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Serious Game Evaluation

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Abstract

The report details the development and evaluation process of the serious game "Talk Science: How much do you say?" - an interactive communication tool to (1) foster trust in relevant scientific bodies as well as subsequent science communication and positively influence how reported scientific uncertainty affects (2) cognitions, (3) emotions, as well as (4) behavioral intentions.

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1 Introduction

As will be laid out later in this deliverable, effective risk communication (including uncertainties in risk research) is essential for helping scientific laypeople understand the current state of knowledge regarding technologies like radiofrequency electromagnetic fields (RF-EMF) and their connection to potential health effects. This understanding is critical for the scientific laypeople to adequately evaluate whether the given technology presents a potential hazard and what the associated risks are. It is also important for fostering trust in scientific authorities as well as subsequent science communication, and may influence people's cognition, emotions as well as behavior intentions regarding scientific uncertainty. To address limitations of traditional, unidirectional informational formats, the objectives of tasks 10.5 through 10.8 are the development and evaluation of a serious game designed to learn about the role of scientific uncertainty in risk research and to reflect on own biases by engaging players in RF-EMF science communication scenarios. Work began in late 2022 with laying out first game design ideas, followed by prototyping several game designs and forming a citizen advisory board in 2023 that guides the main objective of designing and developing the serious game since.

1.1 Uncertainty in RF-EMF Risk Research

Over the past several decades, there has been a growing body of research investigating potential risks linked to RF-EMF (e.g. risks stemming from mobile communication technology). As part of this research numerous studies have investigated whether RF-EMF has negative effects on human health, and results are generally reviewed and evaluated by both national and international organizations. In 2021 for example the European Commission instructed the Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) to update its opinion piece on the potential health effects of exposure to electromagnetic fields. Regarding adverse health effects from low and intermediate frequency fields for the general population, it concludes there to be no moderate or strong evidence (SCHEER, 2024). Similarly, the Scientific Council on Electromagnetic Fields of the Swedish Radiation Safety Authority (SSM) in its latest report finds no established causal relationships between RF-EMF exposure and health risks (Huss et al., 2024). Building on such reviews and further studies, guidelines for limiting the exposure to RF-EMF have been developed by organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2020) or the Institution of Electrical and Electronic Engineers (IEEE, 2020). Exposure to RF-EMF at levels below those established safety limits generally does not result in significant adverse health effects (e.g. Bosch-Capblanch et al., 2024). In fact, the only biological effect of RF-EMF that has been consistently found is thermal (i.e.

heating of tissue) (Foster & Colombi, 2017), while other, possibly indirect effects, that may be detrimental for human health, have not been consistently found (Wood & Karipidis, 2017). Despite this evidence suggesting minimal health risks, there are still some uncertainties regarding potential non-thermal effects and long-term exposure (SCHEER, 2024). Due to such uncertainties the International Agency for Research on Cancer (IARC) classified RF-EMF as possibly carcinogenic to humans, arguing that the available evidence is not sufficient to rule out a risk of developing brain tumors for heavy users of mobile phones (IARC, 2013).

1.2 Effects of Uncertainty Communication

As risk information is limited by uncertainty in the same way as any other information about empirical science, it sometimes becomes difficult for laypeople to keep up with the current state of knowledge and its limitations. To make sense of complex information, individuals tend to use heuristics – these, however, oftentimes result in distorted judgements, known as biases. When it comes to risks there may be a zero risk bias (Raue & Schneider, 2019) which is evident, for instance, in the discrepancy between the perceived risk and the risk deemed acceptable regarding most publicly discussed risks (Slovic, 1987). But how do individuals perceive and react to risk information that is limited by scientific uncertainty, and what are their preferences regarding its communication? Uncertainties in the empirical research process generally occur either at the stage of defining a sufficient sampling frame (i.e. the inability to include all relevant factors affecting the phenomenon), at the stage of sampling (i.e. systematic biases and random errors), or at the stage of modelling (i.e. estimation) (Galesic et al., 2016). In this sense, uncertainty can be understood as being informational – stating and quantifying the deviation from an unachievable, deterministic knowledge (Walker et al., 2003). To effectively convey the current state of knowledge, it is often necessary to communicate the uncertainties, and their subsequent limitations associated with the information. In this case, uncertainty can also be understood as being subjective – meaning the recipient's subjective awareness of their limited knowledge (Han, 2013). In the literature several theoretical frameworks can be found that may explain how individuals react to uncertainty in science communication. For instance, the Uncertainty Reduction Theory (Berger & Calabrese, 1975) states that uncertainty is an aversive state and individuals therefore have the primary concern to reduce uncertainty when encountered. The Uncertainty Management Theory (Brashers, 2001), however, assumes that uncertainty itself is not an inherently negative experience and suggests that individuals make appraisals and consequently determine themselves whether the communicated uncertainty is positive or negative. While communicating uncertainty can increase confidence in reported information when individuals expect uncertainties to exist (Wegwarth et al., 2020), empirical research has shown that ambiguous information about health risks can lead to pessimistic judgments and heightened risk perceptions, worry, as well as avoidance of decision making (Han, 2013). Communicating uncertainties can reduce trust in stakeholders such as scientists and public health authorities, as well as perceived credibility and expertise of these stakeholders (Ratcliff et al., 2022). Furthermore, when scientific uncertainty is presented as a caveat, it often leads to an increase in perceived uncertainty about the science itself, and while effects in past research vary, this can also influence people's emotions (van der Bles et al., 2019). Lastly, although there is only little systematic research on behavioral consequences of reported scientific uncertainties, newer studies show that uncertainty can indirectly affect information seeking intentions (Kim et al., 2024).

1.3 Understanding Scientific Uncertainty

To summarize, reporting scientific uncertainty can play a crucial role in shaping the public's trust in stakeholders, as well as cognitions, emotions, and ultimately behaviors in reaction to science communication (Hillen et al., 2017; van der Bles et al., 2019). This brings into focus the concept of scientific literacy – particularly how individuals interpret uncertainty in risk communication. The National Academies of Sciences, Engineering and Medicine of the United States (2016) understand scientific literacy in general as involving three key aspects: understanding scientific practices, having content knowledge, and understanding science as a social process, including peer review, expertise, and the impact of funding and conflicts of interest. Fensham (2015) further argues that individuals who are educated on uncertainty in sciences are able to assess the value of science and its use in decision-making. In this regard scientific literacy is not merely the ability to recall facts but for individuals to comprehend scientific concepts, express opinions on scientific matters, and engage in scientific discourse (Holbrook & Rannikmae, 2009). However, for scientific literacy to enable individuals to become and stay informed, it needs go beyond just understanding how scientific information is created: According to Howell and Brossard (2021), it should also encompass how the media presents the information, as well as how recipients encounter it and form opinions on it. Following this approach to scientific literacy we understand the idea of increasing laypeople's scientific literacy of scientific uncertainty to be important, as it may help to improve how people perceive scientific uncertainty and shape their expectations regarding its role in risk communication.

2 Development of the Game "Talk Science: How Much Do You Say?"

The objective of task 10.6 was to develop a serious game that lets players experience the role of scientific uncertainty in risk research and communication, while also promoting self-reflection on personal biases regarding such uncertainties. Although the task has been completed, continuous updates to the game are still taking place. To design a game that not only achieves the mentioned objectives but also provides a positive gaming experience requires an iterative design process (see Figure 6) and an interdisciplinary team with diverse expertise (Fullerton, 2024). Therefore, the game is actively designed and developed by a team consisting of game designers, a game developer, and experts from various fields, including scientists specializing in RF-EMF risk research, representatives from radiation protection agencies with expertise in RF-EMF and risk communication, as well as a citizen advisory board consisting of interested members of the public.

2.1 What Are Serious Games?

Serious games are interactive digital applications that combine entertainment with educational or training objectives (Dörner et al., 2016). Unlike purely entertaining games, serious games prioritize pedagogical or informative aspects, seeking to achieve specific goals such as knowledge acquisition, attitude shifts, or behavior modification (Abt, 1970; Krath et al., 2021). By leveraging game design, serious games can make the learning process more engaging, interactive, and effective. To accomplish this, they aim to boost players' intrinsic motivation and encourage active participation in the learning process (Krath et al., 2021). This approach is rooted in constructivist learning theory, which emphasizes the importance of personal experiences and motivational factors in successful learning (Jonassen, 1999). According to this perspective, knowledge is primarily acquired through direct experiences and iterative learning cycles, rather than through instruction alone (Kolb, 2000). Effective serious games incorporate elements such as experience-based learning, active participation, and self-reflection to facilitate players' knowledge acquisition (Krath et al., 2021). By doing so, such a game can promote a deeper understanding of scientific concepts, including the complexities of scientific uncertainty.

2.2 Rationale of the Game "Talk Science: How Much Do You Say?"

Following the approach of Howell and Brossard (2021) regarding scientific literacy, we believe that understanding the role of scientific uncertainty in the production and communication of scientific knowledge, as well as how this uncertainties may be perceived by audiences, shapes an individual's expectations about scientific uncertainty in risk communication. As lined out above, scientific uncertainty can be an obstacle in risk communication. When there is a curious public that seeks clear answers, but empirical research is limited by scientific uncertainty regardless of the weight of the evidence, science communicators face a dilemma: They must balance the need to provide accurate and transparent information with the risk of confusing or frustrating the public, who may be looking for definitive answers (see Figure 1). When science communicators accurately convey scientific evidence, including its limitations and uncertainties, they may raise concerns or create uncertainty among some members of the public. On the other hand, if they try to provide more certainty than the evidence warrants, they risk being scientifically inaccurate. We argue that experiencing this dilemma helps to shape an individual's expectations about scientific uncertainty in risk communication, as all three aspects of Howell and Brossard's (2021) information life cycle (knowledge production, communication, and perception) are being addressed within the dilemma. Therefore, the serious game puts players into the role of a science communicator, tasked with balancing the demand for clear answers with the necessity of scientific accuracy. Initially, players may approach the game from the perspective of the curious public, seeking straightforward answers. However, as they engage with feedback from both the public and scientific experts throughout the game, they may gradually shift to a role as a mediator between these two groups. We expect this experience to help them develop an intuitive understanding of the role of scientific uncertainty in risk research and communication, while reflecting on their own perception of scientific uncertainty and what they may expect from risk communication when it comes to scientific uncertainty. Further, we expect that this may result in (1) fostering trust in relevant scientific bodies as well as subsequent science communication, and positive changes to how reported scientific uncertainty affects (2) cognitions, (3) emotions, as well as (4) behavior intentions.

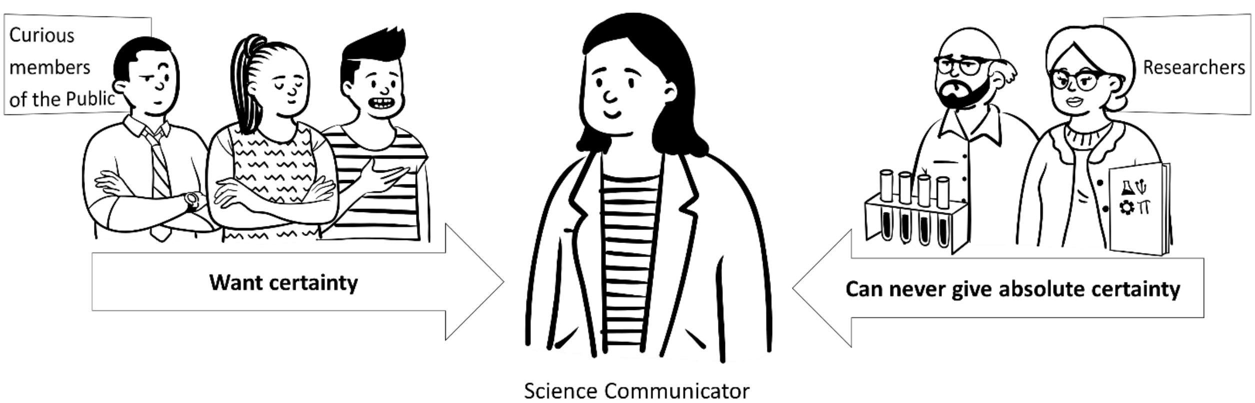

Figure 1. *Scientific Uncertainty as an Obstacle for Risk Communication*

Note. Science communicators oftentimes face a dilemma: Different needs from different stakeholders complicate their communication. From Abacioglu et al. (2024).

2.3 Game Concept

In the fundamental game design for "Talk Science: How Much Do You Say?", players take on the role of a science communicator for a fictional radiation protection agency. They are tasked with communicating to the public about the planned construction of a new RF-EMF base station. The game sequence is depicted in Figure 2. In interactive communication phases, players must respond to questions regarding RF-EMF and health from an in-game audience. Those phases involve multiple questions from members (or their representatives) of an intrigued public, where players can choose from predefined response options. Each response given impacts the trust of in-game stake holders in the player's communication and is followed by another question. After every communication phase, players receive written feedback regarding their communication efforts. After several iterations of this main game loop (communication phase followed by feedback), the game culminates in a phase where consequences of the player's communication are being revealed. The game then ends with concluding remarks regarding scientific uncertainty in empirical research and science communication.

Figure 2. *Game sequence*

2.3.1 Game Introduction

In the first part of the game, players are introduced to the overarching story line of the game. In an interactive dialogue, players discover that plans are underway to construct a new RF-EMF base station in a nearby small town. The town's administration is set to hold a town hall meeting with citizens at the end of the current week to discuss this development. However, there are concerns among residents about the base station, leading many to approach the radiation protection agency with questions regarding the potential health impacts of RF-EMF. Players are tasked with addressing these inquiries before the town hall meeting, as their responses will affect the quality of this upcoming event. After selecting one of several in-game avatars, players are briefed on the importance of building trust in their communication. They are informed that, given the various stakeholders involved in science communication, they must consider the trust levels of the public, scientists, and members of radiation protection agencies in their interactions. Trust from these three stake holders is then explained to be the main metric for the game (see Figure 3).

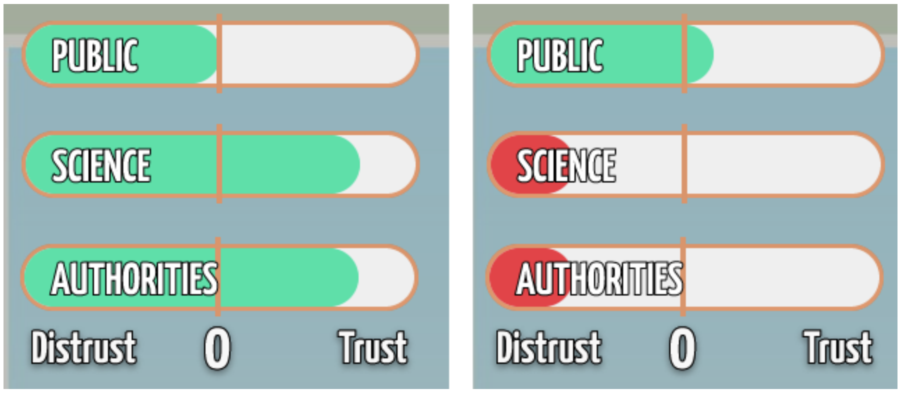

Figure 3. *Trust metric of the game.*

Note. Change of the the three metrics after responding to a question.

2.3.2 Main Game Loop

After the introduction, the main game loop starts. This loop consists of a total of three scenarios. Each scenario presents a slightly different communication setting. In the first setting, the player participates in a radio show and must respond to questions from the host. In the second setting, the player interacts with an interested phone caller, and in the third, the player engages with interactions on social media. Following a question regarding RF-EMF and health, players are presented with options for their response. They receive a detailed answer and must decide the level of detail they wish to use for their actual response. They can opt for a brief informational snippet or choose to elaborate by adding information about scientific uncertainties that limit the available evidence. Additionally, they can include details on how regulatory authorities work to address these uncertainties (see Figure 4).

Every decision impacts the trust metric: Opting for concise responses lowers the trust of scientists and authorities in the player's communication, while boosting trust from the public (see Figure 4). Conversely, introducing uncertainty into the message enhances scientists' trust, but diminishes public trust.

Figure 4. *Choosing a response*

Note. Players have the option to reply with a brief and straightforward message (first option) or provide more elaborate responses. In this case they can choose to add information about uncertainty to their initial message (second option) or add both uncertainty and the measures authorities take to address it (third option).

Finally, incorporating both uncertainty information and mitigating factors into the original message, will elevate trust from authorities only. Following the player's responses to multiple questions, the game progresses to the next scenario, providing feedback on their performance in the previous setting. This feedback is delivered from the viewpoints of representatives of the three stakeholders of science communication in the game: the public, scientists, and members of radiation protection agencies. Based on metric changes for the given stakeholder, he or she will give either positive, neutral, or negative feedback. Figure 5 depicts exemplary feedback from the perspective of a representative from the public.

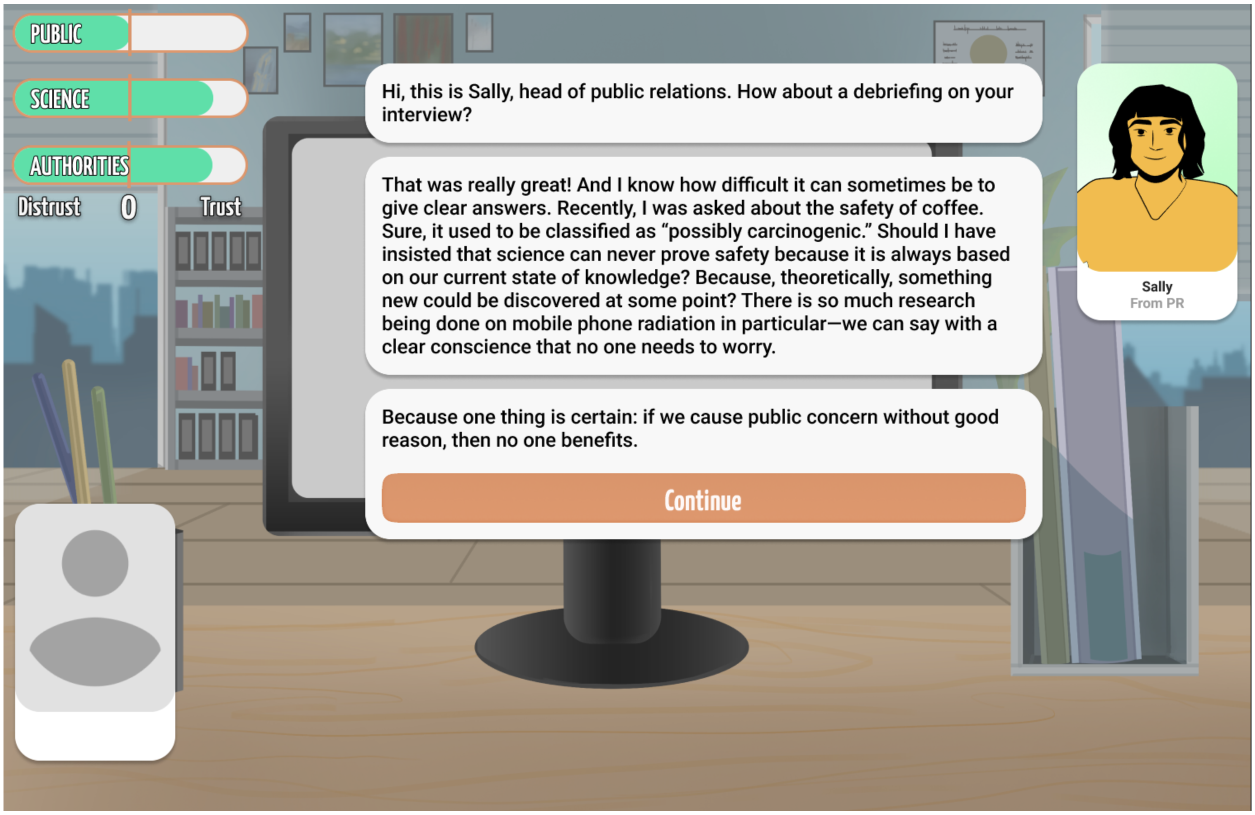

Figure 5. *Feedback system*

Note. The screen shows positive feedback from the perspective of an in-game public relations stakeholder.

2.3.3 Consequence Phase and Game Ending

Based on players' responses and changes of the trust metric, the game leads to different outcomes. If players fail to earn the trust of the curious in-game audience by having focused on discussing scientific uncertainties in their responses during the main game loop, the town hall meeting becomes troubled, as the in-game public will now doubt the competence of risk researchers and the authorities' ability to keep the public safe. Contrary, if players fail to earn the trust of scientists and authorities, these stakeholders will publicly criticize the player's character during the town hall meeting as being misleading and scientifically inaccurate. The game is designed so that players can only gain the trust of either the in-game public or the scientists and authorities. This creates the central dilemma for players, as they must choose which group to align with. After being confronted with the consequences of their communication during the town hall meeting, the player returns to their in-game office. The game concludes with final remarks about the nature of scientific uncertainty in empirical research and science communication. Here it also discusses the varying expectations from different stakeholders on how to handle scientific uncertainty in risk communication.

3 Prototype Iterations and Evaluations

The development of "Talk Science: How much do you say?" is based on an iterative design process that includes three phases: playtesting, evaluation, and modifications to the prototype based on the evaluation outcomes (see Figure 6). Playtests are conducted to identify areas for improvement and to gradually enhance the gaming and learning experience (Fullerton, 2024).

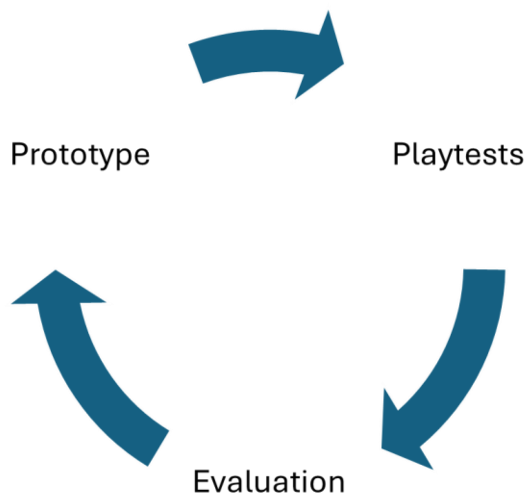

Figure 6. *Iterative design process*

During the playtests, particular attention was paid to learning objectives, unintended side effects, and general gaming experience. During the early stages of game development, the content and elements evolved quickly, leading to playtests that are based on slightly different prototype versions for each iteration. The following sections outline the two key iterations of the game.

3.1 Iteration 1: Basic Game Idea

3.1.1 Prototype Version

In the initial iteration, a prototype version of the game was used, featuring an interactive introduction to the storyline, the three scenarios that form the main game loop, and an evaluation phase. Rather than allowing players to decide the level of detail in their responses to questions from the in-game audience (as shown in Figure 4), the game provides three distinct response options: The first option completely denies any scientific uncertainty, the second acknowledges scientific uncertainty, and the third not only recognizes uncertainty but also includes information about mitigation efforts (see Figure 7).

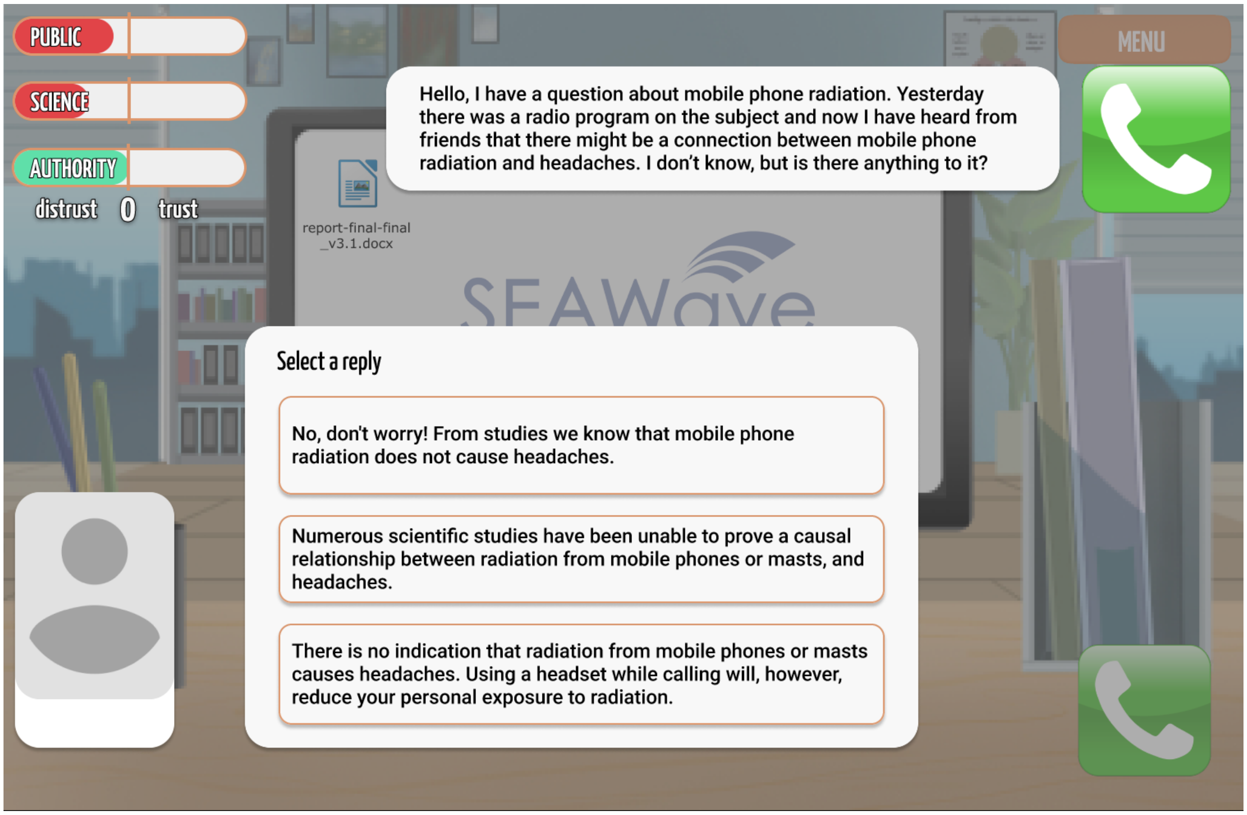

Figure 7. *Iteration 1: First draft of the dialogue system*

Note. This version of the prototype features an earlier version of the dialogue system, where players select from distinct response options rather than deciding the extent of their final response.

3.1.2 Design and Implementation

The initial objective was to validate the trust metric used in the game regarding the general public. To achieve this, 380 participants were recruited to ensure a representative sample from Germany, considering the factors age, gender, region, and education. The study utilized a between-subjects design, randomly assigning participants to one of three groups: those exposed to statements aimed at positively influencing the public, scientists, or authority figures. This design allowed for the evaluation of the impact of different types of statements on participants' trust in the communication. Participants were invited to participate in an online survey, where they were first briefed about the purpose of the study and provided informed consent. After consenting, participants were randomly assigned to one of the three statement conditions. Each participant reads a series of statements relevant to the game, tailored to their assigned condition. Following the reading of the statements, participants were asked to rate their change in trust regarding the science communicator, and their confidence in the protection of health against mobile phone radiation with two five-point Likert scale items.

Following this, the objective was to validate the trust metric used in the game regarding experts in the field of RF-EMF. Ten scientists in the field of RF-EMF and members of radiation protection agencies agreed to participate in a semi-structured interview, rating the same statements outlined above regarding their trust in the communicator.

In a second step, actual playtests were conducted, using a qualitative approach: A total of 22 one-on-one playtests were carried out online, involving a group of university students who participated in exchange for course credits. Prior to gameplay, participants were introduced to the objectives of the playtests, providing them with context and setting expectations. During the play sessions, participants were instructed to think aloud, articulating their thoughts and reactions as they engaged with the game. Following the gameplay, participants took part in a semi-structured interview. This format facilitated a deeper exploration of their insights, feelings, and suggestions regarding the game.

3.1.3 Results

Results of the trust metric validation showed that there are general differences in how scientific laypeople and RF-EMF experts perceive scientific uncertainty in risk communication. A one-way ANOVA revealed that there is a statistically significant difference in levels of trust in the communicator among scientific laypeople based on how scientific uncertainty is included in risk communication (see Figure 8): $F(2, 377) = 3.389$, $p = .035$. When confronted with no scientific uncertainty, laypeople responded with significantly higher trust ratings in the communicator compared to laypeople that were being confronted with scientific uncertainty: $t(377) = 2.461$, $p = .014$. A similar picture emerges for changes in confidence in health protection: A one-way ANOVA revealed a statistically significant difference in the confidence in public health protection among scientific laypeople based on how scientific uncertainty is communicated, $F(2, 377) = 3.918$, $p = .021$. Again, when confronted with no scientific uncertainty, laypeople responded with significantly higher confidence in the communicator compared to laypeople that were being confronted with scientific uncertainty, $t(377) = 2.65$, $p = .008$.

In contrast, experts on RF-EMF stated in the interviews conducted that they were more likely to trust communicators who recognized scientific uncertainty surrounding the topic, compared to those who did not acknowledge such uncertainty.

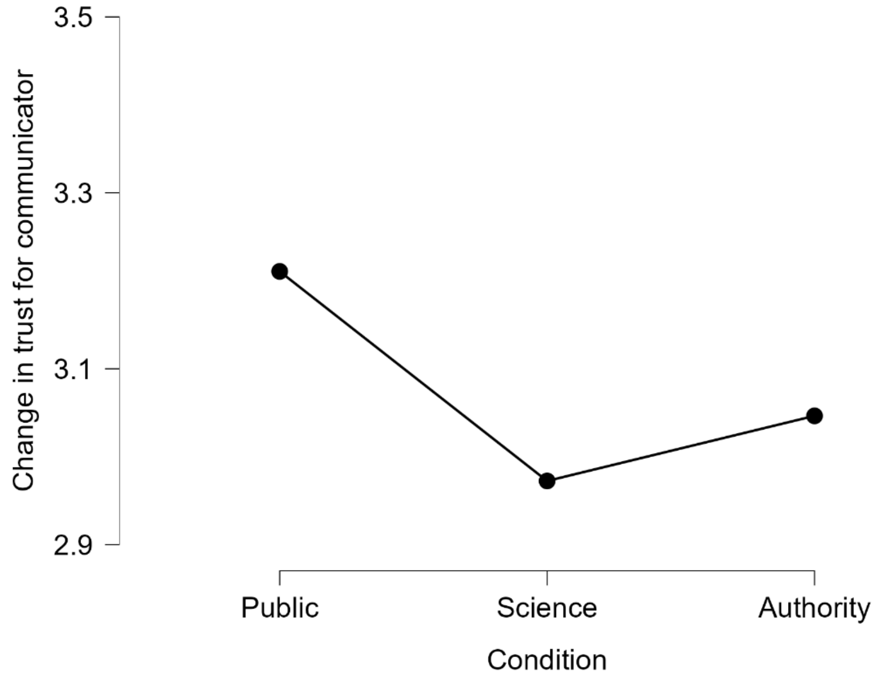

Figure 8. *Scientific laypeople's reaction to different styles of reporting scientific uncertainty*

Note. Public: No inclusion of scientific uncertainty. Science: High inclusion of scientific uncertainty. Authority: Inclusion of scientific uncertainty and strategies for mitigating uncertainty. Measured on a five-point Likert scale.

The results of the first playtest highlighted the need for revisions in two main areas: game experience and unintended side effects. In terms of game experience, only a few participants mentioned that they recognized the dilemma faced by science communicators as a key theme of the game. This perception was influenced by two main factors. First, there was a lack of clarity at the end of the game regarding its overall objective. One participant suggested that the learning objective should be explicitly stated. However, most play testers also pointed out that the game contains large amounts of text, making it difficult to include more content. Second, participants generally did not recognize a consistent pattern in how the response options impacted trust metrics or how they differed from each other. Instead of focusing on how scientific uncertainty is represented in the response options, players tended to evaluate these options as factually “correct” or “incorrect”, believing there was only one correct answer to each question. Notably, some participants expressed that they felt manipulative during the game and linked this feeling to their experiences with real risk communication.

3.2 Iteration 2: A New Dialogue System

3.2.1 Prototype Version

In the second iteration, major changes were made to the texts for both the questions and the response options in the main game loop. Feedback from the initial playtests revealed that players had difficulty distinguishing themes between the response options and recognizing the main perspectives represented by the three types of responses. To address this, efforts were made to emphasize the included scientific uncertainty in the second and third response options by rewriting most of them. However, following an internal playtest, the decision was made to adopt the current dialogue system outlined in chapter 2.3.2. This change aims to allow players to concentrate on the content of their messages (i.e. display of scientific uncertainty) rather than being distracted by the varying wording of the response options.

3.2.2 Design and Implementation

Again, playtests utilized a qualitative method, employing the same semi-structured interview format as in the first playtest. A total of nine students took part in this playtest. Special attention was given to the construct of "trust in science communicators" (items adapted from Hendriks et al., 2017): After playing the game, participants rated science communicators on a five-point Likert scale based on their perceived sincerity, honesty, morality, and manipulativeness. Following this, they were asked to explain the reasons behind their ratings.

Furthermore, specific elements of the game were evaluated in a series of several surveys: Openness to scientific argumentation after playing the game was evaluated, using a semi-structured interview with 13 participants. Changes in perception of scientific uncertainty in the field of RF-EMF risk research and other risk research topics were evaluated, using a semi-structured interview with 10 participants. The impact of including minimal scientific uncertainty in statements tailored for scientific laypeople on the perception of the game's dilemma was evaluated using a quantitative between-subjects design with 104 participants. This was done for the game to be scientifically correct in all statements, something that was deemed mandatory by the citizen advisory board as well as the partners involved in the project. Lastly, enjoyment while playing the game was evaluated, using a mixed-methods approach with 82 participants.

3.2.3 Results

Key results of the playtests and game evaluations described above are summarized in Table 1. At the time of writing, some changes to the game are still being implemented.

Table 1. *Selection of playtests and game evaluations*

Topic of evaluation	Key results	Changes made to the game
General playtest	Participants generally rated science communicators as somewhat manipulative, explaining that communicators have the power to influence recipients. However, when asked about other facets of trustworthiness, participants rated communicators as being sincere, honest, and moral.	Inclusion of at least some level of scientific uncertainty to all response options during the communication phase of the game. This approach ensures that the game remains scientifically accurate, allowing participants to focus on gameplay without worrying about the factual correctness of their responses.
Openness to scientific argumentation	Relevant proportions of participants reported that they will be more critical and attentive when consuming science communication in the future, even though their trust did not change right after playing the game.	–
Change in perception of scientific uncertainty	Relevant proportions of participants acknowledged that scientific uncertainty is a fundamental aspect of scientific practice. They view statements made with absolute certainty as questionable or overly	–

	simplistic. Furthermore, they consider the use of cautious language in scientific communication to be a positive quality, as it demonstrates a thoughtful and careful approach.	
Inclusion of scientific uncertainty in all response options	Relevant proportions of participants still experienced and understood the dilemma presented by the game, even as scientific uncertainty was included in all response options for the communication phase.	–
Enjoyment	Relevant proportions of participants noted a discrepancy between an overall good usability and a limited enjoyment while playing the game. Regarding the enjoyment of the game, the amount of text as well as a lengthy story were mentioned.	Parts of the game’s introduction and end are being rewritten to be more concise and to better fit the plot.

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