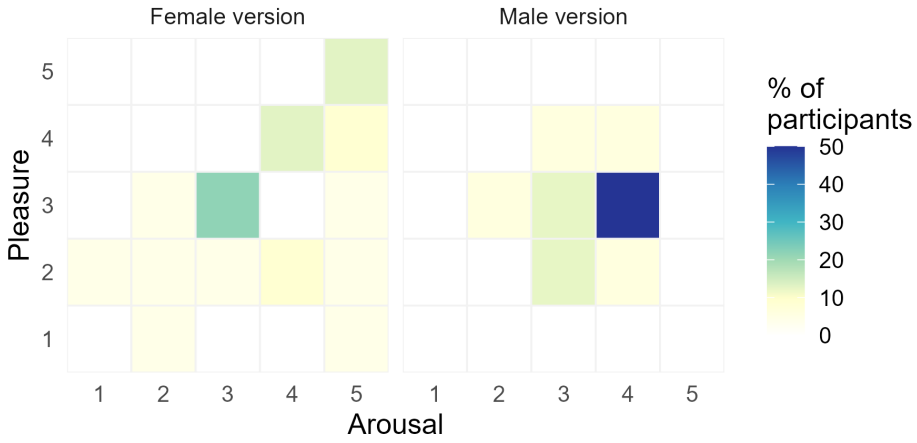


Fig. 5.3: Illustrated: Emotional Connection - discrete heatmap with participant responses

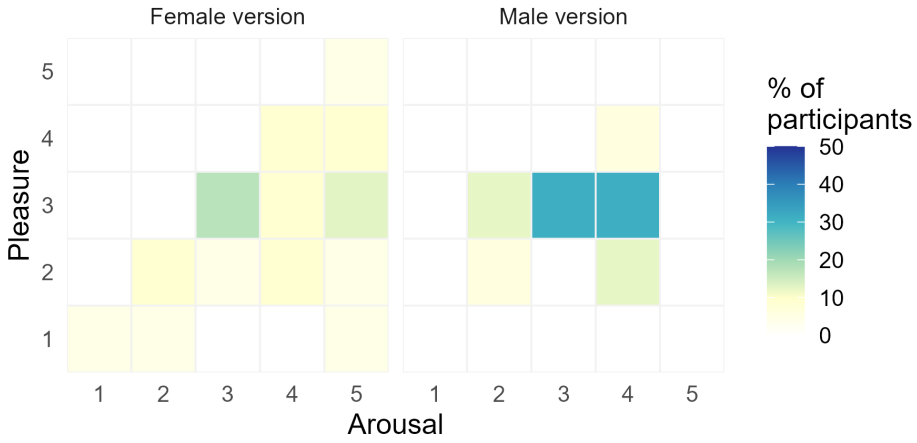


Fig. 5.4: Realistic: Emotional Connection - discrete heatmap with participant responses

When observing the results (fig. 5.2, 5.3, 5.4), the first apparent observation is that the male answers in every character version are more clustered in the middle, whereas the female version is spread out a lot more. Moreover, the male answers show a selection peak in every character style, which is at `arousal = 4` and `pleasure = 3` (`a4/p3`). In the realistic character version, the results are more evenly split between `arousal = 3` and `arousal = 4`, however, the pleasure is consistent. Similarly, in the abstract version (fig. 5.2), apart from `a4/p3`, more answers are spread at `pleasure = 2` across `a2/p2`, `a3/p2` and `a4/p2`. The biggest peak with 50% selection is `a4/p3` in the illustrated male version.
Compared to the compact cluster of the male responses, the female is spread out more evenly. Not one combination has a selection rate of above 25%. Participant, who viewed the female version seemed not to shy away to select extreme amounts. when it came to answered on the upper end of the scale. Where as when it came to `arousal = 1` or `pleasure = 1`, they rarely made the choice. For the male version, except for one square including all three male version visualization, no extreme selections at either end were made. A subtle peak can be spotted in multiple styles of the female version, even if not as extreme when compared to the male version. Both illustrated and realistic show peaks at `a3/p3`, with the illustrated version continuing the trend across the diagonal at `a4/p4` and `a5/p5`, and the realistic across the horizontal, with the next lower peak being at `a5/p3`. The abstract version, however, shows the main peak at `a4/p4` and the next lower peak on the vertical at `a4/p2`. Curiously, both the illustrated and abstract female versions show a lack of entries at `a4/p3`. Overall, the selections within the female versions fill the region under the correlation line quite evenly.

5.2.3 Memorability

Two memorability aspects were examined: the data memorability, which was tested with knowledge questions, and the memorability of the character, which was tested by providing multiple versions of a character with slight variations and asking participants to select the original.

Knowledge Questions

The knowledge questions were analyzed separately, to spot any potential flaws in the question statements. Figure 5.5 shows an overview of all three character styles, split by character version and question. Correct answer percentages are marked purple and incorrect are marked orange.
Overall the abstract knowledge questionnaire has accumulated an error rate of 19,6%. The error rate of the illustrated story knowledge questions came to 11,11% and for the realistic story it was 11,11%, as well. The error percentage is somewhat

even between the female and the male version, as can be observed in figure 5.5. There are some variations, but no obvious trends or outliers are noticeable.

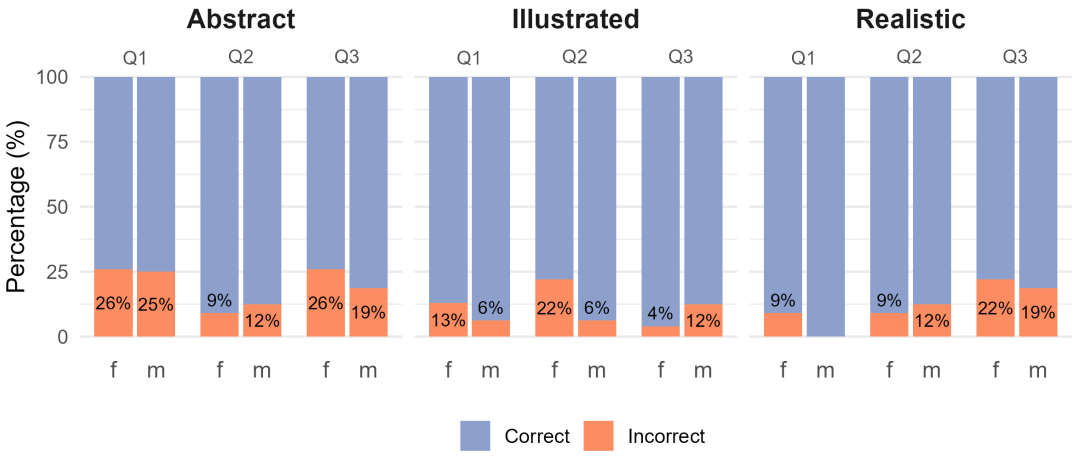


Fig. 5.5: Knowledge check overview

Figure 5.6 shows further splits to examine the knowledge questions based on the participant's medical knowledge. The data needs to be evaluated carefully, as the distribution across knowledge levels is not even.

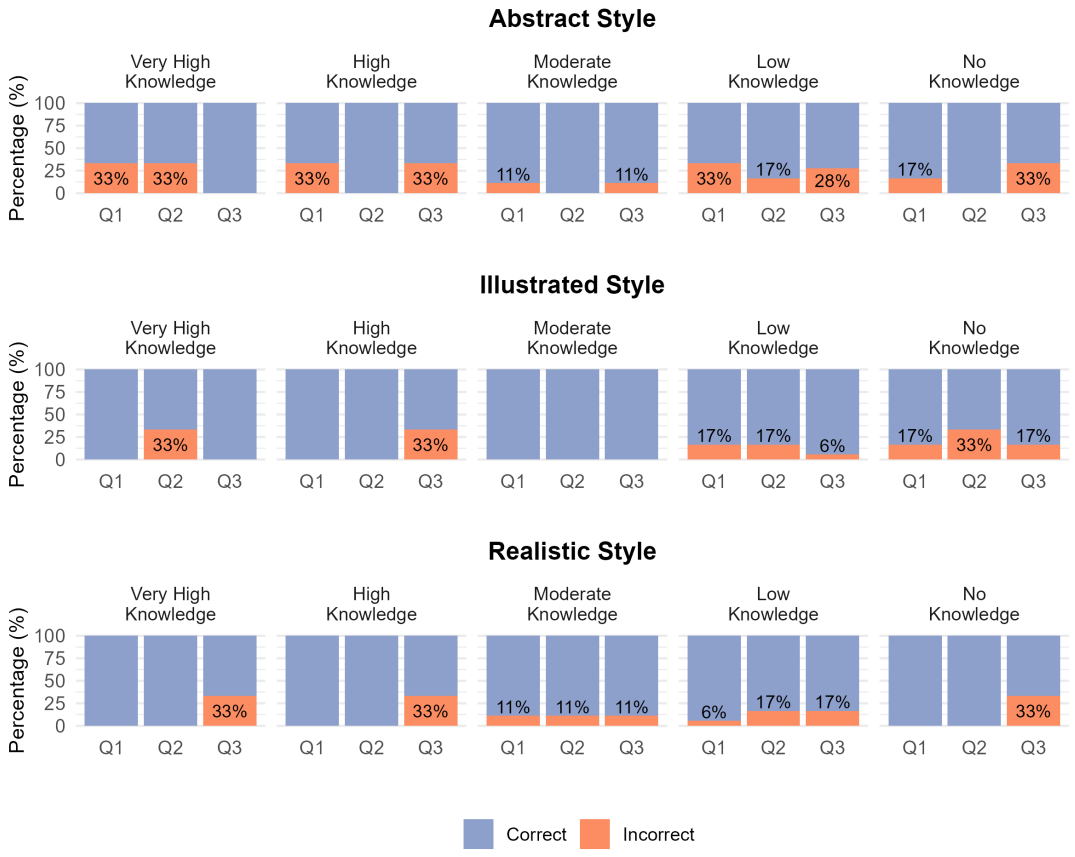


Fig. 5.6: Knowledge check overview: **medical knowledge**

Figure 5.7 shows an equivalent visualization to the medical knowledge, but for the visualization experience of the participants. Here, the same cation has to be applied during evaluation due to the unequal distribution.

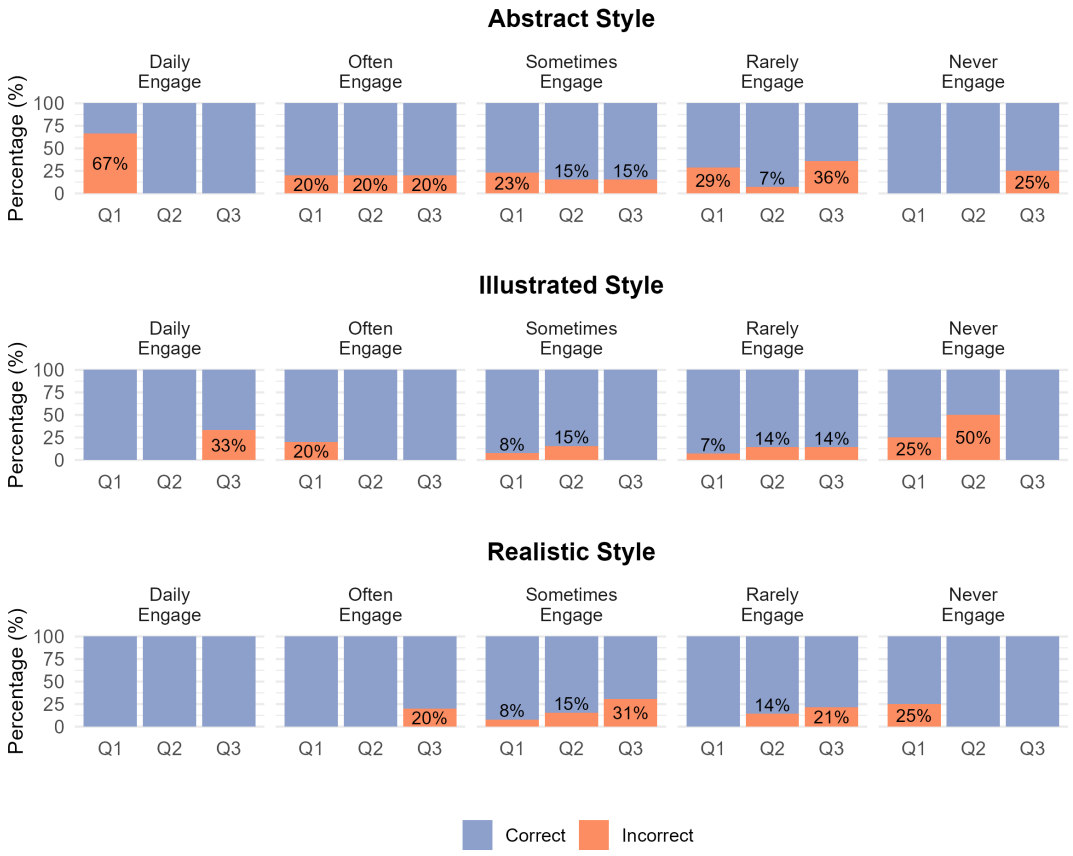


Fig. 5.7: Knowledge check overview: **visualization experience**

Character Memorability

To aid the understanding of the character versions, the table 5.1, which explains the combination of the character traits, will once again be included for reference.

Version	1	2	3	4	5	6	7	8
Face	A	A	A	A	B	B	B	B
Clothes	A	A	B	B	A	A	B	B
Hair	A	B	A	B	A	B	A	B

Tab. 5.1: Combination of traits across eight character versions

The character memorability visualizations (fig. 5.8, 5.9 and 5.10) show the combined selection for both male and female characters as stacked bar charts. With each bar showing the values of each character version selection and the colors within the bar chart showing which rank the section had. For recollections: if the participants were unsure of the version, they had the option to select up to three character versions and were asked to rank them in order of how likely they believed each was to be the correct answer. For clarity purposes, the responses with only one selection are separated from the top responses of a ranked selection.

The results of the abstract version in figure 5.8 show a clear distinction between the original version and the others. Including the lower ranked selections for the original, the characters were selected 17 times overall. What can also be observed is the high amount of rankings in this version. 10 participants selected a second option and 6 added a third option, as well. The original version was selected 11 times as an only pick, 2 times as a first pick, 3 times as second and 1 as third pick. Each version was selected at least once with an only or first selection, with version 3 being the next after the original with overall 9 first or only selections and version 2 having overall 6.

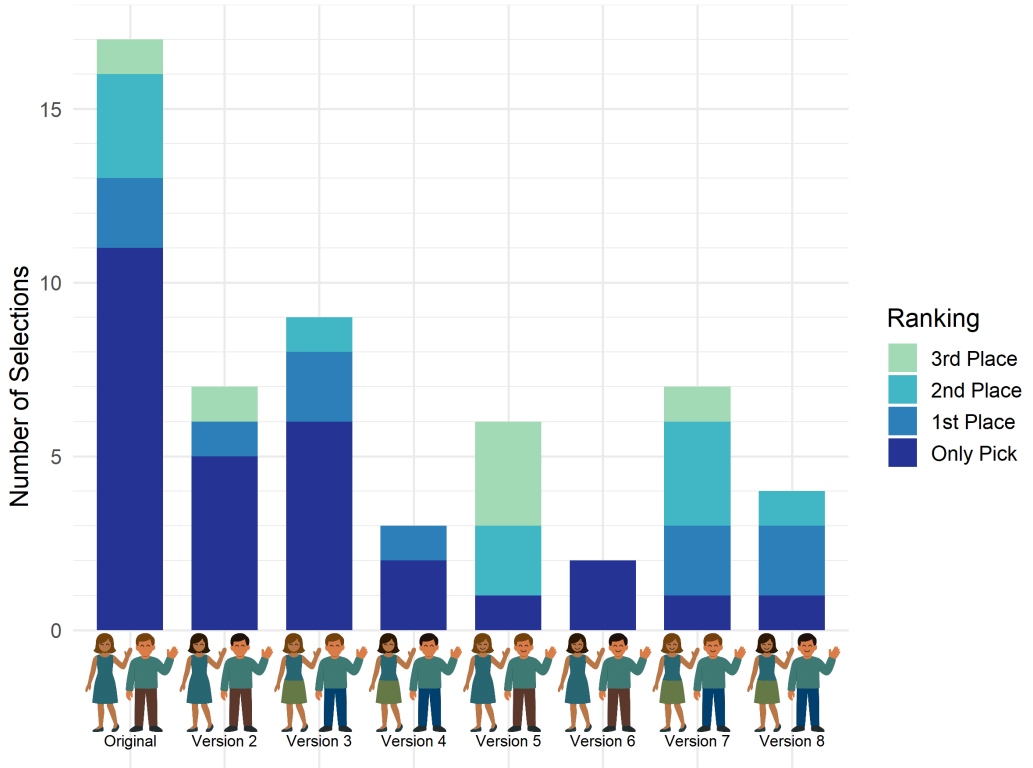


Fig. 5.8: **Abstract:** character memorability

The results for the illustrated version (fig. 5.9) are notably different to the abstract one. There are 7 participants, who selected a second version in the ranking and 2

who added a third option. In total participants selected the original version 26 times, with 2 being the second selection and 24 being the first or only selection. Versions 5, 6, and 8 were selected one time as the only pick. Version 7 was selected one time, but as the third pick. Version 3 received one first selection and one second selection. Version 4 was selected as the only pick 3 times, ad the second pick 3 times and third 1 time. The most popular selection after the original being version 2, with 8 first or only selections and one second place ranking.

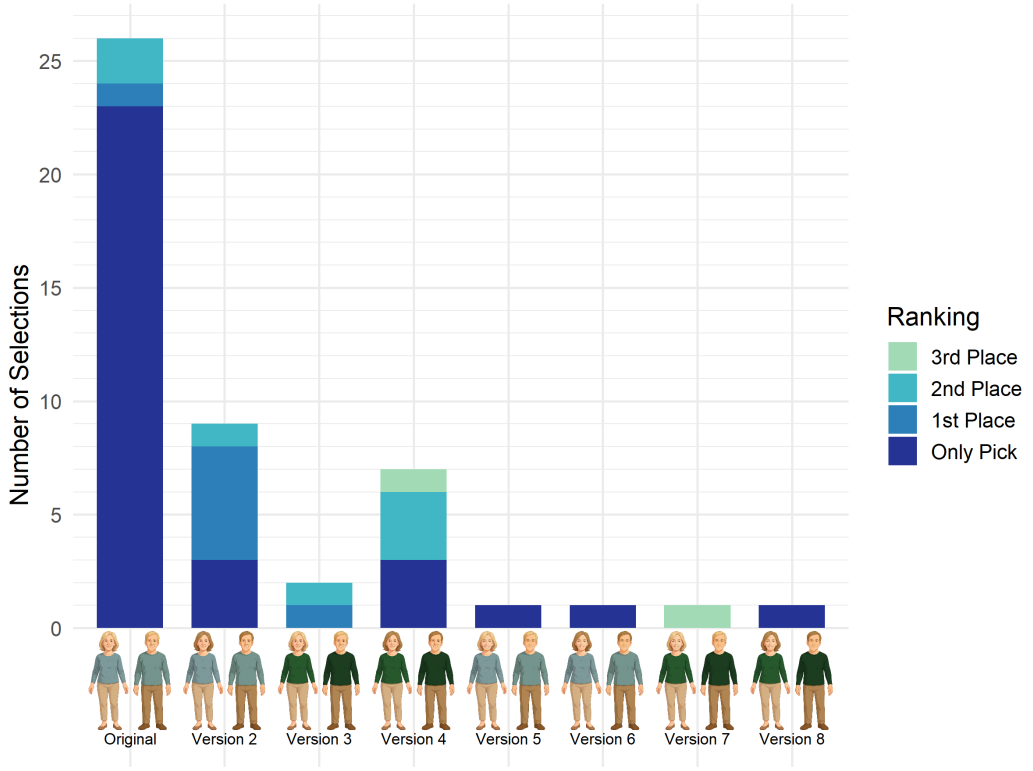


Fig. 5.9: **Illustrated:** character memorability

The realistic character memorability evaluation, as seen in figure 5.10, also has some unusual characteristics. Noticeably, version 5 and 8 were not selected at all. Overall apart from first and only selections, there are 7 second selections and 3 third selections. The original version holds the top spot with 16 first and only selections, 1 second place and 1 third place selection. Following this is version 3, with 12 first or only selections, 2 second place selections and 1 third place selection. The next lower version is number 2 with 6 first or only sections and 2 second selections. With this leaving version 4, 7 and 8 with overall low selection rates not over 4.

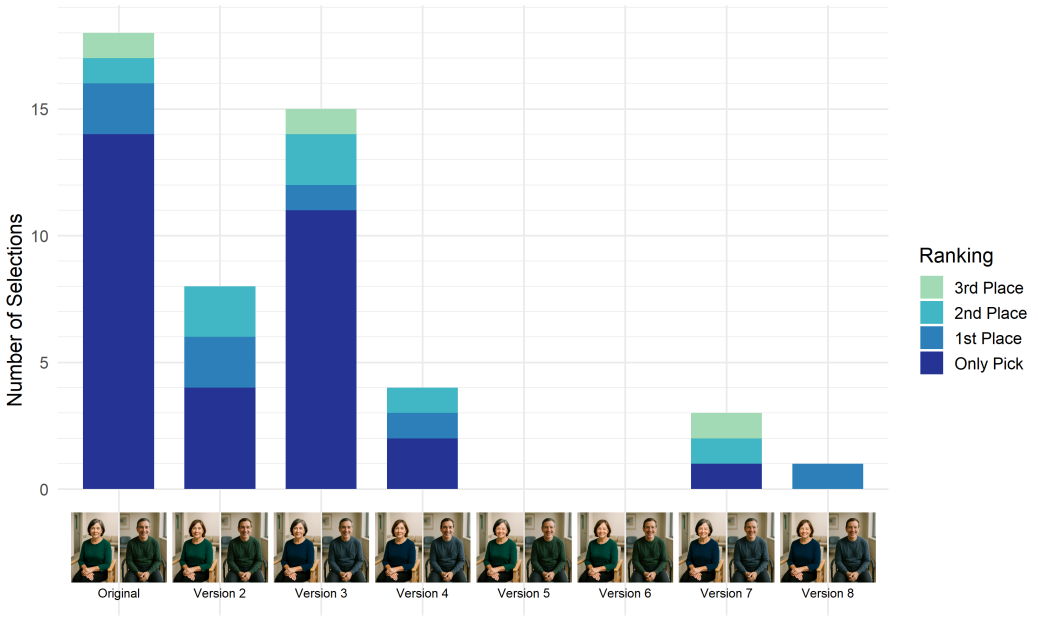


Fig. 5.10: **Realistic:** character memorability

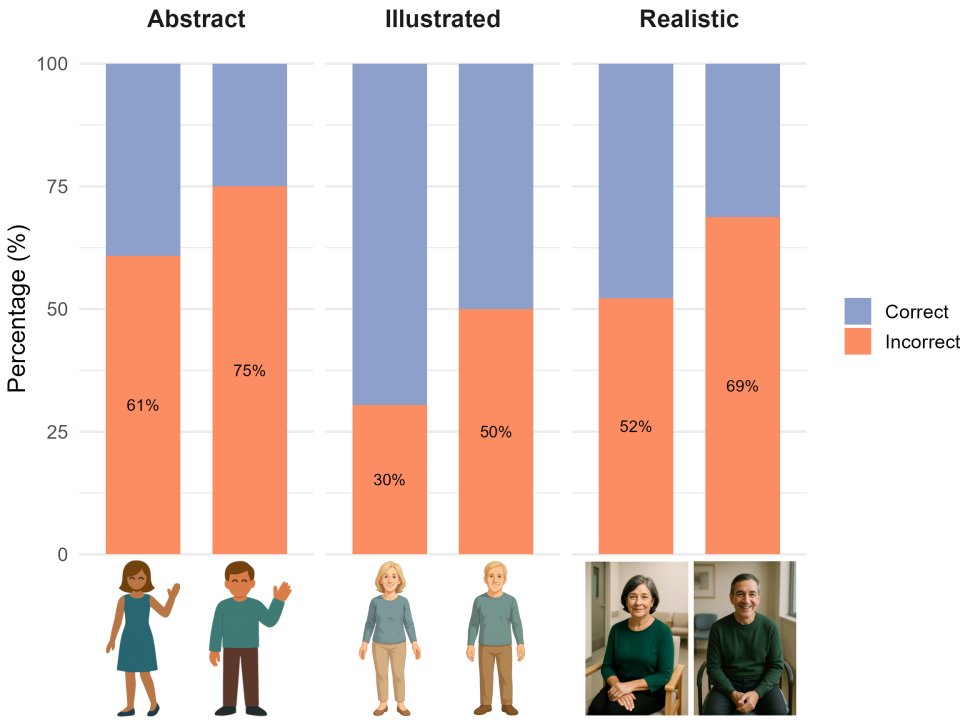


Fig. 5.11: Character selections: male and female version (based on first and only selections)

To evaluate the differences in selection in the female and male versions, the selection correctness for both versions and all three styles was plotted in figure 5.11. The results are presented in percent to make the data comparable despite the differences in participant numbers between male and female. For this plot the first and only selections were used, excluding second and third placement options. The abstract

female version was identified incorrectly in 61% of cases, whereas the male version of the same style was identified incorrectly in 75%. For the illustrated versions, the error rates are a bit lower, with 30% for the female version and 50% for the male version. Lastly, the results indicate, that the female realistic version was identified incorrectly 52% of the times, while the male version has a rate of 69% of incorrect identifications.

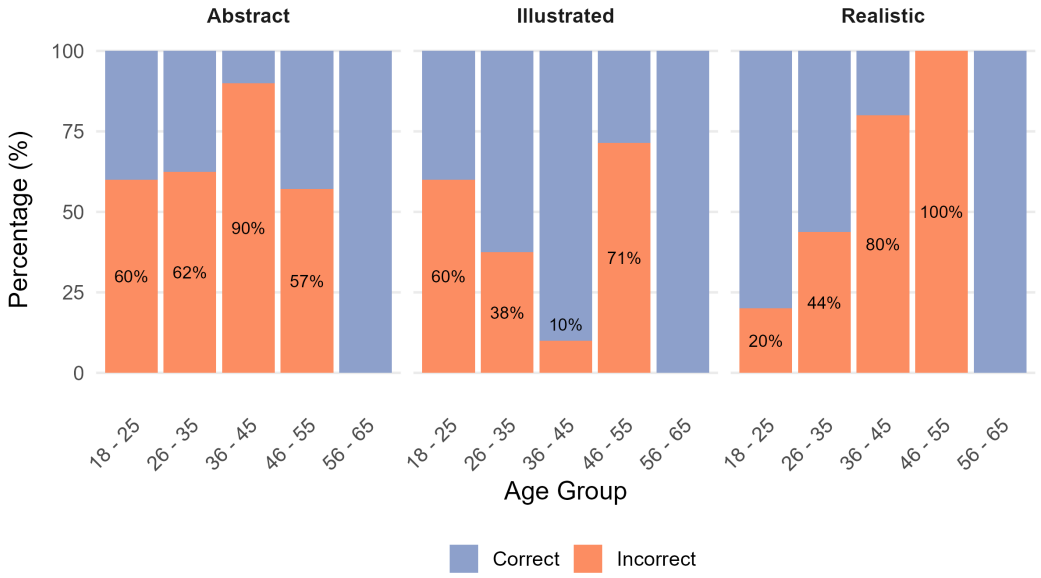


Fig. 5.12: Character selection correctness by age (based on first and only selections)

To examine, whether the age of the participants had any impact on character memorability, figure 5.12 shows the ages of the participants plotted against the correctness of identification for each character style. As with the previous visualization, only first and only selections were analyzed.

In the abstract style most age ranges, namely 18–25, 26–35 and 46–55, hover around an error rate of 60% (+/-3%). Participants between 36 and 45 reached an error rate of 90%.

The age range 56–65 is only represented by one participant, who was able to identify every character correctly.

In the illustrated style, the answers differ a little more. Participants aged 18 to 25 reached an error rate of 60%, while those aged 26–35 and 36–45 reached 38% and 10%, respectively. With an error rate of 71%, participants between the ages of 46 and 55 have the highest rate of this style.

The results of the realistic style show an interesting pattern. Starting at 18–25 and moving continuously through the ranges to 46–55, the error percentages are rising. Starting at 20% for the youngest, moving to 44% at ages 26–36, then 80% at 36–45 and finally 100% of incorrectly identified characters at ages 46–55.

5.2.4 Medical Data Communication

For the communication of the medical data, a keyword analysis needs to be conducted. The participants viewed four characters for each character style. They got to choose any of the sixteen provided symptoms.
When reviewing the results after the study was conducted, an error in the localization table of the last three keywords was found. With this error the English version's last three keyword were: (14) bruises, (15) nausea and (16) breathing difficulty. However, the German version included the keywords: (14) Müdigkeit (fatigue), (15) Schwindel (dizziness) and (16) Übelkeit (nausea). It is unclear, how this error occurred, but it will be taken into account during the analysis. For the keywords (15) nausea and (16) Übelkeit, the associated English and German keywords will be combined, to form one complete data set. The remaining four keywords will have to be analyzed separately. Fortunately, the split between German and English readers was fairly even, as discussed in section 5.2.1, so the results can still be evaluated, taking into account that only about half the participants viewed each of these words. None of the symptoms used in generating the diseased characters was affected by this error.

For the abstract version in figure 5.13, the intended selections are clearly visible. The first symptom for this version was *stomach pain*, which was selected by 38 out of 39 participants. Additionally, *nausea* was selected by 14 participants. *Fatigue*, being a German-only (G.o.) keyword, was selected 5 times. *Flushed face* and *headache* received 2 selections and *dark under-eyes*, *sweating*, *clenched teeth*, *yellowish skin* and *dizziness* (G.o.) each were selected once.
For the second character, the symptom was *headache*, which was selected by 39 out of 39 participants. Additional selections include *dizziness* (G.o.) with 14 selections, *fatigue* (G.o.) with 8, *nausea* with 3, *pale skin* with 2 and *sweating*, as well as *yellowish skin* with 1.
Following this, there are the two characters representing two symptoms. First being *flushed face* with 37 selections and *dark under-eyes* with only 6 selections. In comparison, *rashes* was selected 16 times. *Sweating*, *bloodshot eyes*, *nausea* and *fatigue* (G.o.) was selected two times, and *headache* received one vote.
The last character of the abstract style shows the symptoms *sweating* with 37 selections and *pale skin* with 32 selections. Then, there is *fatigue* (G.o.) with 10 selections and *nausea* with 2. The remaining three received one vote: *dark under-eyes*, *yellowish skin* and *dizziness* (G.o.).

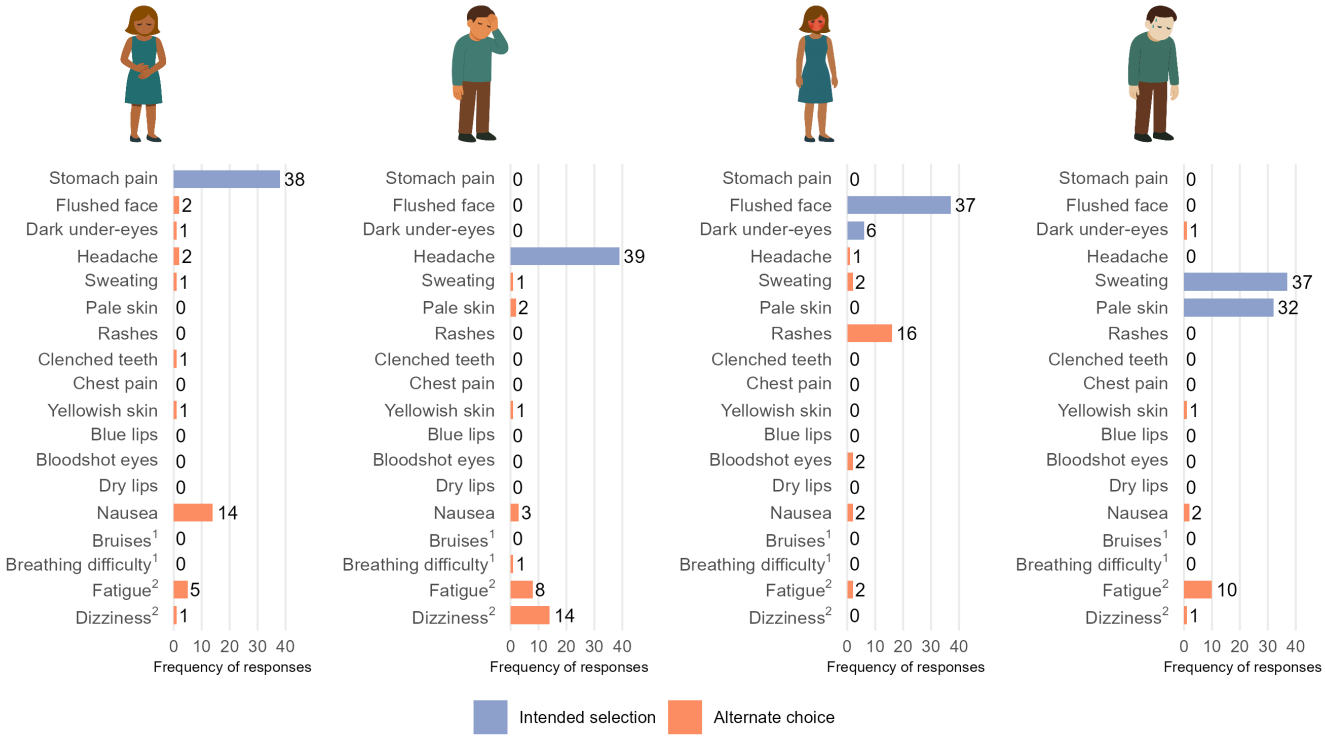


Fig. 5.13: **Abstract:** keyword selection results

For the illustrated version in figure 5.14, the first symptom was *rashes*, which was selected by 25 out of 39 participants. Interestingly, *flushed face* appeared even more frequently, with 31 selections. Further selections included *fatigue* (G.o.) with 8, *dark under-eyes* with 6, and both *nausea* and *pale skin* with 5 selections each. Additionally, *clenched teeth* was chosen 3 times, while *sweating*, *yellowish skin* and *dizziness* (G.o.) were each selected twice. The options *stomach pain*, *blue lips*, *bloodshot eyes* and *dry lips* received one vote each.

For the second character, the intended symptom was *yellowish skin*, which was selected by 33 out of 39 participants. Other frequent selections include *nausea* with 6, and both *dark under-eyes* and *clenched teeth* with 5. *Fatigue* was chosen 4 times, *pale skin* and *dry lips* 3 times, and *stomach pain*, *headache*, *blue lips*, *bloodshot eyes* and *dizziness* twice each. Only one participant selected *flushed face*.

Following this, there are again two characters representing two symptoms. The first shows *clenched teeth* with 30 selections and *chest pain* with 29, both of which were well recognized by most participants. Additional selections include *breathing difficulty* (E.o.) with 5 selections, and *headache* as well as *flushed face* with 2 each. *Stomach pain*, *dark under-eyes*, *yellowish skin* and *nausea* were each selected once.

The last character of the illustrated style displays the intended symptoms *bloodshot eyes* with 19 selections and *blue lips* with 6. The most frequently chosen unintended

[1]Only the English participants were able to select this keyword
[2]Only the German participants were able to select this keyword

symptom for this version was *dark under-eyes*, selected by 26 participants. Additionally, *fatigue* (G.o.)appeared 7 times, while *flushed face*, *clenched teeth*, *yellowish skin*, *dry lips* and *nausea* were each selected 3 times. *Pale skin* and *rashes* were each chosen twice, and *stomach pain*, *headache* and *breathing difficulty* (E.o.) received one selection each.

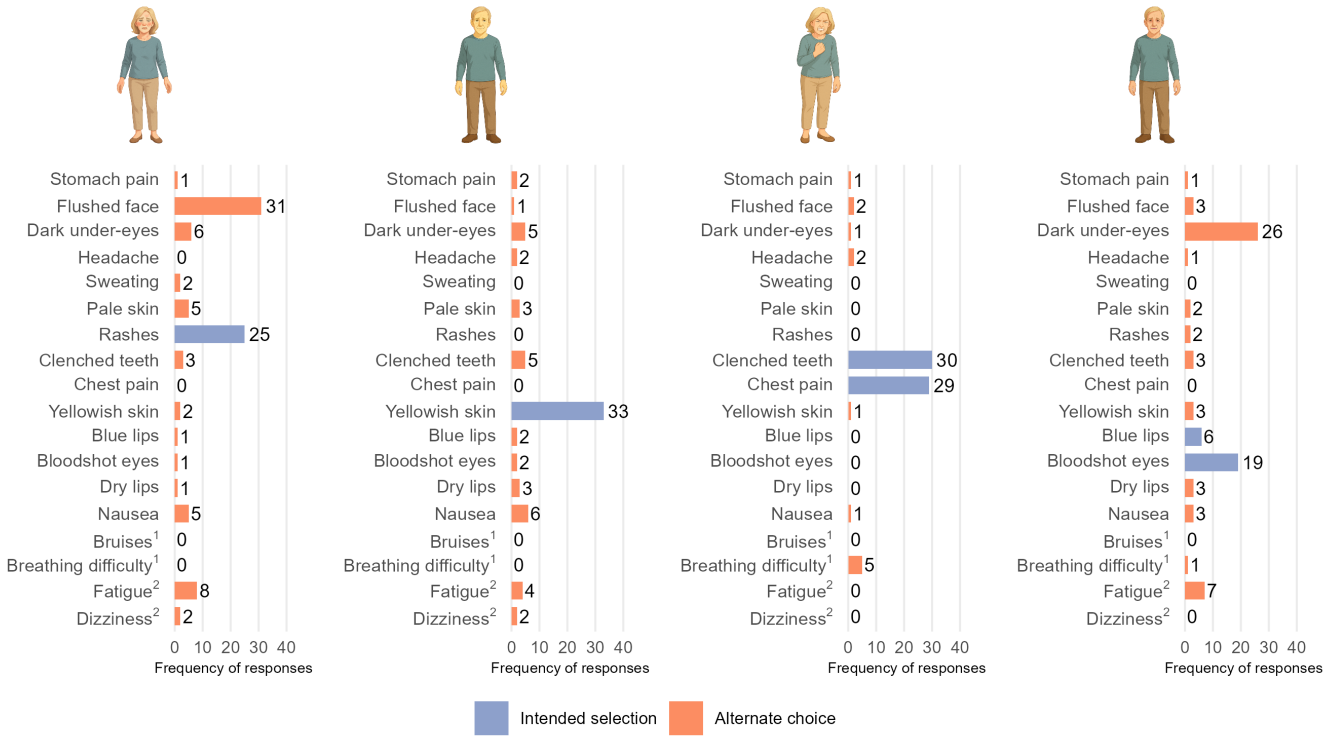


Fig. 5.14: Illustrated: keyword selection results

The first character of the realistic version in figure 5.15 displayed the symptom *headache*, which was correctly identified by 37 out of 39 participants. Additionally, selections include *dizziness* (G.o.) with 8 and *fatigue* (G.o.) with 4. *Clenched teeth* was selected twice, while *stomach pain*, *dark under-eyes*, *pale skin*, *yellowish skin*, *nausea* and *breathing difficulty* (E.o.) each received one selection.

For the second character, the intended symptom was *stomach pain*, which was recognized by 38 participants. In addition, *nausea* was selected by 12 participants, followed by *dark under-eyes* and *pale skin* with 2 selections each. *Breathing difficulty* (E.o.), *headache*, *clenched teeth*, *chest pain* and *dizziness* (G.o.) were each selected once.

The first of the characters with two symptoms shows *pale skin* with 28 and *sweating* with 5 selections. However, *chest pain* was the most frequently selected unintended symptom with 31 participants choosing it, indicating a strong visual association. Further selections include *breathing difficulty* (E.o.) with 9, *nausea* with 8, *dry lips*

[1]Only the English participants were able to select this keyword
[2]Only the German participants were able to select this keyword

with 5, *bloodshot eyes* with 4, and *dark under-eyes* with 3. Additionally, *fatigue* (G.o.) and *dizziness* (G.o.) were each selected twice, while *stomach pain*, *flushed face*, *headache* and *yellowish skin* were each chosen once.
The last character of the realistic style represents the symptoms *rashes* with 27 selections and *dry lips* with 8. Another visual cue was identified more often. *Flushed face* appeared equally frequently to an intended symptom with 27 selections, while *fatigue* (G.o.) was chosen 5 times, *dark under-eyes* 4 times and *nausea* twice. Finally, *headache* and *blue lips* each received one selection.

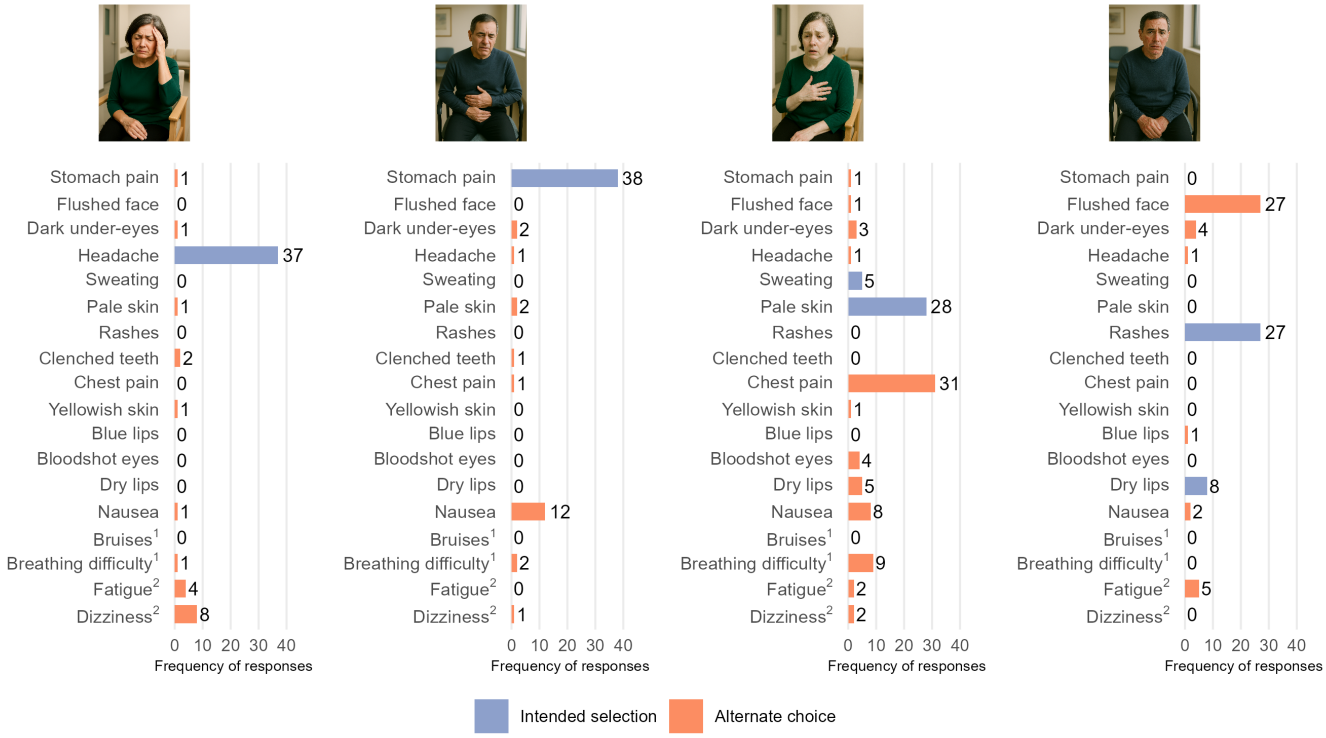


Fig. 5.15: **Realistic:** keyword selection results

5.2.5 Viewing Order

An additional passive evaluation metric was the order in which the participants decided to see the stories, as they had the freedom to choose trough the menu. 22 out of 39 participants reported viewing the stories based on reading order (left to right). Of the remaining 17 participants, 3 reported to have chosen a random order and 14 deliberately chose the stories based on their interest in the characters. For the purpose of this evaluation, the participants, who reported viewing the story just from left to right, will no be investigated further. However, the entries of those who purposely chose based on character preference, will be looked into. Additionally, the

[1]Only the English participants were able to select this keyword
[2]Only the German participants were able to select this keyword

three entries of random orders will be included, as their decision was most likely guided by unconscious preference.

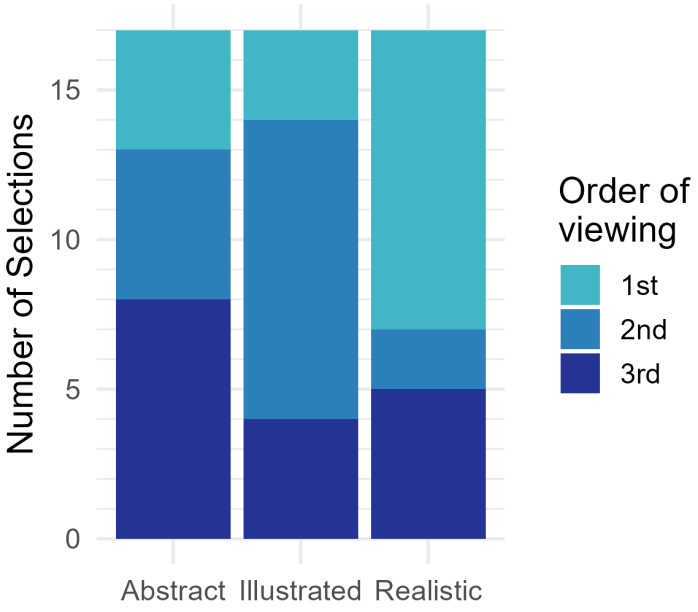


Fig. 5.16: Viewing order of participants who chose based on character

Figure 5.16 shows the selections based on each character style with the colors of the stacks indicating which place in the viewing order the story received. The realistic version was viewed first the most, with 10 out of the 17 choosing to view this option. The abstract version follows with 4 first selections and the illustrated version is last with 3 first selections. However, the illustrated version was viewed second most often, by 10 participants. The abstract version was selected second by 4 participants, followed by the illustrated story with 3 selecting to view it second. The abstract version was the one most frequently viewed last, chosen by 8 participants. The realistic version was viewed last 5 times and the illustrated version was viewed last 4 times.

A number of participants reported to have learned the structure of the study and intentionally trying to commit characters visual appearance to memory. To add context to the memorability results, the character memorability was evaluated in context with the story viewing order. Figure 5.17 shows the identification accuracy percentages of each story style grouped by their viewing order.

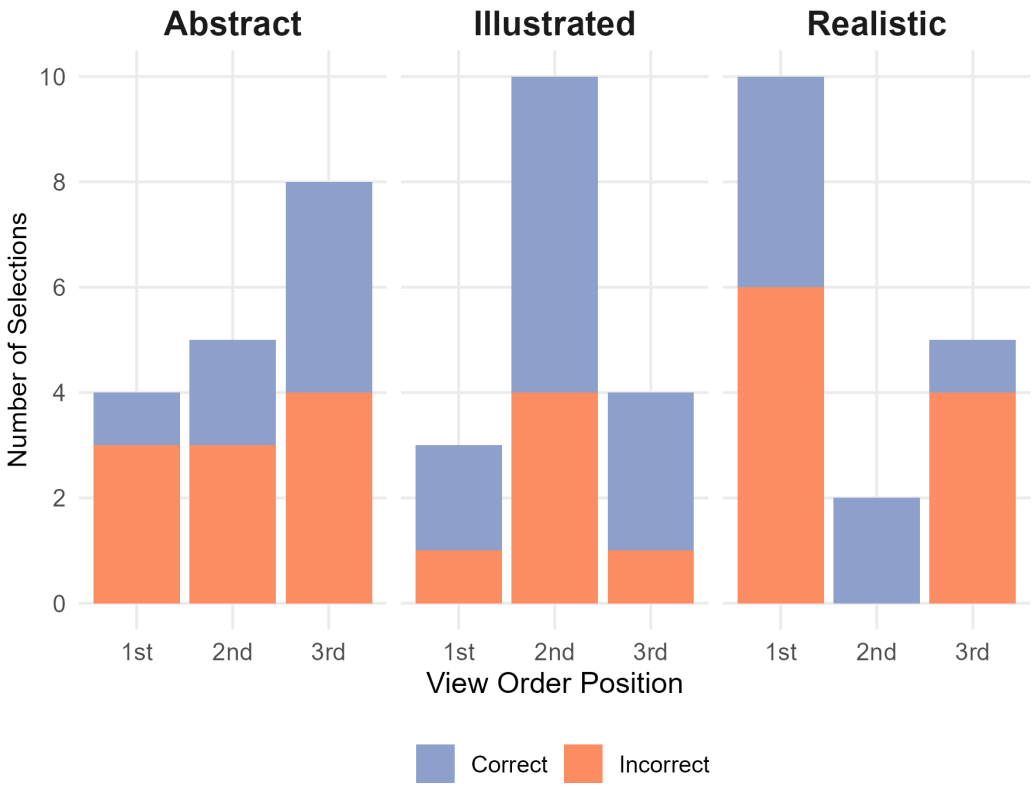


Fig. 5.17: Character identification accuracy, grouped by viewing order

For additional context, the alternate visualization Story viewing order, grouped by character identification accuracy can be found in Evaluation: Additional Plots.

5.3 Discussion

With the results established, we can now examine their implications and identify key findings that address the research questions. This section interprets the results in context and highlights their relevance to the study's aims.

5.3.1 Key Findings

When observing the emotional connection distribution of the participants, the most noticeable aspect was the distinctly different patterns between the female and male participants. While the male responses cluster around higher-mid arousal and moderate pleasure. the female results cover a wider range of responses. When looking for a strong emotional connection, one would expect a large numbers of entries on the extremely high arousal side and either negatively or positively extreme pleasure. The male results don't show any entries on any extreme, while the female results tend to have more answers around the lower end of the pleasure scale and the higher end of the arousal scale. Comparing the patterns of each story, no significant differences can be observed, apart from slight pattern variation.

For the evaluation of the memorability, the results of the knowledge quiz and the character recognition check need to be analyzed separately.
When it comes to recalling the knowledge presented by the story, the abstract story has the the highest error rate of all with 19% while the remaining two have 11%. This could imply that the abstract character influences the knowledge memorability negatively. These results should be challenged in future work, due to limitations in the study setup, which will further be discussed in the later section 6.2. Across all stories female version readers show a tendency for higher error rates.
Previous medical knowledge seems to have little influence on the error rates, as there is no clear pattern of higher rates in lower knowledge levels. Interestingly, some higher error rates occurred at specific questions across all knowledge levels.
A similar observation can be made for the influence of previous visualization experience. The error rates at either side of the experience show similar rates within the stories.

There were a few interesting observations pertaining to the character memorability. The abstract version shows to have the lowest location rate, followed by the realistic version and at the highest recognition rate is the illustrated version. In addition to having the least recognition rate, the abstract version also shows the most uncertainty in selecting, having the highest amount of supplementary selections. The illustrated version shows not only to have the highest recognition accuracy, but

also the lowest uncertainty during the selection, with the realistic version following closely. Interestingly, female characters were recognized more accurately, with the male equivalents usually showing a roughly 14% to 20% decrease in recognition rate.

Another striking pattern within the data shows a rapid decrease around the last four versions. This imply, that the face an essential aspect in character recognition. While the abstract and the illustrated versions show no further noticeable trends in specific recognition aspects, the realistic version selections show, that the clothing was less influential that the difference in hair.

With the additional plot of character recognition across story view order position, it can be determined, that the viewing a character later in the study could have positive influence in the abstract and illustrated versions, but not in the realistic versions. Due to the limited data, this should be investigated further. Additional differences in recognition can be noticed across different age ranges. The abstract version has overall similar recognizability across all ages, with one outlier: ages 36–45, who show an unusually high error rate of 90%. For the illustrated version, the least error rate is at ages 36–45, implying that for this age it is easier to recognize illustrated character then abstract ones. As the participants got younger, the error rate grows, as well. And is highest for the older participants at ages 46–55. When looking at the same age in the realistic version, it shows an error rate of 100Ṫhis could mean that older participants have a harder time recognizing characters overall. Additionally, the recognition rate grows the younger the participants get in the realistic version with 80% at ages 18–25.

As with the character memorability, the character style showed a great impact on the participant ability to recognize symptoms through the visuals of each character. First, overall trends across all styles showed, that more subtle symptoms, particularly in the face like lips and eyes, were rarely identified. In the illustrated version, a larger selection of participants were able to identify a symptom in the eyes, however each type of eye symptom received selections, proving the specifics are not easily identifiable. Skin related symptoms of potentially similar colors were selected interchangeably, which indicated that details such as partial spotted redness and consistent redness can not easily be distinguished.

The most cleanly identified symptoms were on the abstract characters. Each symptom, with the exception of previously explained eye-related ones, was identified by the vast majority of participants. Additionally, very few unintended selection were made here. This is potentially due to the minimalist nature of the design, leaving to space for interpretation.

The realistic version is following closely behind this. Here, the symptoms were not always identified by an overwhelming majority, but still very clearly. Few additional symptoms were added, as well. There is one exception, which is the third character. However, this outlier can be explained by the unfortunately selected image, which

could be interpreted in a variety of ways. This highlights the importance of the image selection and an accurate prompt, when generating with AI.
For the illustrated version, the largest number of additional selections was carried out. This suggests, that the illustrated version is the most open for interpretation when it comes to recognizing symptoms. The intended symptoms were still recognizes quite accurately, but far less than the abstract version, and a little less than the realistic version.

The participants were able to select the order in which they viewed the story. By tracking their choices, an overall visual preferences for characters were expected to be found. This has been confirmed to be the realistic version, as it was selected first by an overwhelming majority. Interestingly, those who did not select it first, were more likely not to view it at second place. The illustrated story was viewed second the most and the abstract story was viewed third the most.

5.3.2 Addressing Research Questions

RQ1: Which visual character style leads to the strongest emotional connection and identification with the audience?
The key findings show, that there is no significant difference between the character styles when it comes to establishing emotional connections. What makes a far greater impact is the gender of the viewer. Some viewers of the female version showed to be experiencing higher emotional responses, while the results of the male version show overwhelmingly moderate reactions.

RQ2: How does visual character style influence the memorability of key medical information and character memorability?
Overall the character style seems to influence the memorability of key medical information in a minimal way. The results indicate, that the abstract character style could give a slight disadvantage, however this needs to be examined further.
When it comes to the character memorability, the character style is highly influential. The most memorable style being the illustrated one, followed by the realistic and lastly the abstract. Male participants were able to identify characters less accurately, than the participates who viewed the male version. In all versions the face war the most influential aspect of the recognition and in the realistic the hair also played an essential role.

RQ3: How accurately can underlying medical data be communicated through different visual character styles in medical storytelling?
There is a clear trend when it comes to communicating medical data trough characters. Overall, small details like changes on the face are not easily identified and also

easily mixed up. Skin conditions are not easily identified by pattern, but more by color.
The abstract version was determined to be the most accurate style to convey specific symptoms, leaving little room for interpretation. With the realistic version at second place and the illustrated style being the least accurate. It is important to emphasize the role the specific character design plays a role as one unfortunately selected image could mean higher inaccuracy.

5.3.3 Additional Notes

The abstract character style shines when it comes to clear visual communication of symptoms, however it seems to not be easy to remember for readers.
Illustrated characters were shown to be the most recognizable out of every option. But they also leave a lot of room for misinterpretation of symptoms.
The realistic character covers a middle ground and also a large percentage of viewers seems to visually prefer or are more curious about the story of a character in this style over the others.

During this character creation process, certain limitations and advantages became clear due to the properties of each style. The following observations are based on the experience creating charters in different styles for this project:

Abstract

- Character and style can be kept consistent easily
- Less expression possibilities due to limited facial features
- Due to limited possibilities, symptom implementation requires more consideration
- Symbols and icons fit well for additional clarity
- Easily adjusted even without much experience

Illustrated

- Character and style consistency hard to uphold
- Large variation possibility in “illustrated” character style
- Visual symptoms can be translated easily to this style
- Moderately easy to adjust

Realistic

- Style is easy to define, as it is “photorealistic”
- Character face changes easily noticeable when generating new versions
- Less expression possibilities due to limited facial features
- Adjustments require more experienced creators, otherwise results may look uncanny

6 Conclusion

6.1 Summary

In this thesis three character types were analyzed to answer three research questions:

- Which visual character style leads to the strongest emotional connection and identification with the audience?
- How does visual character style influence the memorability of key medical information and character memorability?
- How accurately can underlying medical data be communicated through different visual character styles in medical storytelling?

The chosen styles were “abstract”, “illustrated” and “realistic” and were defined by varying degrees of details, shading and overall form. After the character generation using an AI image tool, the characters were inserted into pre-existing medical data stories. These stories were reworked and simplified to enable consecutive viewing without a decline in participants’ attention. To answer the research questions, a three part questionnaire was developed. The first section included the *Affective Slider* to evaluate participants’ emotional connection to the story and the character. During the second phase, the memorability of medical information and the character was tested. For this purpose, the participants first had to answer three knowledge check questions about the core information provided during the story. Following this, eight different character versions were presented, of which the participants were asked to select which they thought was the original character whose story they recently read. Lastly, the participants were shown images of characters in the certain style being evaluated. These characters were generated to have one or multiple visible symptoms, which were to be selected out of a provided set. Before submission, the participants were asked to provide an explanation of their chosen viewing order of the stories, as they were free to choose the order in a previous menu.
During the evaluation, multiple discoveries were made. Emotional engagement was not significantly affected by character style, though female viewers tended to show stronger emotional responses. While character style had minimal influence on the memorability of medical information, it strongly affected character recognition, with illustrated characters being the most memorable, followed by realistic and abstract styles. In terms of accurately conveying medical data, the abstract style proved most effective, minimizing ambiguity, whereas the illustrated style allowed for greater

misinterpretation. Overall, the abstract style communicates symptoms most clearly but is less memorable, the illustrated style is highly memorable but less precise, and the realistic style offers a balanced middle ground.

6.2 Limitations

The main limitation of this study is the decision to assign each visual character style to only one story (abstract – BAV, illustrated – LC, realistic – CSVD). Consequently, it cannot be determined with certainty whether the observed irregularities are a result of the visual character style or of the story's specific structure and content. This constraint was necessary due to the limited time frame and the expected number of participants. Rearranging the character styles across different stories was not possible, as doing so would have introduced learning effects and required further subdivision of participants (see 4.1), resulting in samples too small for meaningful quantitative analysis.

Another limitation concerns the small participant pool, which was unavoidable within the scope and timeline of a master's thesis. To maintain a coherent study design, it was decided to proceed despite the limited sample size, with the understanding that the findings may not be fully representative. A follow-up study is therefore recommended to validate and extend the results.

Additionally, only one representation of each visual character style was tested. In practice, each style, especially when it comes to the illustrated one, can vary widely in the visual execution and degree of abstraction. Exploring these variations could yield more nuanced insights into how stylistic subtleties affect interpretation and perception.

Finally, limited automation capabilities required several manual adjustments during the preparation of visual materials. As AI-based image generation and processing tools continue to evolve, future studies may benefit from higher levels of consistency and reproducibility in visual stimuli creation.

6.3 Future Work

To address the main limitation, a follow-up study could present each character style across multiple stories, isolating the influence of the story content from the visual style itself. This would help clarify whether certain effects—such as differences in emotional response, memorability, or data interpretation—stem from the story narrative or from the design style.

Further research could also explore variations within individual visual styles, particularly the illustrated style, to better understand how stylistic subtleties influence perception and comprehension.

7 Supplementary Material

7.1 Knowledge Questions

7.1.1 Bloodflow

Why are there always going to be vortices in the aorta?

- ✓ Because of the curvature
- • Because of body movement
- • Because of blood pressure

What can form from dangerous vortices in the blood?

- • Vascular crystals
- • Blood clots
- ✓ Aneurysms

Which type of heart defect did the character have?

- • Coarctation of the aorta
- ✓ Bicuspid aortic valve
- • Aortic valve stenosis

7.1.2 Liver Cancer

Which of the following is NOT a diagnostic method for liver cancer?

- • CT
- • MRI
- ✓ ECG

Why are there no symptoms in the early stages of liver cancer?

- ✓ Liver is not sensitive to pain
- • The tumour releases endorphins that mask symptoms
- • Early cancer cells mimic normal liver cells perfectly

What is an ablation performed with?

- A laser
- ✓ A needle
- Tweezers

7.1.3 Cerebral Small Vessel Disease

What happens in the case cerebral small vessel disease?

- The brain increases spinal fluid to balance pressure
- ✓ Blood enters the brain tissue through a damaged blood vessel wall
- Neurons reroute signals through the lymph system

What is NOT a subtype of cerebral small vessel disease?

- HA
- CAA
- ✓ HAA

Which of the following symptoms is triggered by CSVD?

- High blood pressure
- ✓ Speech disorder
- Elevated liver enzymes

7.2 Study Invitations

German Invitation

Hallo zusammen,
im Rahmen meiner Masterarbeit führe ich eine Evaluierung von Charakteren in der medizinischen narrativen Visualisierung durch. Die Teilnahme dauert etwa 15 Minuten und sollte an einem Laptop oder PC erfolgen, um eine konsistente Darstellung zu gewährleisten.
Alle, die Interesse haben, sind herzlich eingeladen, an der Studie teilzunehmen. Die Antworten werden anonym erfasst und die Daten vertraulich behandelt. Wichtig ist, eine ehrliche Meinung abzugeben. Die Studie ist sowohl auf Deutsch als auch auf Englisch verfügbar.
Gerne kann die Einladung zur Studie auch mit FreundInnen, Bekannten oder Familienmitgliedern geteilt werden – je mehr teilnehmen, desto besser!

Hier geht's zur Teilnahme: `https://jejist.github.io/Chatacter-Study/`[1]

Vielen Dank für die Unterstützung!
Evgenia

English Invitation

Hello everyone,
As part of my master's thesis, I am conducting an evaluation of characters in medical narrative visualization. Participation takes about 15 minutes and should be completed on a laptop or PC to ensure consistency in viewing experience.
Anyone who is interested is warmly invited to take part in the study. All responses will be collected anonymously, and the data will be treated confidentially. It is important to provide honest feedback. The study is available in both German and English.
Feel free to share this invitation with friends, acquaintances, or family members – the more participants, the better!

Here's the link to participate: `https://jejist.github.io/Chatacter-Study/`[1]

Thank you for your support!
Evgenia

[1] The study is now offline.

7.3 Evaluation: Additional Plots

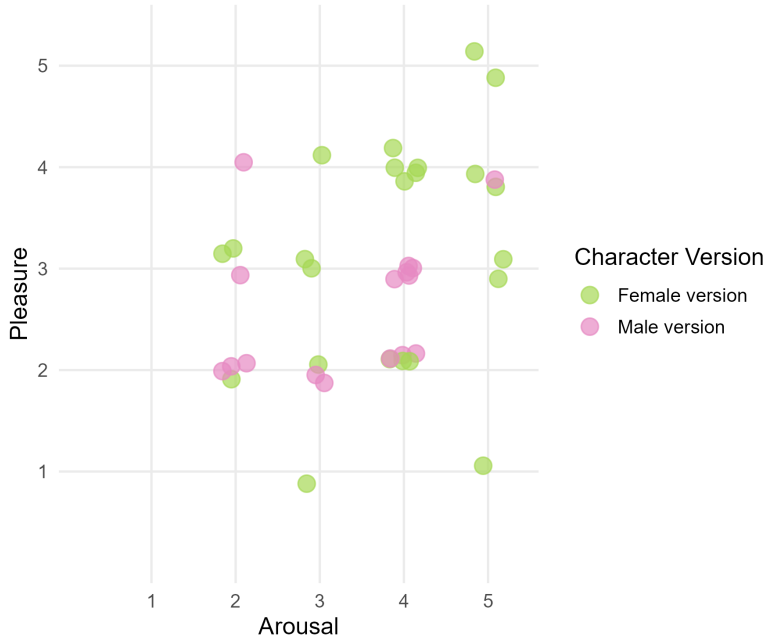


Fig. 7.1: Emotional Connection: Scatterplot - Abstract

Fig. 7.2: Emotional Connection: Scatterplot - Illustrated

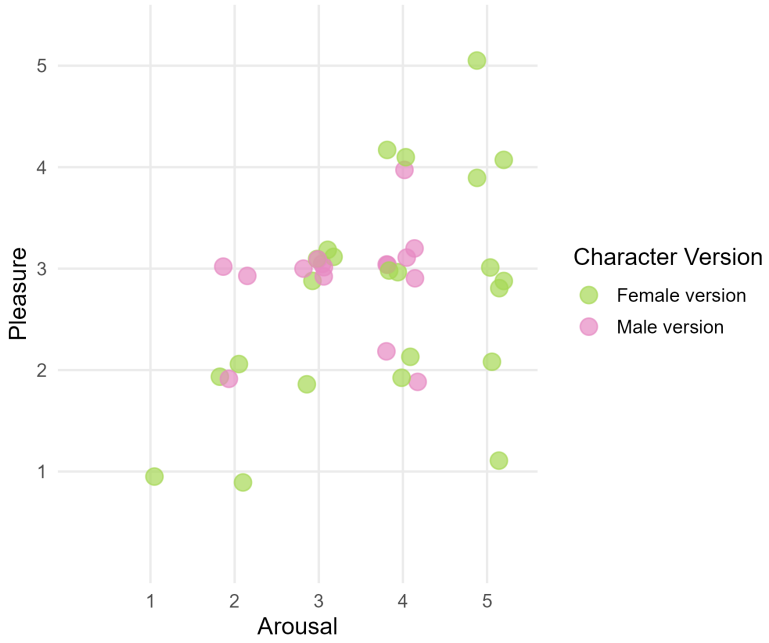


Fig. 7.3: Emotional Connection: Scatterplot - Realistic

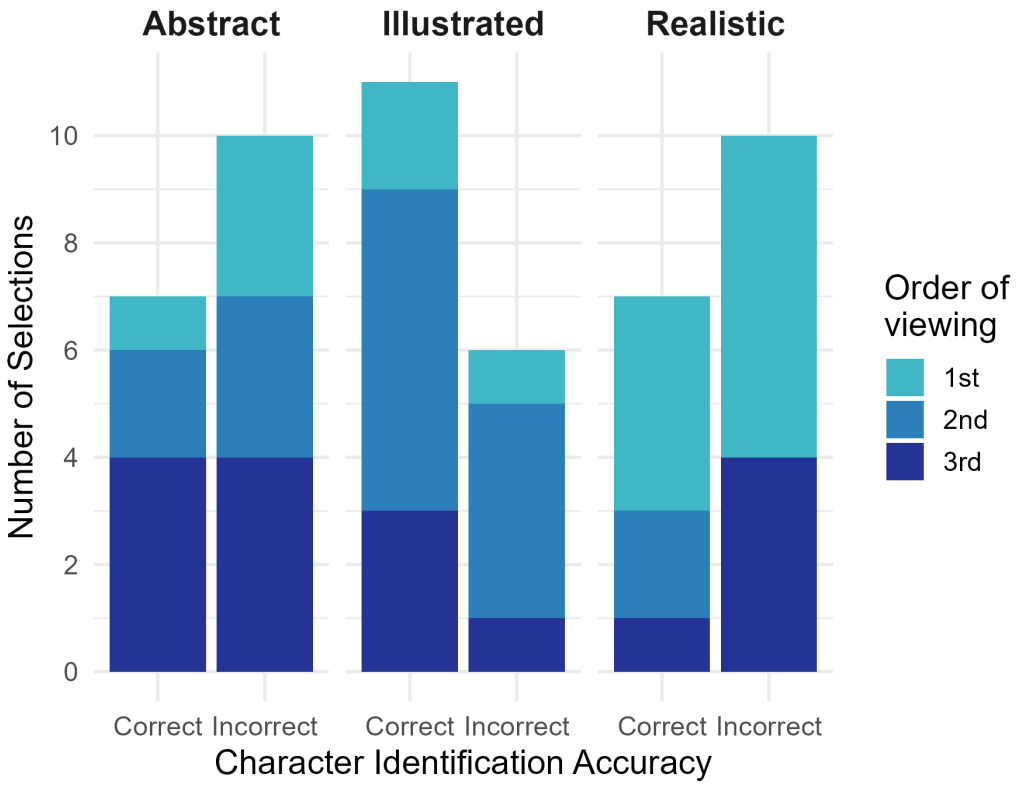


Fig. 7.4: Story viewing order, grouped by character identification accuracy

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Magdeburg, October 18, 2025

Evgenia Stupak