

Assessment of Innovation Readiness and Technology Acceptance Using Immersive Sci-Fi Prototyping

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Abstract: Digital transformation is ubiquitous and is generating unprecedented forms of innovation. However, it brings new challenges due to its comprehensive nature and potentially profound impacts. Technology assessment examines the long-term impacts of technologies on society and the environment. One aspect of this is a broad societal discourse, which is considered indispensable in a functioning democracy. To this end, various perspectives are sought, especially from experts in science, business, and politics, but also the opinion of the public. In practice, however, this poses a challenge. How is the public supposed to be able to form an informed opinion about a technological change, an upcoming innovation, if this change is multi-layered and not easily transparent and comprehensible? In this paper, attitude formation and attitude change are examined in more detail using a science fiction prototype in the democratic field of action. The main focus lies on immersion. The effects of immersive scenarios on attitudes toward technological innovations have not yet been sufficiently studied. The authors believe that conventional methods appeal mainly to cognition, but people are often driven by emotions. The immersive sci-fi prototyping method is designed to allow technological innovations to be experienced with virtual reality and thus also appeals to emotions in the process of forming attitudes. The authors hypothesize that with the immersive sci-fi prototyping method, a better starting point is provided to evaluate technology acceptance and innovation readiness. For this purpose, a laboratory experiment is conducted with a pre- and post-survey. The results of the low-immersion group, who click through the sci-fi prototype as hypertext in the browser, are compared with the high-immersion group, who experience the sci-fi prototype in a VR environment. The results show that both sci-fi prototyping and immersive sci-fi prototyping are suitable for capturing attitude. In the immersive sci-fi prototyping method, subjects are better able to visualise the technology and, in general, VR has shown a stronger impact on attitude change. These results relate to the digital democratic assistant presented in the sci-fi prototype.

Keywords: virtual reality, science-fiction prototyping, multilinear narratives, immersion, attitude change

1. Introduction

Digital technologies are generating unprecedented forms of innovation that transcend traditional industry/sector boundaries. They encompass networks, ecosystems and communities and accelerate the ideation, development and evolution of associated products and services (Nambisan et al., 2020). The comprehensive nature and potentially profound impacts pose novel challenges to society (Nambisan et al., 2020). These impacts and challenges need to be recognized and discussed to shape the digital future. To address concerns about the long-term environmental and social impacts of technological development and to meet the information needs of decision-makers, impact assessments are undertaken (Van Eijndhoven, 1997). In democratic countries like Switzerland, the primary decision-maker is the people. Technology impact assessments must be transparent, argumentative and reflective, since they have an advisory function in the democratic system and influence the formation of public opinion (Grunwald & Saretzki, 2020). To set a valid frame of reference for technology assessment, it is important to know the significant semantics of public political customs (Grunwald & Saretzki, 2020). For this reason, it is essential to assess the readiness to innovate and the acceptance of new technologies.

Common approaches with textual or pictorial representations and a downstream survey, primarily address the cognitive side. In reality, however, decisions are strongly guided by emotions (Lerner et al., 2015). For example, a person who is afraid of the possible technology consequences behaves more conservatively and prefers the safer option to a potentially more lucrative one (Lerner et al., 2015). To capture the actual readiness to innovate, the emotional side must be considered accordingly.

The scientific community explored various approaches to capture these emotional aspects. For example, Brucker-Kley et al. (2021) examine attitude change with regard to smart farming using a sci-fi prototype (SFP) based on Johnson (2011) and find that the multilinear story has an influence on attitude formation. Thus, they confirm the results of Pirker et al. (2014) who state that SFP are a powerful tool to imagine and explore future technologies. Other researchers investigate the influence of the media format on subjects' attitudes by

manipulating technical immersion (Ahn et al., 2014, 2015, 2016; Barberia et al., 2018; Ma, 2019, 2020; Tussyadiah et al., 2018). This paper combines the two strands of research and investigates the influence of technological immersion through VR using the method of sci-fi prototyping. The SFP used is in the domain of democracy because it is relevant for determining framework conditions that shape technological change. And also, because digitalisation promotes the emergence of micro-targeting (D'Anna-Huber, 2021), echo chambers and filter bubbles (Messingschlager & Holtz, 2019), as well as fake news (Appel & Doser, 2020). These challenges in information gathering can have a negative impact on the democratic process and could push the current system to its limits. The use of new technologies can minimise these risks.

2. Research objectives

The stimulus used is an SFP based on an exploratory development scenario that introduces a digital democratic assistant (PolitBot) that will evolve over time. In the first scenario, the election recommendation is introduced, which the PolitBot creates with the help of artificial intelligence (AI). In a second step, the PolitBot can also be used to cast a vote directly. In a third step, the veto function will be introduced, in which the voter must actively oppose the recommendation. In the last scenario, a form of direct democracy is possible through the fully automated voting and the complete representation of the voting citizens by the PolitBot. Subjects can decide for or against the PolitBot at any time and thus experience the consequences of their choice and the possible development of this technology in the context of democracy. The SFP is therefore structured as a multilinear story and the protagonist or subject is directly addressed in the story at the decision points. The original story is available in German as hypertext on OSF (OSF, 2022).

Through the identification with the protagonist, the feeling of having an influence on the story as well as the information about the presented technology and the technology consequences, both experimental groups have impulses for a change in attitude. VR creates more emotional experiences than conventional media such as text or video (Visch et al., 2010). Therefore the recorded change in attitude in participants placed in a virtual environment by HTC Vive VR-glasses (VR group) is expected to be stronger than in participants reading the story in the web browser (web group). This leads to the following hypothesis:

H1: Consuming the SFP in an immersive virtual environment will have a stronger impact on attitude change (composed of the components cognition, affection, and behavior) than when the SFP is read as hypertext in a web browser.

People reading a story can be transported into a narrative world (Green & Brock, 2000). Gerrig (1993) has described this process using an actual journey: The traveller embarks on a journey with a means of transport – a narrative – and thus moves away from his or her world of origin, making some aspects of that world inaccessible. When the traveller returns to his or her world of origin, he or she has changed somewhat because of the journey. According to Roth and Koenitz (2016) identification with the characters in the story, curiosity, suspense and believability are among the key factors in becoming immersed in a narrative. Narrative involvement is also often referred to as engagement or absorption and refers to the experience of readers focusing on the events being portrayed, becoming immersed in the text and temporarily losing awareness of the real world around them (Busselle & Bilandzic, 2009; Green & Brock, 2000; Slater & Rouner, 2002). It is a mental process in which a fusion of attention, images and feelings take place (Green & Brock, 2000). In this paper, the term engagement is used. If engagement is high, it is likely to evoke strong feelings in readers towards the protagonist, and the protagonist's experiences or beliefs will have an impact on the reader's beliefs in the real world (Green & Brock, 2000). Since the use of VR-glasses shields the subjects more from the outside world and the audio effects and visual representations engage multiple senses, the participants immerse themselves better in the story than those who read the story. For this reason, the following hypotheses are put forward:

H2a: Consuming the SFP in an immersive virtual environment (compared to hypertext) will lead to higher levels of engagement.

H2b: The media format will indirectly affect the level of attitude change through the engagement with the narrative.

The concept of presence is also considered one of the key indicators for effective VR applications. In the literature, presence is often conceptualised as spatial, social and self-presence (Lombard et al., 2015). In this paper, presence is understood as the feeling, sense, or state of "being there" in a mediated environment, i.e., the aspect of spatial presence. Sas and O'Hare (2003) postulate that spatial presence involves a person's

cognitive processes being directed towards another world, which can be either technologically mediated or imagined, to the extent that the mental state of “being there” resembles that of physical reality.

Presence appears to be a causal factor in information processing performance (Kim & Biocca, 1997; Lombard & Ditton, 1997) and intensifies physical arousal as well as emotional processes, which is why the experienced story is felt more intensely and the narrative arguments seem more convincing (Breves, 2021). Immersive media such as VR enhance the perception of spatial presence. A higher degree of technical immersion in an interactive virtual simulation, leads to stronger perception of spatial presence and correspondingly to a more persuasive story (Flavián et al., 2019; Hofer, 2016; Pianzola et al., 2021). The sense of presence leads the SFP consumer to perceive a real and unmediated environment. The experience is therefore seen as direct or first-hand, which has a direct impact on attitude change (Grigorovici, 2003; Kim & Biocca, 1997). By experiencing the scenario first-hand, the technology consequences are not only cognitively, but also emotionally understood. The hypotheses are therefore as follows:

H3a: Consuming the SFP in an immersive virtual environment (compared to hypertext) will lead to a higher level of presence.

H3b: The media format will indirectly affect the level of attitude change through perceived presence during the story.

Three control variables are included for the investigation of these hypotheses. The political participation because of the political utilization of the introduced technology. The path through the story as it depends on the consumer’s decisions. And the gender because various studies have found a stronger effect of immersion in female participants (Ma, 2019). The conceptual model is depicted in Figure 1.

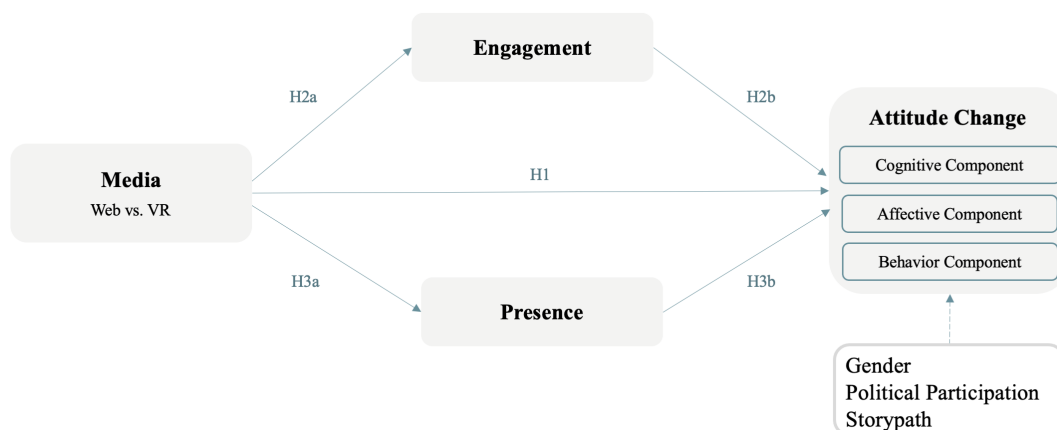


Figure 1: Conceptual model

3. Methodology and approach

The research design is based on A/B testing. This method is often used to evaluate different website interfaces, but can also be used to examine the different ways in which information is delivered in an experiment (Bateman et al., 2009). The experiment was conducted with two groups consuming the SFP in a different media format. To ensure homogeneity of the experimental groups and to ensure that the participants had the same understanding of the baseline, three criteria were established. As the SFP story is about the political process in Switzerland, participants must be eligible to vote in Switzerland. Age and education have been shown to influence voting behaviour (Madeux et al., 2021), therefore only participants between the ages of 18 and 35 who have completed a degree or are enrolled at a university are eligible.

For the web group, the subjects were recruited via the university distribution list "Research Surveys" of the ZHAW. Each participant carried out a logged online session (approximately 20 minutes) comprising 1) a pre-survey, 2) reading the hypertext story, and 3) a post-survey. The interview session and logging of the narrative intervention were conducted anonymously via a digital platform integrated through LimeSurvey. For the VR group, students were recruited directly via social networks, via the module professors of "Digital Futures" and "Digital Society", and via a poster on site. Due to the required infrastructure, the experiment for the VR group took place in the ZHAW's Mixed Reality Lab. The duration of the experiment is about 30 minutes. It includes 1)

a pre-survey, 2) experiencing the story in the virtual environment via HTC Vive VR-glasses, and 3) a post-survey. The pre- and post-surveys could be anonymously filled out on paper questionnaires or via MS Forms. They were later merged and completed with the recorded movement through the story (matching via workstation ID and timestamps). The data collected from both groups were analysed using SPSS.

The focus in the pre- and post-survey is to capture attitudes towards the functionality of the digital democratic assistant. According to the tripartite theory, an attitude consists of the components cognition, affection and behavior (Eagly & Chaiken, 1993; Fabrigar et al., 2005). In the questionnaire, the cognition component is evaluated via the dimension of imaginability with the statement "I can imagine what the function looks like". The affection component is assessed via the dimension of desirability with the statement "I find this function desirable" and the behavioral component is assessed via the dimension of utilization with the statement "I would use this function myself". The statements can each be rated on a 5-point Likert scale with the end points "Do not agree at all" and "Fully agree". The same scale is also used to evaluate the two mediators "engagement" and "presence". The statements were created based on constructs from the MEC Spatial Presence Questionnaire (MEC-SPQ) and the Temple Presence Inventory (TPI), as these are suitable for cross-media applications (Lombard et al., 2009).

The research design with the SFP, the pre/post survey and the instructions were validated in several iterations in advance with a total of nine test subjects.

4. Results

A total of 140 people participated in the experiment. Of these, nine people were excluded because the questionnaire was not completed in full or the criteria for subject selection were not met. A total of 93 data entries in the web group and 38 data entries in the VR group were analysed. In the web group the gender of the participants was almost balanced with 44% female and 55% male subjects; in the VR group only 21% of the participants were female.

Table 1 shows the mean values of the dependent variables by media. The Whitney-Mann-U-test revealed a significant influence of the media format on the attitude change ($U = 1265.500$; $p < .05$) with a weak effect ($r = .22$). Analysis of the different components of the attitude show a significant change in the cognitive component ($U = 1151.500$; $p < .05$) and the media format exerts a weak effect ($r = .028$) on the change in imaginability. The affective component shows no significant difference between the media formats ($U = 1562.500$; $p = .291$). The behavioral component shows a marginally significant difference ($U = 1414.500$; $p = .069$) and the media format has a weak effect ($r = .16$) on the change in utilization. To better understand how the changes are composed, the responses to the separate items in the pre- and post-survey were visualised (OSF, 2022). It appears that the media format has a stronger influence on the functionalities introduced later in the story resp. in a scenario further in the future.

In order to measure the influence of the media format after adding the mediators "engagement" (M1) and "presence" (M2) or the indirect influence of the media format via these two mediators on attitude change, a parallel mediation analysis is carried out as shown in Figure 2. The media format resp. the technical immersion exerts a significant influence on the presence and contributes a moderate share to the variance explanation ($R^2 = .1564$). The impact on engagement, on the other hand, is not significant. According to this, the media format is not decisive for the transportation into the story. Consequently, engagement has no influence on attitude change. On a confidence interval of 95%, a direct effect between media format and attitude change is evident ($\gamma' = 2.93$, 95% [1.11; 4.75]). Analysing the mediation on a confidence interval of 90% reveals an indirect effect via the variable presence ($\alpha_2\beta_2 = -.8137$; 90% [-1.56; -1.12]) as well as an indirect overall effect ($\alpha\beta = -.7292$; 90% [-1.39; -1.12]) (OSF, 2022). However, according to Cohen (1988), the model only makes a weak contribution with 7.7% ($R^2 = .0771$) to the variance explanation of the attitude change. Regarding the individual components, the model can explain 7.5% ($R^2 = .0748$) of the cognitive component and 4% ($R^2 = .0394$) of the behavioral component, whereby the mediators only exert an influence on the cognitive component ($\alpha\beta = -4.739$; 95% [-.95; -.02]). The model has no significant influence on the affective component (OSF, 2022).

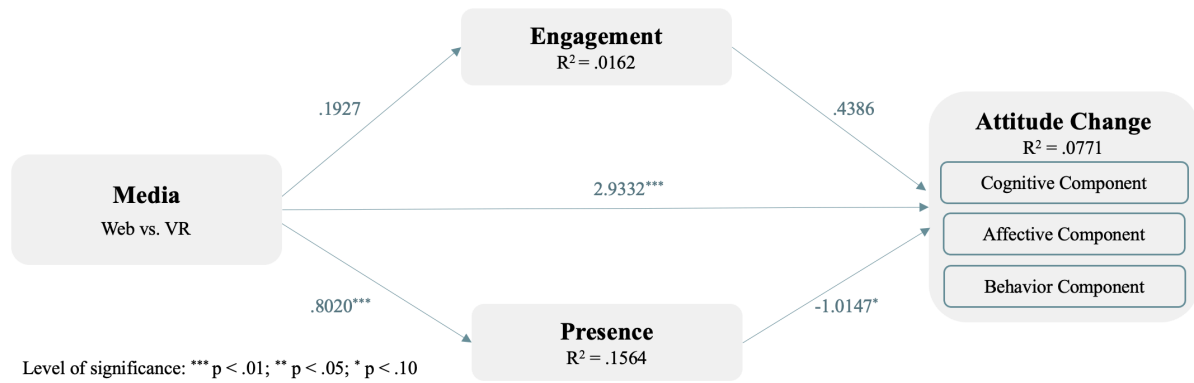


Figure 2: Model testing the impact on attitude change

When the control variables gender and political participation are included as covariates in the model, 8.7% ($R^2 = .0873$) of the variance in attitude change can be explained. Note that for gender, only the "female" and "male" groups were used. For political participation, there were two respondents who did not want to provide information on their political participation. For these reasons, the sample size for this mediation analysis was $N = 129$. Political participation shows no influence on the mediators or the dependent variables. The gender analysis shows that women have a higher engagement with the story and higher perceived presence, but no influence on attitude change is observed.

Table 1: Overview means by media, gender, and political participation

Variable	Groups		Engagement	Presence	Diff. Attitude Change	Diff. Imaginability	Diff. Desirability	Diff. Utilization
Media (N = 131)	WEB (n = 93)	Mean	3,60	2,97	6,56	2,30	2,31	1,95
	VR (n = 38)	Mean	3,79	3,77	8,76	3,63	2,58	2,55
Gender (N = 131)	male (n = 81)	Mean	3,58	3,16	7,43	2,79	2,43	2,21
	female (n = 49)	Mean	3,76	3,27	6,80	2,57	2,29	1,94
	non-binary (n = 1)	Mean	4,50	3,50	8,00	0,00	4,00	4,00
Political Participation (N = 129)	passive-little to never (n = 6)	Mean	4,11	3,54	6,00	2,00	2,00	2,00
	passive-often (n = 46)	Mean	3,58	3,36	7,76	3,00	2,37	2,39
	passive-always (n = 71)	Mean	3,64	3,05	7,00	2,61	2,41	1,99
	active (n = 6)	Mean	3,86	3,17	8,00	2,50	3,17	2,33

The paths were analysed visually and since not all possible paths through the story were chosen, they were grouped into four categories according to technology acceptance during the story (OSF, 2022). Due to the different group sizes, the influence of these categories was evaluated using the Kruskal-Wallis-test. However, the result showed that path choice was not significant in either the Web group ($H(3) = 2.452, p = .484$) or the VR group ($H(3) = 2.281; p = .516$). But it became clear that technology acceptance is much stronger in the story than in the post-survey results. Yet, the groups with rather strong technology acceptance have higher mean scores in the post-survey than the groups with rather weak technology acceptance (OSF, 2022).

5. Discussion

Hypothesis H1 can be confirmed. This result is also in line with previous research findings (Ahn et al., 2014; Barberia et al., 2018; Tussiyadiah et al., 2018). The impact of the media format is particularly evident in the scenarios that take place in the distant future in which the participants are confronted with framework conditions or technology premises that are less familiar and seem inconceivable from the current perspective.

However, looking at the individual components of attitude, it is noticeable that the media format has the greatest influence on the change in the cognitive component, followed by the behavioral component. For the affective component, there is no significant difference. This result is surprising, as Visch et al. (2010) observed an increase in the intensity of emotions with higher immersion, suggesting that VR triggers stronger emotions, which in turn are reflected in the affective component.

Hypothesis H2a can be rejected. The literature indicates that transportation through narratives can occur across media (Green & Brock, 2000), which is confirmed by the high mean values for engagement in both groups. Further reasoning is provided by the mental models approach for narrative engagement (Busselle & Bilandzic, 2009). Busselle and Bilandzic (2009) argue that narrative engagement competes with other mental processes for cognitive and emotional resources. Although subjects in the VR group were more shielded and absorbed the SFP with multiple senses, they also received more and richer impressions. The latter can be distracting or, as Busselle and Bilandzic (2009) explain, lead to greater competition. Hypothesis H2b can also be rejected. This result is at odds with the literature. Research by Green and Brock (2000) has shown that the attitudes of subjects who were transported into the world of the narrative changed more than the attitudes of subjects who were not transported. However, the SFP triggered high levels of engagement in both groups. The differences in attitude can therefore be attributed to other factors.

Hypothesis H3a can be confirmed. The results of the mediation analysis indicate a moderate variance explanation of presence by media format. This result reflects the positive relationship between technical immersion and presence found in the literature (Breves, 2021; Cummings & Bailenson, 2016; Flavián et al., 2019). However, when testing hypothesis H3b, the results of the mediation analysis only show a significant difference at a confidence interval of 90%. Hypothesis H3b can nevertheless be confirmed, as there is a marginal significance, which is mainly due to the cognitive component. This result is consistent with the literature insofar as a significant effect is found between presence and attitude change (Breves, 2021; Flavián et al., 2019). In contrast to Ma (2019), however, there is a positive direct effect of media format and a negative indirect effect via presence on attitude change in this experiment. Furthermore, it is shown that the two mediators make no or only a weak contribution to the variance explanation of the attitude change and hardly explain the effect of the media format. But the media format itself also makes only a weak contribution to the variance explanation of attitude change. This leads to the conclusion that there are other factors besides the media format that led to the change in attitude.

In summary, immersive sci-fi prototyping is suitable for capturing innovation readiness or technology acceptance in the domain of democracy. As Brucker-Kley and Keller (2020) note, there is a lack of a shared, emotional experiential basis to engage in a common discourse about desirable futures. The results of this paper suggest that immersive sci-fi prototyping could provide this foundation, as the biggest difference of technical immersion lies in imagination. For this reason, VR is particularly suitable if a concrete and shared vision of possible technology assessments is to be created.

6. Limitations and further research

This paper contributes to a better understanding of immersive sci-fi prototyping and the assessment of innovation readiness. However, the insights gained are subject to the limitations of the experiment.

The results are highly dependent on the quality of the story and the presentation of the SFP on the respective medium. To mitigate influence of other sources than the story, the web prototype was designed without animations or images, apart from a suitable background. In the VR prototype, the setting and the protagonist were visualised. To further enhance the immersion the avatars gender is selectable by the subject, but limitations in design and mobility of the avatar can lead to barriers for the identification with the protagonist. An improved sensory-motor coupling, for example by implementing full body movement, would enhance the technical immersion and therefore reinforce the perceived self-presence (Slater, 2009, 2018). Another strength of VR is the interaction with other avatars and the perception of non-verbal communication (Latoschik et al., 2017). The employed SFP did not utilize this strength as the story was built from a single-protagonist perspective and the character was isolated. With the inclusion of additional avatars, multiple protagonists could act differently, and the technology implications could be more fully conveyed. In addition, a SFP with multiple avatars would create a sense of social presence, which is a potential influence on attitude change. It would be interesting to investigate the extent to which the level of technical immersion plays a role

in attitude change to better understand the relevant factors of technical immersion in relation to attitude change or the measurement of innovation readiness.

Likewise, this paper only examines the impact of the technology presented in the story. General statements about attitudes towards new technologies cannot be derived from the results. Further research is required to investigate the influence of the technology's field of action and to reveal the suitability of the immersive sci-fi prototyping method for other technologies.

Further limitations result from the small number of subjects in the two experimental groups and the lack of representativeness. Due to the selection of participants and the existing non-response bias, the results cannot be applied to other groups of people. The different experimental conditions could also distort the results and should be considered in future studies.

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