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Priming uncertainty avoidance values: Influence of virtual reality stimuli on design creativity in ideation

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ABSTRACT

Previous studies have clearly established the impact of culture on design creativity. For example, the presence of cultural values with low uncertainty avoidance (UA, the degree of anxiety and risk aversion that people feel during ambiguous situations) is linked to low workability of creative ideas. Currently, there is limited research on potential remedies to alleviate the impact of culture, specifically with respect to UA. Therefore, this study investigates the use of technology to prime UA cultural values and mitigate their potential negative impacts on design creativity. This was achieved using stimuli that had been generated by virtual reality (VR) technology and presented in an immersive environment. Participants in an experimental study were exposed to VR stimuli designed to either decrease or increase their UA. The results showed that the VR stimuli had successfully increased and decreased low and high UA values, respectively, which mitigated the influence of UA on design creativity. Furthermore, the VR stimuli influenced the emphasis of the participants on ideation, with lowered and enhanced UA values leading to them prioritizing novelty and usefulness, respectively. Overall, the findings provided evidence that VR could be leveraged from a psychological standpoint to reduce cultural influences on creativity through targeted priming. These findings indicated the essential implications of the study in terms of understanding the effect of immersive technologies in shaping human behaviors and mindsets.

1. Introduction

Ideation, also known as conceptual design, involves a range of activities aimed at generating and developing ideas (Safin, Dorta, Pierini, Kinayoglu, & Lesage, 2016), particularly within the realm of design domain (Gonçalves & Cash, 2021). During the ideation phase, designers engage in idea generation and decision-making processes (Cross, 2006). Research in ideation evaluates the creativity of outcomes to verify the effectiveness of various techniques and stimuli (Dean et al., 2006; Lee & Ostwald, 2022). It is suggested that creativity manifests when individuals generate ideas, solutions, or products that are both novel and of value (Dean et al., 2006; Sarkar & Chakrabarti, 2011; Shah, Smith, & Vargas-Hernandez, 2003).

Creativity, a central theme in ideation, is influenced by numerous factors, including culture (Erez & Nouri, 2010; Wodehouse & Maclachlan, 2014). While the impact of culture on creativity has been examined, there remains a lack of concrete solutions to address or mitigate this influence. Few studies have proposed potential strategies, albeit without empirical support (Gong et al., 2022; Gong et al., 2023). Therefore, our study seeks to investigate the mitigation of cultural influence on creativity through virtual reality (VR) technology, with a specific focus on the cultural dimensions of uncertainty avoidance (UA).

2. Background

To deepen our understanding of the concepts and terminology utilized in this study, we conducted an in-depth review of the terms presented in our paper. We elaborated on their interrelationships within the context of our foundational framework, which incorporated seminal studies, such as the 4Ps of creativity (Rhodes, 1961) and Hofstede's theory of cultural dimensions (Hofstede, 2001), as illustrated in Fig. 1. Moreover, we have recognized the existing void in research and clearly

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stated our research aim at the end of this section.

2.1. Creativity

Creativity is defined as a person through a series of mental processes to create outputs (products) (Rhodes, 1961). This process is influenced by external forces—collectively referred to as "press," such as environmental conditions, which encompasses the 4Ps of the creativity model depicted by a pale pink oval around three circles with the white text in Fig. 1 (Rhodes, 1961). The individual or "person" is a primary determinant of creativity, with certain traits (e.g., ambition) enhancing creative output (Puccio & Grivas, 2009). "Process," or the mental activity involved, such as motivation and critical thinking, significantly shapes the creative outcome (Rhodes, 1961). The "product," viewed as a result of creativity, plays a crucial role. When a product is deemed creative, it implies that the person, process, and press are effectively synchronized (Gruszka & Tang, 2017).

When discussing "design creativity," we find this definition most succinct: "Creativity is a process by which an agent uses its ability to generate ideas, solutions or products that are novel and useful" (Chakrabarti, 2009, p. 22). Notably, design creativity demands that outcomes be both novel and useful, a specificity not as explicitly required in general creativity. Although the definition of design creativity does not mention the press, its influence is implicitly understood. Thus, design creativity is seen as a branch of creativity where an individual, influenced by internal and external factors, generates ideas and solutions that are novel and useful.

Assessing creativity in design is challenging because of its subjective nature (Park, Chun, & Lee, 2016; Sarkar & Chakrabarti, 2011). Diverse methods, both subjective and objective methods can be used to evaluate creativity in design (Casakin & Georgiev, 2021; Georgiev & Casakin, 2019; Guegan et al., 2017; X. Yang, Lin, Cheng, Yang, & Ren, 2019). Objective assessments require significant resources, including the development of frameworks, grading systems, and the creation of algorithms (Park et al., 2016). For example, Georgiev and Casakin (2020) proposed semantic measures to evaluate design conversations by analyzing theoretical measures from conversation transcripts, where participants discussed and exchanged ideas about the design task. They confirmed that semantic measures can effectively predict the creativity of design outputs. Subjective evaluations often rely on self-reporting, where participants judge their own creative abilities, performances, or experiences (Park et al., 2016). While self-assessments can align with other creativity metrics (Carson, Peterson, & Higgins, 2005), they may be influenced by biases related to social acceptability and consistency (Durmaz, Dursun, & Kabadayi, 2020). Furthermore, it is important to note that a comprehensive evaluation of design creativity often involves both subjective and objective approaches. One widely used method is the product-based evaluation method, where experts in the field evaluate the creativity of a product based on their experiences and knowledge, and the consensus among them is assessed (Long & Wang, 2022).

2.2. Culture

Culture involves transmitting and creating values, ideas, and other elements that can influence and shape the cognitive and behaviors of individuals (Kroeber & Parsons, 1958). It acts as a collective mental framework, distinguishing one group of individuals from another, named the "collective culture," as shown in Fig. 1 by an oval pink frame with black font (Hofstede, 2001). Culture plays a crucial role in the development of individuals and significantly affects the design and utility of products (Ludwig, 1992).

Hofstede (2001) identified cultural values through the delineation of six cultural dimensions: power distance, uncertainty avoidance (UA), long-term versus short-term orientation, masculinity-femininity, individualism versus collectivism, and indulgence versus restraint. To achieve this, he analyzed data from over 100 countries to establish the cultural values associated with each dimension across these nations, making his work a reference point in design and human–computer interaction studies (Ki & Shin, 2015; Peters, Winschiers-Theophilus, & Mennecke, 2015; Shin, Chotiyaputta, & Zaid, 2022; Snelders, Morel, & Havermans, 2011; Sokolov Mladenović, Mladenović, Milovančević, & Denić, 2017).

In addition, it is suggested that the collective culture, such as national culture, and individual thought and behavior interact (depicted in Fig. 1). This interaction leads individuals to develop their unique individual cultures. The blend of collective and individual culture within an individual depends on their acceptance of the collective culture (Gong, 2024; Gong et al., 2023). Furthermore, researchers recommend focusing on individual culture in studies that transcend national and societal contexts, acknowledging the unique differences among individuals despite similar backgrounds (Jung & Kellaris, 2004; Yoo, Donthu, & Lenartowicz, 2011; Yoo & Shin, 2017).

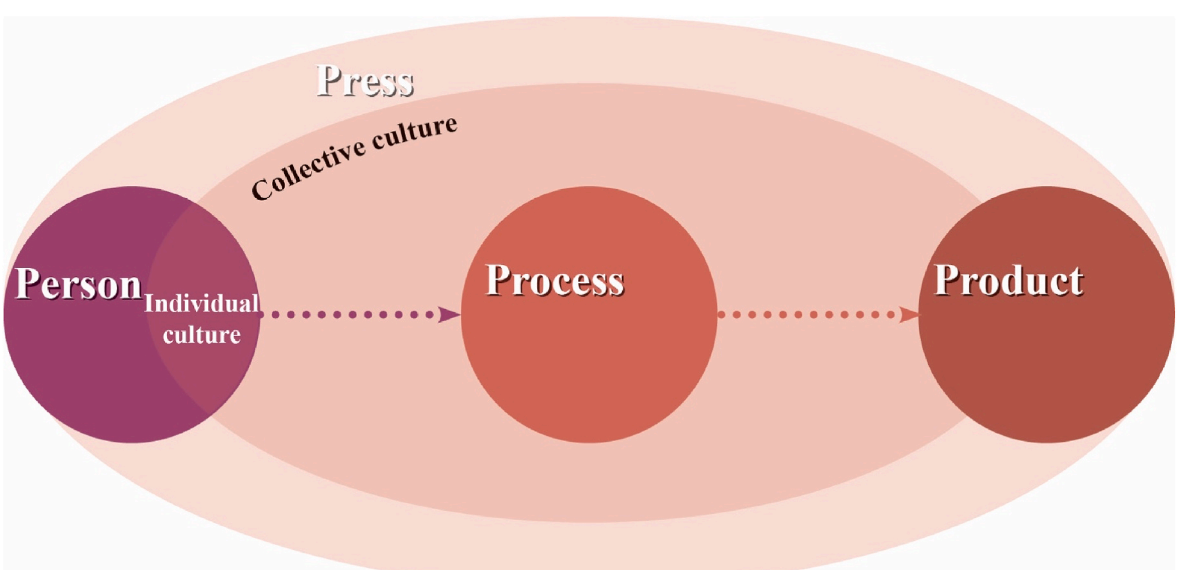


Fig. 1. Framework of the study.

2.3. Cultural influence on creativity

The interplay between collective culture and individual significantly shapes their individual culture, influencing their creative processes (Fig. 1). Studies suggest that individuals with distinct cultural values experience varied emotions, behaviors, and team collaboration approaches in creative tasks (Détienne, Baker, Vanhille, & Mougenot, 2017; Taoka, Kagohashi, & Mougenot, 2021; Wodehouse & Maclachlan, 2014). A framework based on the componential theory of creativity and Hofstede's cultural dimensions illustrates how culture affects creativity, impacting task motivation, creativity-related processes, and social environment (Gong et al., 2023). The interaction among domain-relevant skills, creativity-related processes, task motivation, social environment, and physical environment further enhances creativity (Gong, 2024; Gong et al., 2023). For example, researchers confirmed the cultural dimension (i.e., power distance) negatively affects creativity by hindering open idea sharing in hierarchical settings (Taoka et al., 2021).

Despite receiving limited attention, the dimension of UA also significantly influences creativity and innovation, as evidenced by existing research (Erez & Nouri, 2010; Gong, 2024; Shane, 1995; Wodehouse & Maclachlan, 2014). This dimension pertains to the level of apprehension and risk avoidance exhibited by individuals in situations with limited clarity or definition (Hofstede, 2001; Lai, Wang, Li, & Hu, 2016). Some cultures accept life's inherent unpredictability and the challenges it brings, while others view uncertainty as a significant threat (Hofstede, 2001; Lai et al., 2016) that affects individuals' behaviors, interpersonal interactions, and motivations (Gong et al., 2023; Wang & Liu, 2019). Cultures with high UA tend to avoid ambiguous situations, whereas those with low UA might embrace risk, influencing their creative output (Gupta, Esmaeilzadeh, Uz, & Tennant, 2019). This tendency toward risk-taking behavior affects creativity (Albar & Southcott, 2021; Wan, Lee, & Hu, 2021). Adair and Xiong (2018) conducted two experiments to investigate the impact of UA on the novelty and usefulness of creativity. Their findings indicated that individuals with higher UA levels tend to value usefulness over novelty in their creative processes. Additionally, studies have shown a negative relationship between UA and idea generation (Wodehouse & Maclachlan, 2014), with high-UA individuals generating ideas that are less novel but more useful (Erez & Nouri, 2010; Gong, 2024; Wodehouse & Maclachlan, 2014). During the ideation phase, UA influences the selection of ideas, impacting the balance of the various characteristics of design creativity. People who focus on workability tend to generate, select, and refine ideas that are highly workable (Erez & Nouri, 2010; Gong, 2024; Gong et al., 2023; Wodehouse & Maclachlan, 2014). Moreover, individuals with high UA levels seed clear, straightforward solutions, avoiding ambiguity in favor of reliable and well-defined systems (Hofstede, 2001; Sankaran et al., 2017). The ideas they favor typically excel in workability within the creative design process, outperforming other creativity aspects during ideation.

In general, cultural differences influence creativity through its aspects of novelty and usefulness. The social environment and the nature of the task can moderate these effects (Erez & Nouri, 2010). Furthermore, cultural norms regarding creativity and risk-taking significantly influence creative behaviors; cultures that value innovation may promote experimentation, whereas those that value tradition may inhibit taking risks. Creativity is also influenced by social interactions and cultural heritage, which are crucial for human culture's growth and transformation (Glăveanu, 2011). Additionally, the social setting influences the impact of culture on creativity, making shared cultural values more prominent in collective settings than in solitary work (Nouri et al., 2015).

Despite research on the link between culture and creativity, there is a lack of practical strategies to successfully address or mitigate the influence of culture on creativity. Several studies have proposed a promising method to reduce the influence of culture on design creativity, which involves activating cultural values via stimuli (i.e., VR stimuli) (Gong et al., 2023; Zhengya Gong et al., 2022; Gong et al., 2023).

2.4. Stimuli in ideation

Stimuli play a crucial role in inspiring designers to generate ideas using diverse approaches for creativity enhancement (Borgianni, Maccioni, Fiorineschi, & Rotini, 2020; Gonçalves, Cardoso, & Badke-Schaub, 2014). Research by Goldschmidt and Smolkov (2006), Gonçalves, Cardoso, and Badke-Schaub (2013), and Gonçalves et al. (2014) underscores the significance of stimuli in facilitating individual creativity in design. Specifically, certain stimuli could result in priming effects (priming), which is based on Brunauer's idea of "perceptual readiness," suggesting that presently available information and emotions influence thoughts and actions (Bruner, 1957). Priming activates a particular collection of information or sensations in the brain, making ideas, memories, and emotions connected with this activation more accessible, thereby influencing related views, choices, and behavior (She & MacDonald, 2014).

Studies have demonstrated that cultural values could be primed, influencing the subsequent intentions and behaviors (Israel, Rosenboim, & Shavit, 2014; Trafimow, Triandis, & Goto, 1991), and the influence of culture on creativity also verified by previous studies (Erez & Nouri, 2010; Shane, 1995; Wodehouse & Maclachlan, 2014). Therefore, researchers proposed that individuals' cultural values might be primed for creativity enhancement (Gong et al., 2022; Gong et al., 2023). One of the promising ways involves using VR technology to offer immersive experiences that prime cultural values for creativity enhancement, differing from traditional stimuli (Gong et al., 2022; Gong et al., 2023).

2.5. VR in ideation

Numerous studies have applied VR technology in the field of design and human-computer interaction (Ameen, Hosany, & Paul, 2022; Huang & Chang, 2023; Kaewkitipong, Beaunoyer, Ractham, & Guitton, 2023; Karnchanapayap, 2023; Pizzolante et al., 2023). VR is defined as "*a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels. These sensorial modalities are visual, auditory, tactile, smell, and taste*" (Burdea & Coiffet, 2003, p. 30). It offers distinct possibilities for facilitating the activities of individuals through real-time interactions in a simulated virtual environment (P. Wang, Miller, Han, DeVeaux, & Bailenson, 2024), thereby enhancing the sense of immersion, presence (Slater, 2018), and engagement (Hawes & Arya, 2022). VR has been instrumental in advancing interactions between humans and computers in design phases, such as ideation (Huang & Chang, 2023; Rieuf, Bouchard, & Aoussat, 2015, 2017; E. K. Yang, Lee, & Lee, 2023; E. K. Yang & Lee, 2020). In ideation, in contrast to an online teleconferencing setting, collaborative efforts facilitated by VR offer superior support for external representation activities that enable the expression and sharing of visual and spatial constructs related to potential garment design concepts. Using VR in idea generation enhances the cognitive process from idea generation to evaluation and improves evaluation sessions (E. K. Yang et al., 2023).

In this study, the term "VR stimuli" refers to stimuli developed using VR technology or the use of VR as a means of stimulation. Several studies have adopted VR stimuli in their designs (Rieuf et al., 2015, 2017). These researchers compared stimuli using VR-based immersive mood boards with two conventional mood boards (Rieuf et al., 2015). The experiences of 20 industrial designers were measured and analyzed based on a cluster of physiological, cognitive, and behavioral data. Their findings showed that VR environments significantly increase emotional engagement and active participation among designers, thereby enhancing the originality and aesthetic quality of their ideas (Rieuf, Bouchard, Meyrueis, & Omhover, 2017).

Moreover, VR stimuli have been proposed to mitigate the adverse effects of cultural influences on creativity (Gong, 2024; Gong et al., 2023). For example, researchers proposed traditional stimuli (e.g., text and photo-based stimuli) that might be presented in VR, providing more opportunities to prime individuals' cultural values based on features of VR, such as immersive experiences. This closely mimics real-world sensory modalities and produces higher arousal and presence. In addition, a VR stimulus is greatly beneficial for individuals as it integrates images, narrative, and voice; it vividly presents the stimulus and leads audiences to enhance their engagement and interest (Gong et al., 2023; Gong et al., 2023).

However, this innovative approach is still under exploration, with ongoing research required to validate that VR stimuli can mitigate the influence of UA on design creativity comprehensively.

2.6. Research aim

Although numerous studies have explored the impact of culture on design creativity (Adair & Xiong, 2018; Taoka et al., 2021; Wodehouse & Maclachlan, 2014), efforts to counteract the potential effects of culture on design have been minimal (Taoka, Kagohashi, Saito, & Mougenot, 2018). Researchers have devised a tool that is designed to support anonymous ideation (Taoka et al., 2018). This tool aims to mitigate the impact of a high power distance, which is commonly observed in East Asian countries (Taoka et al., 2018, 2021). Additionally, digital technologies, notably VR, have been proposed as an effective means for priming cultural values to mitigate their adverse effects on design creativity (Gong et al., 2023; Gong et al., 2023). However, there is limited empirical data in diminishing cultural influence on design creativity.

In this study, we experimentally investigated how the stimuli presented by VR could prime individuals' culture, specifically UA, as identified by Hofstede, and influence design creativity during ideation, as shown by the green elements in Fig. 2. The primary aim is to identify strategies for mitigating the impact of culture on design creativity through the application of VR technology in the ideation process.

The rest of the manuscript is organized as follows. Section 3 presents the proposed hypotheses. Section 4 presents the experiments performed to verify these hypotheses. Subsequently, section 5 presents the results of the experiment, and section 6 discusses the results in relation to the study's objectives. Finally, section 7 concludes the paper.

3. Proposed hypotheses

Inspired by previous studies, this study explores the potential of VR in modulating the effect of UA on design creativity. Therefore, we devised VR stimuli intended to prime the UA values of individuals prior to engaging in creative ideation tasks. Consequently, we aimed to decrease and increase the UA values of participants exhibiting high and low UA values, respectively, as depicted by the transition of footprints from navy blue to fleshy pink and from orange to fleshy pink, respectively, in Fig. 3. The initial hypotheses are.

Hypothesis 1. The UA values of participants can be influenced by VR stimuli designed to prime their UA values.

Hypothesis 1a. Individuals' UA values can be decreased by a VR stimulus designed to prime their UA values low when they have high UA values.

Hypothesis 1b. Individuals' UA values can be increased by a VR stimulus designed to prime their UA values high when they have low UA values.

In addition, the UA values of an individual have a significant influence on their design creativity during ideation (Gong, 2024; Gong et al., 2023; Wodehouse & Maclachlan, 2014). Individuals with high UA values have lower novelty while exhibiting a greater workability of ideas (Gong, 2024), as depicted by the navy blue icon in Fig. 4. Conversely, individuals with low UA values exhibit diminished workability and higher novelty (Gong, 2024), as depicted by the orange icon in Fig. 4. Considering previous studies on the influence of UA on design creativity (Gong, 2024; Gong et al., 2023; Wodehouse, Maclachlan, Grierson, & Strong, 2011; Wodehouse & Maclachlan, 2014), we postulate that after the UA values of individuals are primed contrary to their initial UA values (Hypothesis 1), the subsequent impact of UA on design creativity will be negligible. In short, we expect that the VR stimuli will "even out" the influence of cultural dimensions on the participants' creative output, meaning that no difference regarding design creativity should be found between participants with high UA or low UA, after they are primed (Fig. 4, the footsteps from the orange and navy blue icons to the fleshy pink icon). The proposed hypothesis is as follows.

Hypothesis 2. Priming participants with VR stimuli contrary to their initial UA values will counteract the effects on design creativity, balancing individuals' UA values.

4. Experimental

We conducted experiments to validate the proposed hypotheses. VR stimuli were designed to prime the UA values of the participants. In the experiment, we first requested partcipants to complete a questionnaire to collect their UA values, based on which they were divided into two conditions. After they interacted with the VR stimulus and performed the ideation task, their UA values were collected again.

4.1. VR stimuli

The VR stimuli were developed based on a story called "Sostoras" (Gong et al., 2023; Gong et al., 2022; Gardner, Gabriel, & Lee., 1999; Trafimow, Triandis, & Goto., 1991) to facilitate the activation of

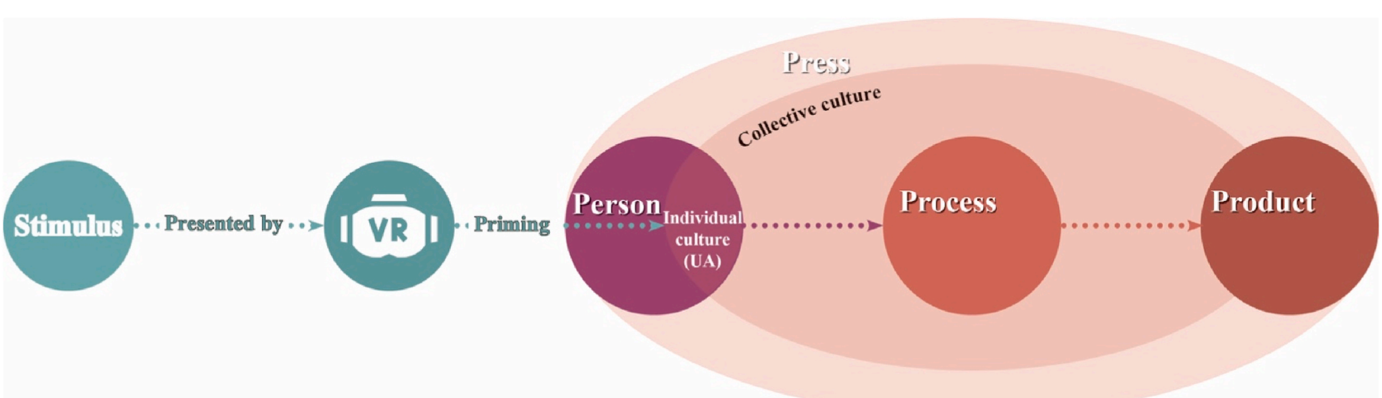


Fig. 2. Research aims.

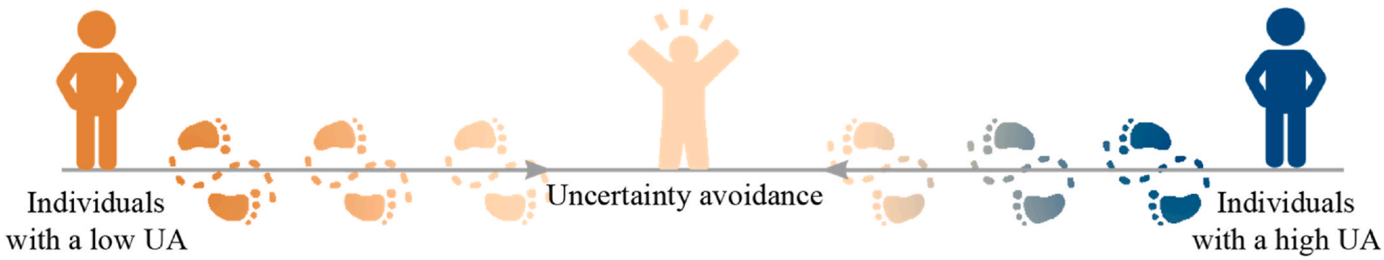


Fig. 3. Hypothesis 1. Individuals with higher UA values (navy blue icon) exhibit a decrease in UA (fleshy pink icon) after being exposed to VR stimuli and those with low levels of UA (shown as an orange icon) exhibit an increase in UA (fleshy pink icon) after being exposed to VR stimuli.

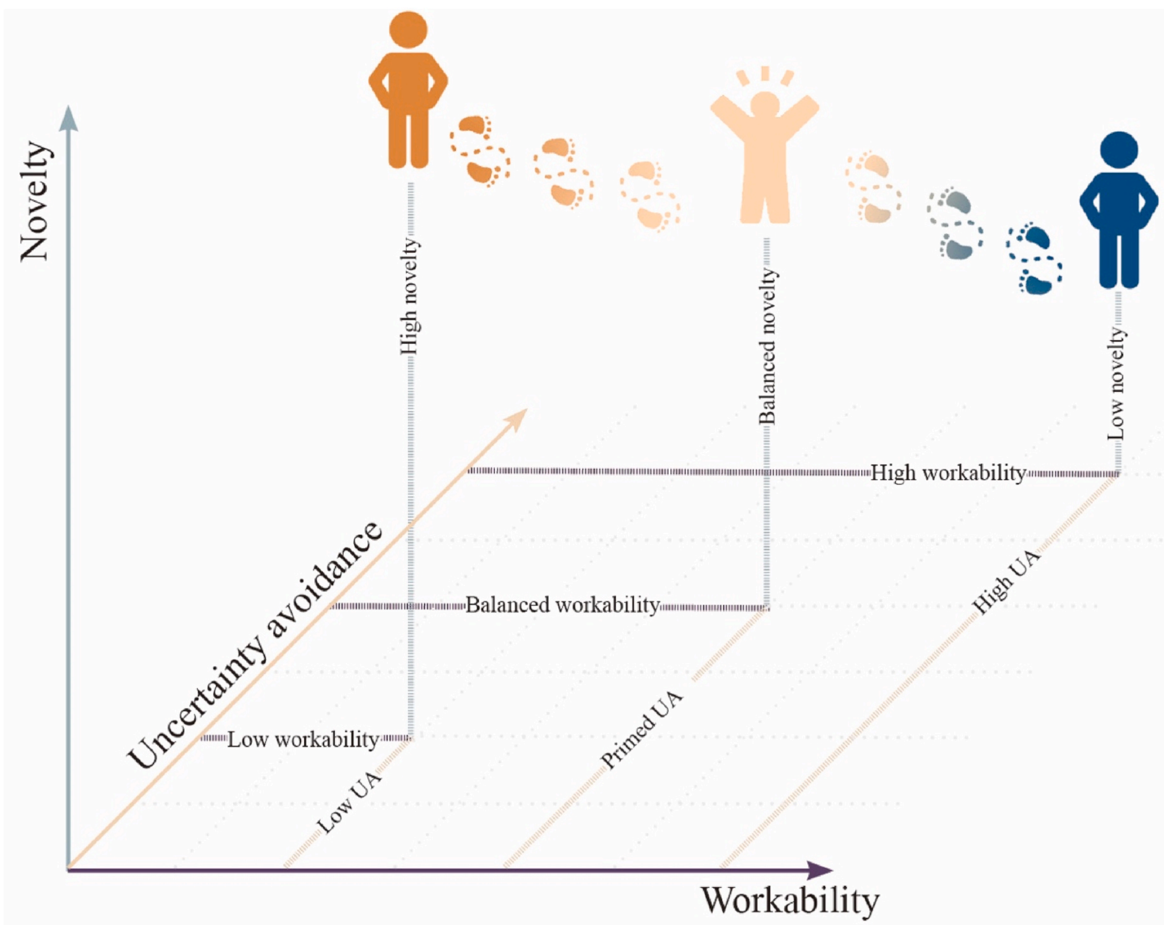


Fig. 4. Hypothesis 2. The orange icon symbolizes individuals with low levels of UA that consequently generate ideas that are highly novel but less workable. The navy blue icon represents individuals with high levels of UA that consequently generate ideas that are highly workable but less novel. The fleshy pink icon represents individuals whose generated ideas after UA value priming strike an equilibrium between novelty and workability in design creativity, which implies that the influence of UA on the novelty and workability of design creativity is negligible.

individuals' values pertaining to individualism and collectivism. The story script was adapted by authors based on the theoretical frameworks of UA and priming outlined by Hofstede (2001) and Tulving and Schacter (1990), respectively.

The VR stimuli depicted a situation in which a monarch was required to select a military commander (Gong et al., 2023). Since his nation was on the brink of armed conflict, he had to select a commander-in-chief capable of securing victory in the impending war. **In one of the conditions** (priming the UA values to be high), the monarch selected a seasoned commander, Tiglath, who had demonstrated invincibility in numerous military engagements. The monarch deemed this course of action the most reliable means of securing victory during the conflict. The selection of this commander, who had vast war experience and was the best general and thereby had greater chances to win, aimed to prime participants with higher UA values (e.g., priming individuals to avoid risk and choose a safe option). **In another condition** (priming the UA values to be low), the monarch selected a youthful individual, Tiglath, who possessed aptitude but lacked the prior experience required to serve as a military commander. He held the belief that despite the inherent risks, it was imperative to provide the younger generation with the opportunity to develop their skills through military engagement (e.g., priming individuals to be risk takers who would like to afford a risky option). Ultimately, this commander and his army emerged victorious and received compensation from the losing side.

4.2. Procedure

Prior to the experiment, we sought ethical clearance from the Delft University of Technology where we conducted the study. Following approval of the ethics committee, participants were recruited using two distinct methods. Posters were affixed within the premises of an Industrial Design Engineering faculty to solicit applications from potential candidates pursuing a master's degree program there. Several educators were involved in sending e-mails to potential candidates to request their involvement in our research endeavor. Regarding the two recruitment methods, students were required to scan a quick response code to respond to a pre-experiment questionnaire that encompassed demographic characteristics such as age, and UA scale (Jung & Kellaris, 2004). Upon completing the pre-experiment questionnaire, potential participants were contacted, and details on their availability for the experiment were obtained. Additionally, they were categorized into two

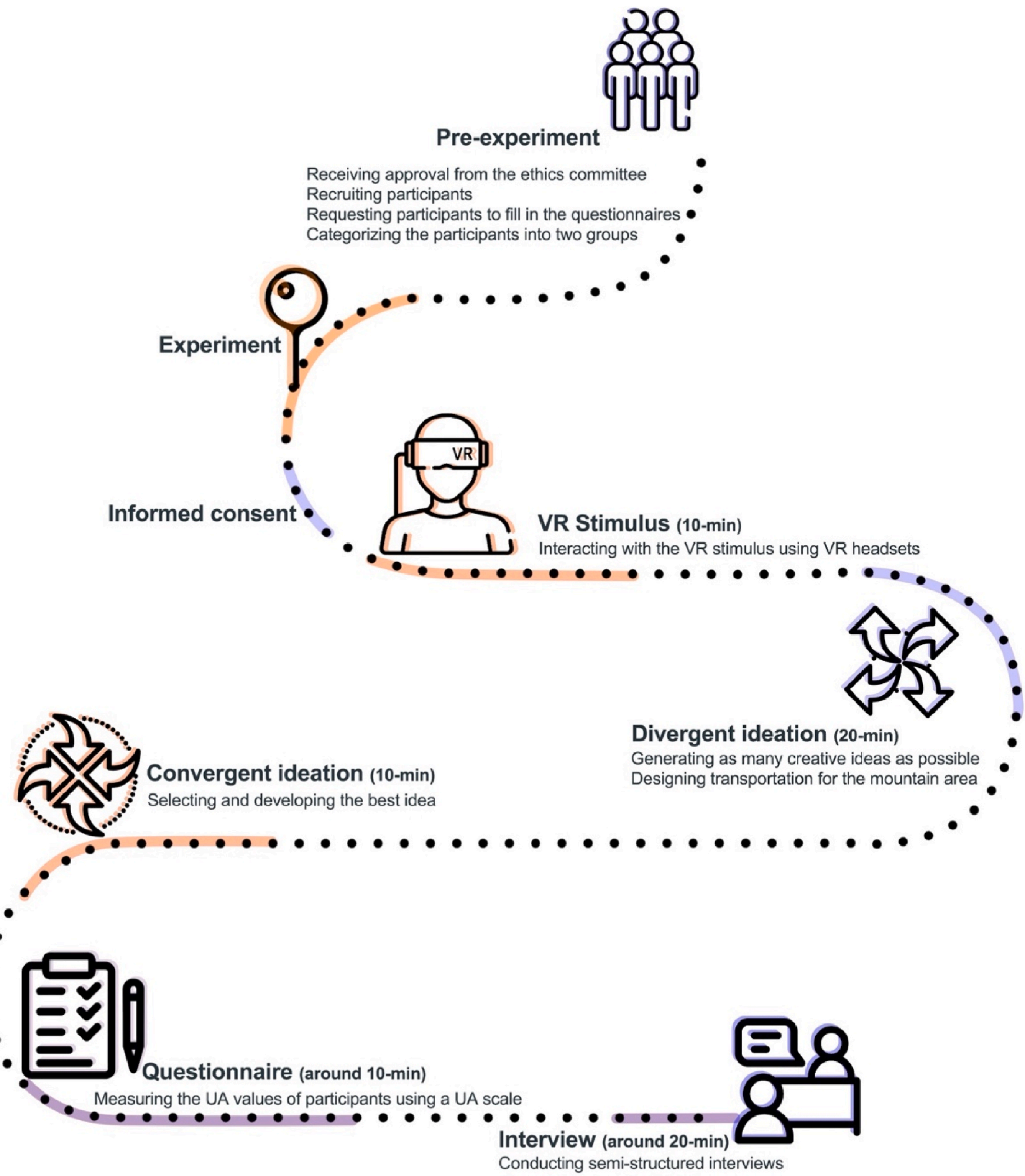


Fig. 5. Experimental procedure.

conditions based on the UA values collected in the pre-experiment questionnaire. Participants with already high UA levels were assigned to a condition aimed at priming low UA values (PLUA), while those with low UA levels were assigned to one aimed at priming higher UA levels (PHUA). All the experimental steps are illustrated in Fig. 5.

The experimental sessions were conducted in a specially prepared room with cameras and unadorned walls, in accordance with comparable ideation studies (Cash, Elias, Dekoninck, & Culley, 2012; Gonçalves & Cash, 2021). The experiment consisted of six steps, as illustrated in Fig. 5.

1. 5-min introduction: The participants were briefed on the steps in the experiment, following which they provided informed consent.
2. 10-min VR stimulus: The instructor (one of the authors) instructed the participants on correctly utilizing VR headsets (Oculus Quest 2) and a handheld device based on the pre-experiment questionnaire that had been administered to assess their dexterity. Additionally, the instructor assisted the participants in putting on the headsets. The participants testified on their degree of comfort with the headsets and confirmed that the interface was clear, there were no visual distortions, and that the controller was easy to use. Subsequently, they engaged with the VR stimulus twice. The first was a warm-up, in which they acquainted themselves with the application to ensure that there would be no difficulties in using it. In the second session, they explored the virtual environment and interacted with the VR stimuli (the short story described in Section 2.1) by clicking on the presented text.
3. 20-min divergent ideation: Participants were provided with a design brief and given 20 min to generate as many creative ideas as possible to "*design transportation for the mountain area."*
4. 10-min convergent ideation: Immediately following the divergent ideation, participants were asked to select, develop, or generate their best creative idea (the most novel and useful idea), along with sketches explaining it, including its working in mountainous areas.
5. Questionnaire completion: Following task completion, participants responded to a short questionnaire covering certain topics, mostly focusing on the UA scale (same as that used for the questionnaire that had been administered when they had been recruited) (Jung & Kellaris, 2004).
6. Semi-structured interview completion: After completing the questionnaires, we conducted semi-structured interviews (10–30 min) in which we asked the participants about their ideation, employment of stimuli, and the aspects they considered when generating their final idea. Furthermore, to ensure that the participants would be unaware of the priming manipulation, we posed the following inquiries: "To what degree did the VR experience influence your ideation process?" and "Do you still remember the story that you watched with the VR headsets?"

At the end of the experiment, we clearly explained our research aim to the participants. They expressed that they had not noticed the aim of the stimulus (VR stimuli), which is necessary for priming-related studies.

4.3. Participants

The online questionnaire was completed by 30 students, of which only 24 completed the experiment; the remaining six did not participate because of scheduling conflicts or communication-related issues. Thus, this study included a sample of 24 participants (14 female and 10 male). The participants were master's degree design students with a mean age of 25 years. As previously stated, based on their initially assessed UA values, the participants were assigned to one of two groups that each represented a distinct priming condition. There were seven females and five males in each group. The PHUA and PLUA conditions exhibited mean ages of 24.7 and 25.4, respectively (Table 1). The participants comprised individuals of different nationalities from diverse countries owing to the international nature of the program.

4.4. Data collection

The quantitative data collected were analyzed using IBM SPSS version 26.0 (IBM SPSS Statistics, Chicago, USA); internal consistency was checked with Cronbach's alpha coefficient, agreement among raters was assessed using Kendall's coefficient of concordance, the paired-sample *t*-test (Shapiro–Wilk test) helped analyze differences within pairs of conditions, the Mann–Whitney *U* test was used to compare differences between two conditions, and Spearman's rank correlation coefficient was used to examine the association between two variables. Detailed information on the data collection and results can be found in Sections 4.4 and 5, respectively.

4.4.1. Measurement of the uncertainty avoidance values

Jung and Kellaris (2004) developed a UA scale based on the definition and description of UA (Hofstede, 2001), which is reliable and has been adopted for various types of research such as that on customer behavior (Chung & Saini, 2022) and the innovative behaviors of employees (J. Yang, Chang, Chen, Zhou, & Zhang, 2020). Regarding 5- and 7-point scales, they are equivalent when used in analytical tools (Dawes, 2008), with 7-point scales potentially resulting in lower-quality data (Revilla, Saris, & Krosnick, 2014). Therefore, we developed a UA scale using a 5-point Likert scale to measure the UA values of the participants across seven items (Jung & Kellaris, 2004), with 1 indicating "strongly disagree" and 5 indicating "strongly agree."

We assessed the internal consistency of the scale as a reliability metric; internal consistency refers to the degree to which the items on a scale measure the same underlying construct. The results of the questionnaire completed by the participants indicated that the scale had demonstrated a high level of internal consistency, as evidenced by its Cronbach's alpha coefficient of 0.814.

4.4.2. Measurement of creativity

Regarding creativity metrics, there are many for assessing creativity or ideas (Adams, Aleong, Goldstein, & Solis, 2018; Dean et al., 2006; Ou, Goldschmidt, & Erez, 2023; Sääksjärvi & Gonçalves, 2018; Shah et al., 2003; Toh & Miller, 2015; Verhaegen, Vandevenne, Peeters, & Duflou, 2013). As suggested by scholars, ideas should be evaluated based on four aspects: novelty, variety, quality, and quantity (Shah et al., 2003). However, our primary emphasis was on the ultimate manifestation of the creativity of the individuals, which could be ascertained by evaluating their final ideas. Therefore, several dimensions such as variety and quantity, as suggested by the prior research of Shah et al. (2003) and Verhaegen et al. (2013), were not considered in our study. Moreover, we aimed to evaluate ideas, rendering certain creativity assessments, such as those based on products, inappropriate for our study (Jagtap, 2019).

Table 1
Descriptive statistics for the two priming conditions.

		PHUA (*n = 12*)			PLUA (*n = 12*)			Total (*n = 24*)		
			n	*%*		*n*	*%*		*n*	*%*
Age	M	24.7			25.4			25		
Gender	Male		5	41.7		5	41.7		10	41.7
	Female		7	58.3		7	58.3		14	58.3

After analyzing existing creativity metrics and applying exclusion criteria, we adopted the metrics and processes for evaluating ideas outlined in the research of Dean et al. (2006). According to them, when examining idea creativity, it is important to consider two dimensions of assessment: novelty and quality. Quality can be further categorized into three dimensions (workability/feasibility, relevance, and specificity), each with two sub-dimensions.

Novelty refers to the extent to which an idea is original and modifies an existing paradigm. It includes two sub-dimensions - *originality* and *paradigm relatedness* (Dean et al., 2006), where *paradigm relatedness* pertains to the extent to which an idea aligns with or deviates from existing paradigms; it is categorized as either paradigm preserving or paradigm modifying.

Workability/feasibility comprises *acceptability* and *implementability*, and pertains to the degree to which an idea can be practically executed without contravening established limitations (Dean et al., 2006).

Relevance refers to the pertinence of an idea with respect to the issue being addressed and its potential to result in a successful resolution. It can be further classified into two sub-dimensions: *applicability* and *effectiveness* (Dean et al., 2006).

Specificity, including two sub-dimensions: *completeness* and *implicational explicitness*, which pertains to the level of detail and clarity with which an idea has been developed (Dean et al., 2006).

The ideas were evaluated independently by two highly qualified raters who had a professional background of approximately ten years each in the fields of design and creativity. The 24 best ideas (selected and developed by participants) were assessed by raters in eight sub-dimensions: originality, paradigm relatedness, acceptability, implementability, applicability, effectiveness, completeness, and implicational explicitness (Dean et al., 2006). The ratings were conducted independently, ranging from 1 to 4 for the former six sub-dimensions and 1–3 for the latter two, based on the recommended application (Dean et al., 2006).

Kendall's coefficient of concordance (Kendall's *W*) was used to evaluate the inter-rater agreement. This metric is frequently utilized for continuous or ordinal scales, particularly in scenarios involving multiple raters (Bassler, Marascuilo, & McSweeney, 1978). The degree of creativity exhibited by the 24 evaluated ideas was assessed using a 3- or 4-point scale. The two raters exhibited a statistically significant level of agreement in their assessments, as indicated by Kendall's W ($W = 0.755$, $p < 0.0005$), which implied a strong agreement and high confidence in the rankings (Schmidt, 1997).

4.4.3. Qualitative data

For analyzing the qualitative data, we followed the thematic analysis approach (Kiger & Varpio, 2020). The process began with an in-depth engagement with video-based interviews, converting these visual data into text for detailed examination. The initial step is crucial for identifying data elements, inquiries, and relationships between data points. Thus, we classified the data into two primary themes based on the participants' comments during the interview: *emphasis on design creativity* and the *influence of VR stimuli* in the design process.

During the analysis, responses related to their consideration of creativity and the influence of VR stimuli were collected and examined. A review of these themes led to the generation of additional sub-themes from the interview transcripts. For example, for the sub-theme of *emphasis on design creativity*, discussions that revolved around the practicality, feasibility, and implementation of ideas were categorized under the sub-theme of "emphasis on usefulness." Conversely, conversations highlighting novelty, uniqueness and originality were classified under "emphasis on novelty." If participants did not explicitly lean towards novelty or usefulness, their responses were classified under "balanced emphasis," indicating an equal consideration for both aspects of design creativity. Further analysis allowed for the detailed coding of sub-themes, such as the "immersive experience of VR", "observations within the virtual environment", and "negative influences" identified, all categorized under the broader theme of *influence of VR stimuli*. The final stage involved naming each theme and presenting the findings in the results and discussion sections (sections 5 and 6), showcasing the nuanced impact of VR on design creativity from the participants' perspectives.

5. Results

To fulfil our research objective and validate our hypotheses, we analyzed the data obtained from the assessed ideas and questionnaires. The subsequent subsections delineate the comprehensive outcomes in the order of our research inquiries.

5.1. Effectiveness of stimuli

The UA values of the participants were measured twice, both before and after exposure to the VR stimulus, to assess the efficacy of priming their UA values with the VR stimuli. A paired-sample *t*-test was used to ascertain whether the mean disparity between the paired observations had been statistically significant.

The absence of outliers in the data in the PLUA condition (aimed at priming a low UA value) was determined by visually inspecting a boxplot. The normal distribution of the difference scores between the initial and subsequent UA values was evaluated using the Shapiro–Wilk test, yielding a p-value of 0.443. There was a statistically significant decrease in the UA values of the participants after they had engaged with the VR stimulus in the PLUA condition. Specifically, the mean UA value decreased from 24.75 ± 2.83 (before the VR stimulus) to 21.25 ± 2.77 (after it), resulting in a decrease of 3.5 (95% confidence interval [CI]: 4.57 to -2.43), $t(11) = -7.22$, and $p < 0.0005$. The findings conclusively support Hypothesis 1a, demonstrating that VR stimuli can effectively decrease the UA values in participants who initially exhibit high UA levels, with statistical significance.

The PHUA condition (aimed at priming a high UA value) exhibited an outlier that exceeded 1.5 box lengths from the edge of the boxplot; the outlier was removed. The normality of the differences scores between initial and subsequent UA values was evaluated using the Shapiro–Wilk test, which yielded a p-value of 0.609, indicating a normal distribution. The statistical values presented in the data are expressed as the mean ± standard deviation unless explicitly specified otherwise. The study's findings indicated that the UA values of the participants, after the VR stimulus exposure in the PHUA condition, increased significantly from 16.18 ± 3.77 to 17.63 ± 3.11, with a mean increase of 1.45 (95% CI: 2.88 to 0.34), $t(11) = 2.28$, and $p = 0.046$. This supports Hypothesis 1b suggesting that VR stimuli can effectively increase low UA value in participants.

5.2. Design creativity

All the scores were averaged for each idea, based on the ratings of the two raters. The Mann–Whitney *U* test was performed to determine whether there had been differences in creativity scores under the PHUA and PLUA conditions as a nonparametric alternative to the independent-samples *t*-test (due to outliers). The distributions of creativity scores for the PHUA and PLUA conditions were similar, as assessed by visual inspection. The median creativity scores (novel, workability, relevance, specificity, and quality) were not statistically significantly different; an exact sampling distribution was used for U (Hollander, Wolfe, & Chicken, 2013), as shown in Table 2.

To provide evidence for **Hypothesis 2**, Spearman's rank-order correlation was used to evaluate the correlation between the UA values and creativity. An initial visual examination of the scatterplot revealed a monotonic relationship. However, the study found no significant statistical correlation between UA values and any aspect of creativity, as indicated in Table 3. These findings affirm **Hypothesis 2**, suggesting

Table 2
Results of the Mann–Whitney *U* test.

Creativity	Group	Median	Mann–Whitney *U* test	Z	Asymp. Sig. (2-tailed)
Novelty	PLUA	5.25	55.50	−0.96	0.34
	PHUA	4.50			
Quality	PLUA	16.50	65.50	−0.38	0.71
	PHUA	16.50			
Workability	PLUA	5.00	51.00	−1.22	0.22
	PHUA	5.75			
Relevance	PLUA	6.00	64.50	−0.44	0.66
	PHUA	5.50			
Specificity	PLUA	5.00	70.50	−0.09	0.93
	PHUA	4.25			

that the influence of UA on design creativity could be negligible when participants' UA values are primed by VR stimuli aiming to balance individuals' UA values. Previous research has established correlations between UA and design creativity (Gong, 2024; Wodehouse et al., 2011; Wodehouse & Maclachlan, 2014). The results confirmed that the influence of UA on the novelty and workability of design creativity could be reduced by using VR stimuli to prime the UA values.

5.3. Emphasis on design creativity

The interview results showed that the ideas of 7, 4, and 13 participants had prioritized novelty, a balance of both novelty and usefulness, and usefulness (Fig. 6), respectively. A statistically significant difference was observed between the two conditions of PHUA and PLUA, as indicated by the results of the Mann–Whitney *U* test ($U = 31.5$, $z = -2.593$, $p = 0.017$). Overall, the emphasis on design creativity differed when the UA values of the participants had been primed. Specifically, individuals primed to have high and low UA values prioritized the usefulness and novelty of design creativity, respectively.

6. Discussion

As previously elucidated, design creativity, especially novelty and workability, is impacted by the UA values of individuals (Gong, 2024). We created VR stimuli to prime the UA values of individuals to mitigate the effects of UA values on design creativity (i.e., novelty and workability). Specifically, the UA values of the participants were primed to decrease and increase when their initial UA values had been high and low, respectively. We aimed to verify whether the influence of UA on design creativity could be mitigated by VR stimuli, which was confirmed by the absence of a correlation between design creativity and UA values after priming the UA values of the participants.

In this section, we discussed the influences of VR stimuli on the UA values of individuals, design creativity and ideation. In addition, we explored the significance of our findings in the fields of culture and design creativity, highlighting the theoretical and methodological strengths of the study while acknowledging its limitations.

6.1. Influences of VR stimuli on the UA values of individuals

The study observed significant differences in UA values before and after the VR intervention, as illustrated in Fig. 7. Here, initial UA values are represented by navy blue and orange dots, with post-exposure, VR-primed values are shown as fleshy pink dots. The navy blue arrows

Table 3
Spearman's rank correlation coefficient.

		Novelty	Quality	Workability	Relevance	Specificity
Primed UA	Correlation coefficient	0.072	−0.142	−0.278	0.067	−0.260
	Sig. (2-tailed)	0.737	0.507	0.188	0.757	0.219

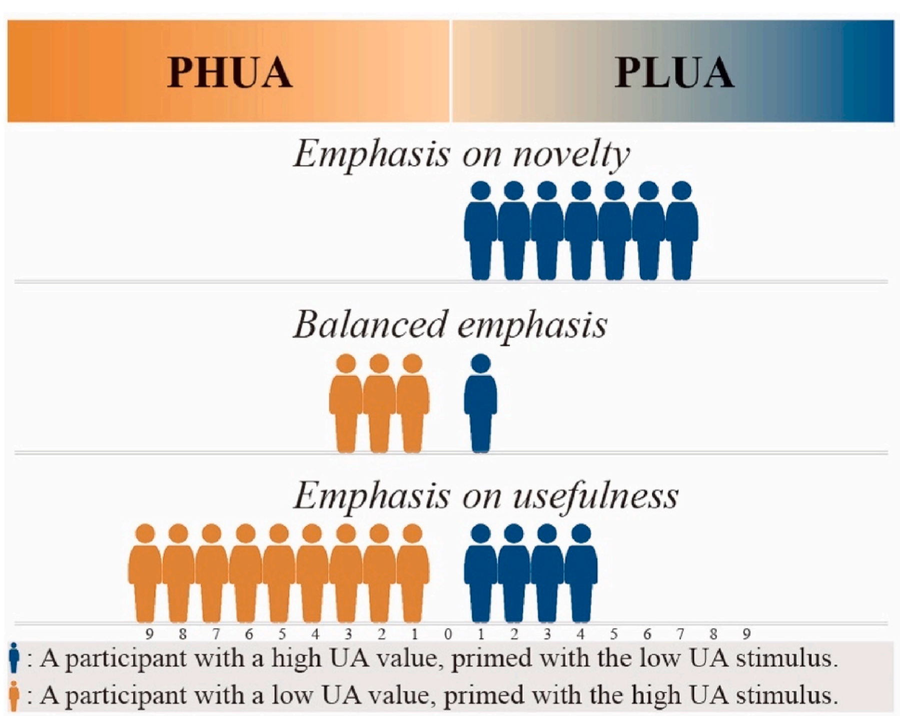


Fig. 6. Distribution of emphasis on the design creativity under different conditions.

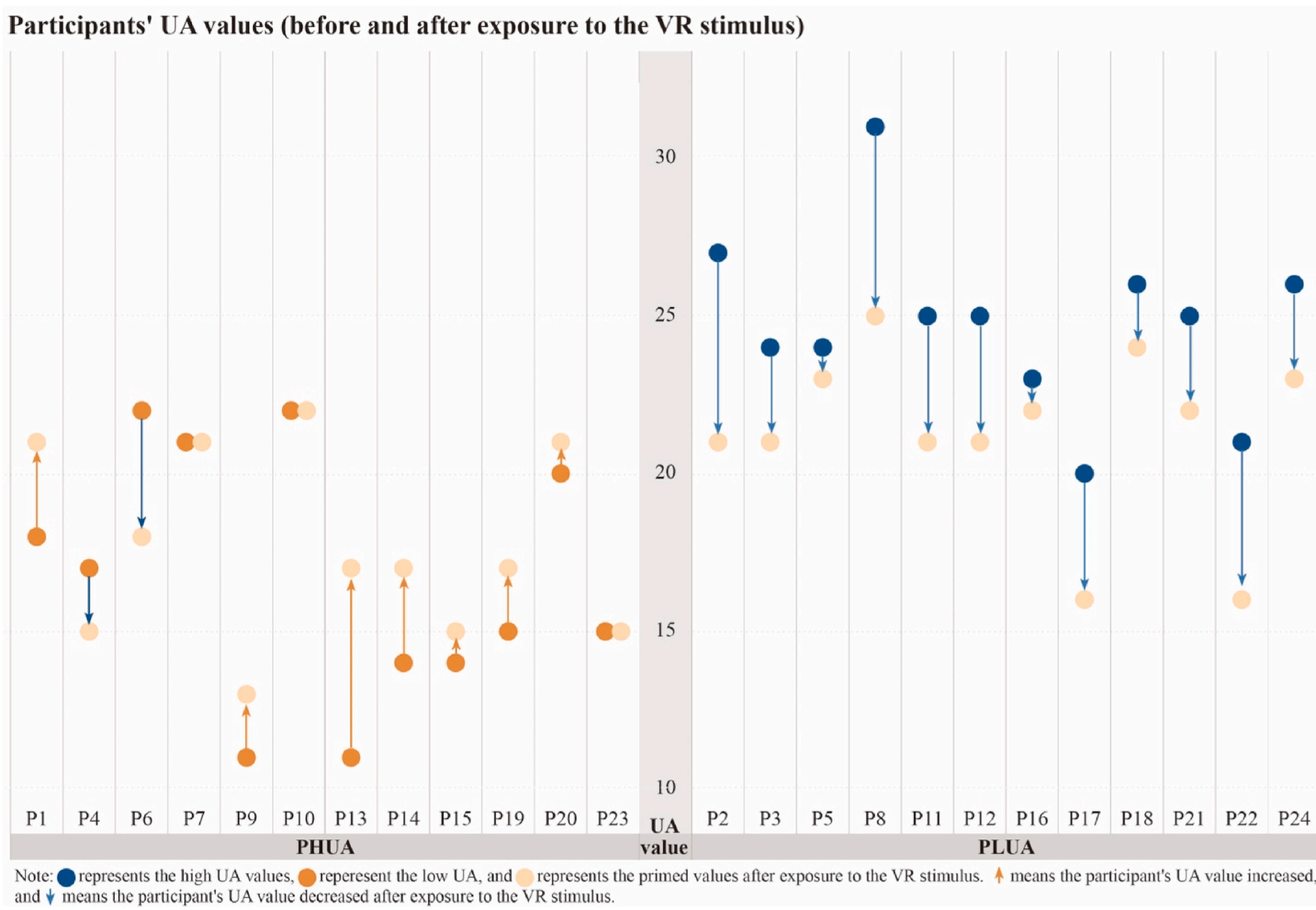


Fig. 7. Recorded UA values of the participants before and after being exposed to the VR stimulus.

indicate UA values primed to be low, while the orange arrows indicate those primed to be high. Despite most data aligning with expectations, some UA values post-priming deviated, prompting a deeper analysis through qualitative insights from participant interviews.

Regarding the UA values of the participants, the results indicated that before and after exposure to the VR stimuli, the PLUA and PHUA conditions had difference scores of 3.5 and 1.45, respectively. These findings indicated that low priming UA values might be more effective than high priming UA values. This could be attributed to individuals, especially those in design-related fields, tending to perceive risk-taking as important for generating creative and pioneering ideas and products. The responses of participants to the explanation of our research aims became apparent after the post-interview, supporting our inference. Upon informing them of their higher UA values and tendency toward risk aversion, many expressed skepticisms in the form of responses such as “*I would not say that*” (Participant 22). They declined to be risk-averse in the design process and maintained that it would not be advantageous for the design process. By contrast, individuals with low UA values expressed a sense of pride and satisfaction with their low UA values. For example, Participant 15 expressed the view that “*uncertainty triggers creativity*.”

Regarding the unexpected results of priming, Participants 4 and 6, who had anticipated being primed and had exhibited a higher value than their initial UA value, exhibited a decreased UA value. Furthermore, there were no changes in the UA values of Participants 7, 10, and 23. Based on the data derived from the interviews, it was observed that the participants had perceived VR stimuli as a source of distraction or a negative influence owing to their inability to disengage from the virtual environment. For example, Participant 6 said that he had found the VR experience somewhat distracting because of the presence of a prominent and intimidating knight character. Participant 7 reported feeling stuck during ideation because of the VR stimulus, stating, “*Yeah. The first thing that I was thinking, I was still in the story thinking about wagons and about animals pushing the wagons up, and there was not say it (design task) has to do anything with the story (VR stimuli). Yes. However, it made me think about the goods transportation part of that.* Two participants (Participants 5 and 15, who had a minor change in UA after exposure to the VR stimulus) were entrapped within the virtual environment, as exemplified by the statement, “*It is really hard to get out of the zone. Thus, I did some random things to kind of develop my understanding. However, it was hard to think outside that area*,” and “*I would say that the surroundings scenes had influenced me a lot because I could not picture any flat place in the mountains*."

Therefore, VR stimuli may be a double-edged sword in the design process, serving as a tool to prime the UA values of participants to influence their subsequent performance and output in ideation. However, it is plausible that VR stimuli could serve as potential distractions, thereby exerting a detrimental effect on the subsequent performances of participants. Nevertheless, our current understanding on their effects remains limited, necessitating additional investigations for a more comprehensive understanding.

6.2. *Influences of VR stimuli on design creativity*

Our results revealed that VR stimuli aimed at priming UA values had mitigated the influence of UA on design creativity. Moreover, we gained a deeper understanding through the interviews regarding the perception of participants toward their UA values and how it had influenced their idea generation and selection. Participants exposed to a VR stimulus aimed at priming high UA values had emphasized the usefulness of the ideas while generating viable transportation solutions for mountainous regions. In contrast, those exposed to a VR stimulus aimed at priming low UA values tended to focus their attention on novel ideas, such as those that were infrequent or rare, potentially disregarding concerns regarding their feasibility.

The present study confirmed no correlation between UA values and design creativity across all dimensions and no difference between the two conditions in design creativity when participants had been exposed to VR stimuli that had primed their UA values. It suggests that the influence of UA values on design creativity, particularly in terms of workability and novelty, had been mitigated. Novelty and usefulness are the two fundamental dimensions that encompass the concept of creativity. Achieving equilibrium between them guarantees that ideas possess originality and practicality in real-life contexts. An idea characterized by high novelty but low workability may not yield substantial effects, whereas a highly workable yet unoriginal idea may not foster innovation.

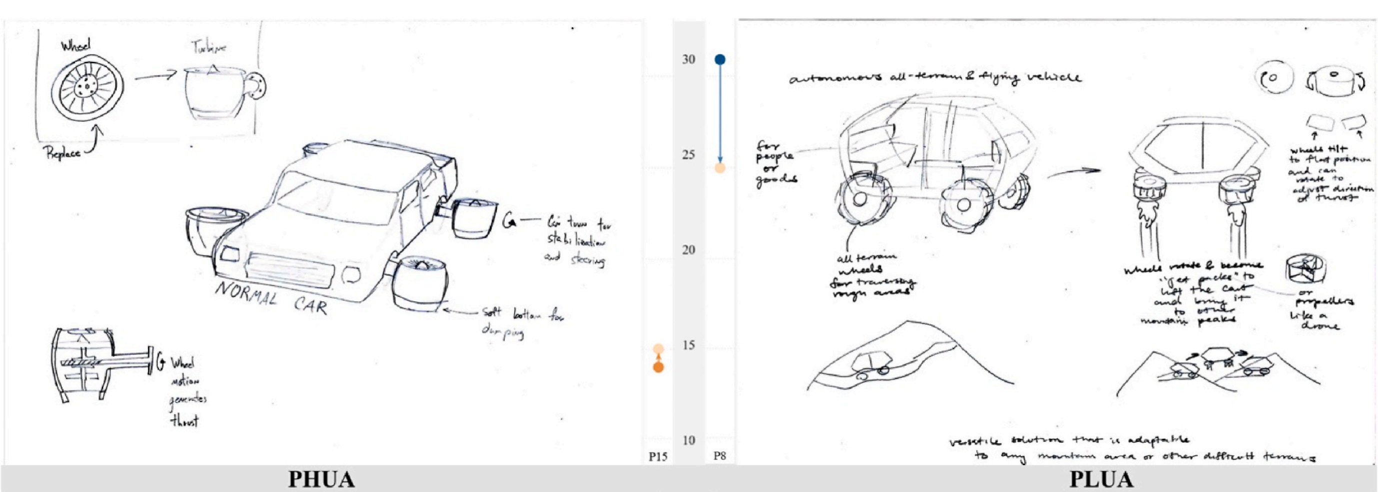
The left and right sides of Fig. 8 depict the ideas generated by Participant 15 (P15) and Participant 8 (P8), respectively. P15 demonstrated a low UA value and was subsequently subjected to a VR stimulus to elicit a high UA value, and P8 had initially exhibited a high UA value and was subsequently exposed to a VR stimulus to elicit a low UA value. Based on previous research examining the influence of UA on design creativity (Adair & Xiong, 2018; Gong, 2024; Wodehouse & Maclachlan, 2014; Wodehouse et al., 2011), it was expected that P15 might exhibit a tendency to generate ideas characterized by a high degree of novelty but a low level of workability. Conversely, P8 was expected to produce ideas with low novelty but high workability. However, the scores for their ideas exhibited a comparable level of novelty and workability after exposure to the VR stimuli, and their UA values had been primed. This observation confirmed that the impact of low levels of UA on the workability of design creativity and that of high levels of UA on the novelty of design creativity could be mitigated by the presence of VR stimuli.

Fig. 9 presents two separate instances that further explain the influence of VR stimuli in priming UA on design creativity; the left and right sides present ideas characterized by high levels of workability and novelty, respectively. Participant 4 (P4) initially had low UA levels. It was inferred that he had preferred risk taking and novelty to workability, as indicated in a previous study (Gong, 2024; Gong et al., 2023). However, although the UA value of P4 did not increase as expected (the navy blue arrow on the left side of Fig. 9), the final idea (as the best idea) he had generated and selected prioritized workability over novelty. This suggested that his focus had shifted toward workability over novelty following exposure to VR stimuli to prime UA values, verifying that the influence of a low UA value on the workability of the design had been mitigated. Furthermore, the interview corroborated this insight; the participant believed that his final idea was more focused on usefulness rather than novelty. In contrast, participant 24 (P24) had been subjected to a VR stimulus that had resulted in a reduction in UA value. Her final idea had a high novelty score, as shown in Fig. 9 (right panel). She confirmed that she had prioritized novelty rather than usefulness when developing her final idea, further verifying that the influence of a high UA value on the novelty of the design had been mitigated.

6.3. *Influence of VR stimuli on ideation*

As mentioned previously, the influence of VR stimuli during the design process can be either positive or negative. On the one hand, the participants indicated that their VR experience had served as a source of inspiration, as it had offered immersive experiences, including making them feel as if they were there (presence) and giving them an opportunity to observe the mountainous area. More than half of the participants expressed positive experiences related to immersion and presence. Participant 16 stated, "*I really like that environment. For me, it was like going in a different zone. Seeing the mountains and all for a minute made me feel like I was not in the room,*" Participants also stated, "*It was nice to see the mountains and be slightly immersed in how it looked,*" and "*It was more like being in a natural environment.*" Another participant described how she had been stuck generating more ideas and subsequently recalled her VR experience of standing on a mountain, which had inspired further ideas of progression. Additionally, the participants could observe the virtual environment related to their ideation tasks, which had helped them recall their past experiences in this context.

However, VR stimuli could potentially result in the adoption of fixation behaviors, including becoming ensnared within the virtual environment and experiencing an inability to disengage from the state. Participants became trapped within the confines of the virtual environment, rendering them unable to extricate themselves and limiting their ideation exclusively to ideas associated with the presented environment. The interview responses conveyed that several participants had been trapped in the virtual environment to varying degrees, such as in ancient times and steep mountains; this requires further exploration.



Note: represents the high UA values, reperesent the low UA, and represents the primed values after exposure to the VR stimulus. means the participant's UA value increased, and means the participant's UA value decreased after exposure to the VR stimulus.

Fig. 8. Examples of ideas with similar workability and novelty scores generated by participants in two conditions.

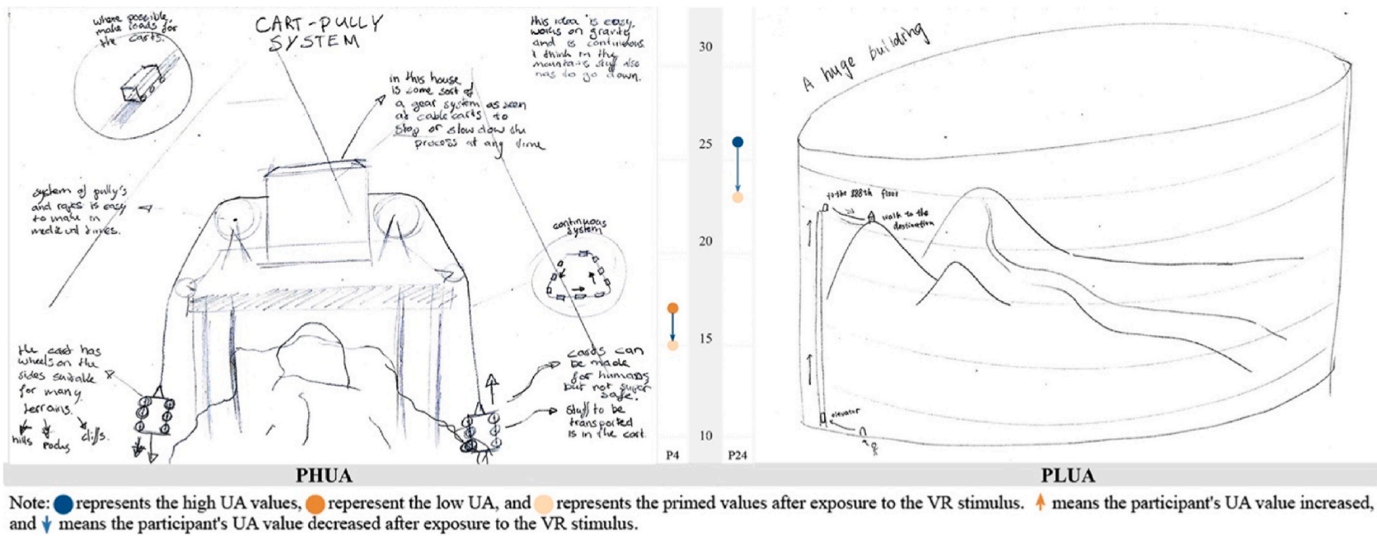


Fig. 9. Examples of ideas with high novelty and workability scores generated by participants in two conditions.

6.4. Significance and implications of findings

6.4.1. Significance of findings

Our research provides theoretical and methodological insights on the connections between culture, design creativity, and the role of VR in priming from psychological and social mechanisms, as depicted in Fig. 10. This study is the first to use a VR stimulus to prime culture in the context of design creativity, showcasing that priming can effectively diminish the cultural influence on design creativity. When individuals' culture was primed, their ideation processes were influenced by the stimulus they were exposed to. This was reflected in their outputs (design creativity), as illustrated in Fig. 10 by the green elements.

In design research, a stimulus refers to sources of information that aid designers in developing ideas by presenting potential sources of inspiration (Gonçalves et al., 2014). It can be introduced either before starting or during the ideation process (Vasconcelos & Crilly, 2016). The effects of the stimulation are evaluated through objective metrics (e.g., the number of ideas or the diversity of ideas) or subjective assessments (e.g., novelty or workability) (Vasconcelos & Crilly, 2016). However, the stimulus used in our research was intended to induce priming effects on individuals' culture rather than serving as an inspiration, marking a novel approach in the design field.

Cultural priming, a concept from cross-cultural psychology and social psychology, involves the study of how individuals perceive events and ideas, such as cultural frame-flipping and self-concept (Kitayama & Dov, 2010). Researchers used stimuli to prime participants' cultural values (long-term versus short-term orientation) by reading a paragraph, thus influencing their intentions (Wong & Wyer, 2016). Previous studies have shown that an individual's culture could be primed to impact their subsequent intents and actions (Gardner, Gabriel, & Lee, 1999). However, no research has used this concept in design studies to enhance design creativity by priming individuals' cultures. Our work is novel, suggesting a new avenue for researchers in the design field to investigate the enhancement of creativity through a cultural preceptive.

VR technology, recognized for its potential to enhance creativity beyond traditional methods, introduces immersive environments that heighten participant engagement (Hwang, Sun, McKee, & Stevenson Won, 2020). In addition, researchers conducted a large-scale experiment, with over two hundred participants, to outline the typical design behaviors and their connection to the final design and its context (P. Wang et al., 2024). There are limited studies on VR stimuli. One study comparing VR stimuli to two-dimensional stimuli found that immersive VR experiences encouraged participants to enhance the novelty and feasibility of design creativity, resulting from interpreting abstract semantics at a deeper level, spending more time observing stimuli, and experiencing heightened emotional, and positive responses (Chai et al.,

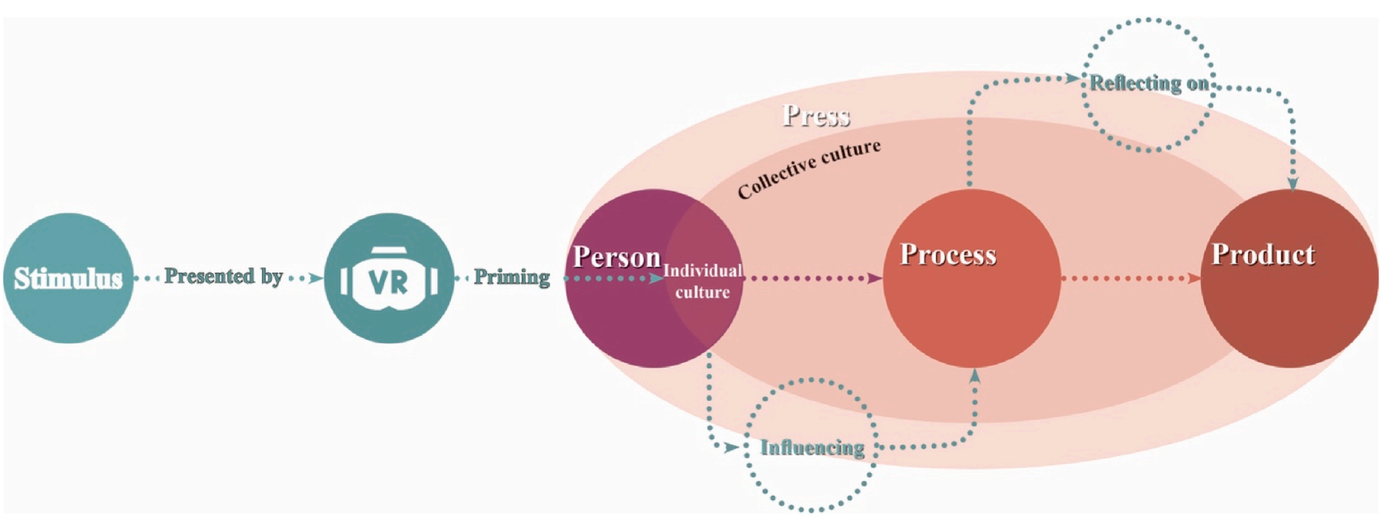


Fig. 10. Contribution of the current study.

2023). In addition, some researchers proposed using VR stimuli for cultural priming (Gong et al., 2022; Gong et al., 2023) though this remains largely theoretical and needs more empirical research. Our study confirms that individuals' cultures can be primed by VR stimuli, prompting a shift in ideation focus and fostering a balance in design creativity that mitigates cultural impacts.

6.4.2. Implications of findings

Culture influences individual and collective design processes. Individuals' UA values influence their creative output, with a preference for either originality or practicality (Erez & Nouri, 2010). In practical terms, lowering individuals' UA values via VR stimulation encourages risk-taking in design, leading to novel outcomes. Conversely, increasing UA prompts more careful and deliberate idea selection, enhancing practicality in idea choices and saving resources. The approach of using VR stimuli to influence cultural values in design could be applicable to other cultural values as well.

The implications for real-world application in creative projects, design practices, or technological innovation are manifold. They include (1) mitigating the negative influence of cultural values in individual creative endeavors within sectors like product design, where cultural biases can inadvertently influence the innovation process, leading to less innovative solutions; (2) promoting an optimal balance of risk-taking and workability in team design practices to achieve balanced novelty and workability; and (3) reducing cultural barriers in technological innovation within diverse workplaces, particularly in creative projects that span multiple countries and locations.

6.5. Limitations

Our study encountered several limitations that may influence the interpretation and applicability of our findings. It involved a relatively small sample size of 24 participants, which may constrain the generalizability of the results to a broader population. In addition, all participants were from the Industrial Design Engineering faculty, and likely possessed a higher familiarity with VR technology than the general population. Incorporating a more varied participant demographic might have yielded insights applicable across a broader spectrum. Moreover, we did not account for individual differences, such as personality traits or previous VR experiences, which may affect responses to VR stimuli. Furthermore, a control group might be integrated into our research methodology to evaluate the discrepancy between the two priming conditions and neutral condition. However, our study was intended to be an exploratory research phase to gather initial insights and data on mitigating the influence of culture on design creativity. It may be better to incorporate a control group in future studies to build on our findings. Simultaneously, conducting a comparative experimental study between VR stimuli and other stimulus media (i.e., video, text, and images) with more rigorous empirical evidence holds significant promise for validating the influence of VR stimuli. Furthermore, the precise duration of the priming effect remains uncertain due to the limited timeframe covered in our testing.

7. Conclusions

This study investigated the use of VR technology to prime the cultural values of individuals and thereby influence their creative output in the design realm. Initially, VR technology was utilized to create stimuli aimed at priming UA, a cultural dimension. Subsequently, some participants were tasked with generating ideas for a mode of transportation suitable for mountainous areas. The findings suggested that their UA values could be primed by specific VR stimuli, subsequently impacting their design creativity. Specifically, these stimuli reduced the impact of UA on their workability and novelty in design creativity.

The influence of culture on design practices is evident in the outputs of both individual and collective design processes within the design field. Previous studies proposed several promising ways to mitigate the influence of culture on design creativity through digital technologies, such as VR. Overall, this experimental work pioneered a human–computer interaction approach that leverages the immersive capabilities of VR to mitigate the potentially negative influence of culture on design creativity through priming. The findings showed that VR could successfully increase or decrease targeted cultural values, such as UA, indicating its potential to influence mindsets and risk-taking behavior. Furthermore, VR priming mitigated the negative impacts of UA on design creativity, suggesting that VR could alleviate negative cultural effects on innovation. However, drawbacks such as distraction and design fixation should also be considered when psychologically implementing VR. Psychological implications range from enhancing creativity and reducing cultural barriers in organizations to priming cultural openness in society. This paradigm offers new avenues for social psychology research using computer technologies, such as VR, to induce cultural mindset shifts and drive positive behavioral changes. Integrating psychological VR priming into design and innovation processes could profoundly transform how computers are used to manage cultural influences on human thinking and activities and have noteworthy implications for scholarly inquiries in diverse areas.

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CRediT authorship contribution statement

Zhengya Gong: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Data curation, Conceptualization, Formal analysis. **Milene Gonçalves:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Vijayakumar Nanjappan:** Supervision. **Georgi V. Georgiev:** Supervision, Methodology, Funding acquisition, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix

Appendix 1. Uncertainty avoidance scale (Jung & Kellaris, 2004)

Items of uncertainty avoidance ▸	Reliability
	0.81
1. I prefer structured situations to unstructured situations. ▸	
2. I prefer specific instructions to broad guidelines.	
3. I tend to get anxious easily when I don't know an outcome.	
4. I feel stressful when I cannot predict consequences.	
5. I would not take risks when an outcome cannot be predicted.	
6. I believe that rules should not be broken for mere pragmatic reasons.	
7. I don't like ambiguous situations.	

Appendix 2. Idea evaluation metrics and scores (Dean et al., 2006)

Metrics	Sub-metrics	4	3	2	1
Novelty	Originality	Not expressed before (rare, unusual) And Ingenious, imaginative or surprising; may be humorous	Unusual, interesting; shows some imagination	Interesting	Common, mundane, boring
	Paradigm relatedness	Paradigm modifying (radical)	Paradigm modifying (high transformational)	Paradigm modifying (low transformational)	Paradigm preserving
Workability	Acceptability	Common strategies that violate no norms or sensibilities	Somewhat uncommon or unusual strategies that don't offend sensibilities	Offends sensibilities somewhat but is not totally unacceptable	Radically violates laws or sensibilities or totally unacceptable business practice
	Implementability	Easy to implement at low cost or non-radical changes	Some changes or reasonably feasible promotions or events	Significant change or expensive or difficult but not totally impossible to implement	Totally infeasible to implement or extremely financially nonviable
Relevance	Applicability	Solves an identified problem that is directly related to the stated problem (do X to get Y, and Y is part of the stated problem)	Solves an implied problem that is related to the stated problem (do X to get an implied Y, which applies to the stated problem)	May have some benefit within a special situation and somehow relates to the stated problem (do X, which somehow relates to the stated problem)	Intervention is not stated or does not produce a useful outcome (no X) or (do X for useless Y)
	Effectiveness	Reasonable and will solve the stated problem without regard for workability (If you could do it, it would solve the main problem)	Reasonable and will contribute to the solution of the problem (It helps, but it is only a partial solution)	Unreasonable or unlikely to solve the problem (It probably will not work)	Solves an unrelated problem (It would not work, even if you could do it)
Specificity	Completeness	–	Comprehensive, with three or more parts from at least two of the 5 Ws + H (who, what, why, when, where, how), e.g. (what + when + where) or (what + what + why)	Contains two parts from different dimensions (5 Ws + H), such as, but not limited to (what + where), (what + why), (what + how), or three or more parts of only one of the 5 Ws + H (e.g., what + what + what)	Contains one or two parts from the same dimension and usually the "what" (e.g., (what) or (what + what))
	Implicational explicitness	–	Implication is clearly stated and makes sense (do X so that Y)	Implication is not generally accepted or is vaguely stated (do X, which solves a not-generally accepted Y) or (do X which solves a vaguely stated Y)	Implication is not stated, even though relevant (do X without a stated Y)

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