Hsu, W.-C., Tseng, C.-M., & Kang, S.,-C. (2018). Using Exaggerated Feedback in a Virtual Reality Environment to Enhance Behavior Intention of Water-Conservation. *Educational Technology & Society*, *21* (4), 187–203.

Using Exaggerated Feedback in a Virtual Reality Environment to Enhance Behavior Intention of Water-Conservation

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ABSTRACT

Taiwan has long been categorized as a country suffering from water shortages. The acquisition of knowledge and development of the concept of water conservation, and the development water conservation habits, are considered a civic responsibility of the citizens. The purpose of the present study was to utilize an immersive virtual environment technology (IVET) to create virtual experiences that expose individuals to vivid information with personal relevance and immediacy in hopes of increasing the behavior intention to conserve water. A mediated virtual experience was provided in the form of an experiential learning game, in which participants were situated in a virtual bathroom and asked to repeatedly use a 600-milliliter bottle to fill a specific water tank to flush a toilet and take a one-minute shower. While consuming the water resources, participants received exaggerated feedback (EF) to intensify the negative consequences of water consumption (direct EF) and/or environmental damage (ambient EF) that emphasized personal affective responses. A total of 165 players, separated into four groups according to the ambient or/and direct EF conditions, experienced the game activities. ANOVA was used to examine the effects of the experimental intervention. The results showed that the immersive virtual reality game in this study caused significant changes in cognition and behavior intention. This study contributes a novel persuasive technology specific to water resources.

Keywords

Water Environmental Education, Water conservation, Virtual reality, Experiential learning, Exaggerated feedback

Introduction

Long categorized as a country suffering from water shortages, Taiwan has only about 4,074m^3 of annual rainfall per person, less than 20% of the world average of 21,796m^3. The government and industry have sought to promote water resource conservation activities, and students and the general populace are expected to learn about water conservation. Recent water conservation education in Taiwan has focused on theoretical and conceptual knowledge. Although the education, in the form of knowledge domains and procedures, and effectiveness and social knowledge, is still able to influence students' pro-environment attitudes (Larson & Redman, 2014; Steg & Vlek, 2009), a particular challenge is that the environment-related knowledge is abstract, is comprised of multiple behaviors, and has low personal relevance, thus causing limitations in the individual's ability to distinctly perceive the environmental issue (Bray & Shackley, 2004; Pooley & O'Connor, 2000; Redman, 2013; Swaim et al., 2014). Limited consciousness of the issue continues to be an impediment to automatic triggering of individual environmental responsibility and behavioral modification (Breunig et al., 2014; Mobley et al., 2010).

Awareness of the environmental problem is an important prerequisite for promoting pro-environmental behaviors (De Groot & Steg, 2009; Grothmann & Patt, 2005; Van Der Werff & Steg, 2015). However, the three major characteristics of environmental risk make it more challenging to achieve personal higher perceptual and behavioral responses. First, the use of the natural resources is abstract. This abstraction leads to cognitive complexity, which causes people commonly to underestimate the actual amount of resource consumption (Attari et al., 2010; Jamieson, 2006). When the misconception is constructed in individuals' minds, they lack motivation to review their pro-environmental notions and habits (Markowitz & Shariff, 2012). Second, environmental degradation, like the scarcity of water, is hard to observe directly and immediately (Weber, 2006). This uncertain future consequence of the environment creates little personal concern for water as a scarce resource and lowers people's intention to care about the water conservation (Moser, 2010; Newton & Meyer, 2013; Uzzell, 2000; Wiek et al., 2011). Individuals then consider the pro-environmental behavior as an unnecessary adaptation. Finally, the daily consumption of water and energy is unnoticeable. With the insulation of modern people from the environment, individuals cannot easily perceive the excessive resource usage of their personal habitual behaviors (Blühdorn, 2011). Therefore, despite people's belief in the existence of environmental problems, they still feel less responsibility to make efforts to develop conservation behaviors (Kagawa, 2007; Parker & Sams, 2015; Sarabia-Sánchez et al., 2014).

In summary, the temporal distance between an unnoticeable cause and the abstract effect of environmental problems causes difficulties in raising environmental consciousness. To reduce the gap and further engage people in pro-environmental behaviors, it is necessary to portray water consumption vividly and conceptualize the environmental risk as the negative consequences of personal behaviors. Indeed, it is critical that individuals be provided with direct experiences that effectively clarify and increase individual perceptions of the problem.

In the current study, the authors aimed to develop an effective intervention for individuals to increase awareness of personal relevancy (cause) and vivid consequences (effect) through a persuasive experience simulated by immersive virtual environment technology (IVET). We used IVET to produce a virtual reality game that illustrates how individuals directly cause negative consequences as they consume water. We predicted that a vivid and personally relevant virtual experience (e.g., depleting one's physical energy to afford habitual water usage) would trigger individual cognition, change the attitude toward the water conservation issue, and increase behavior intention to conserve water. Furthermore, we proposed the incorporation of immediacy by speeding up the time to display accelerated negative outcomes in the experiential feedback of consuming water resources, known as exaggerated feedback (EF). Participants were exposed to a scenario wherein when they consumed water, the loss of water resources and the degradation of the external environment would be aggravated; i.e., the actual feedback was exaggerated. We assumed that the virtual experience applying exaggerated feedback would result in higher levels of cognitive and affective responses and produce greater improvement of behavior intention to conserve water. Specifically, two research questions were examined as follows:
Q1: Does experiencing vivid and personally relevant virtual experience change participants' responses in water saving cognition, attitude, and behavior intention?

Q2: Does the exaggerated feedback in the virtual experience have a positive impact on water saving cognition, attitude, and behavior intention?

Vivid information of the effect

In resource conservation policies and programs, the vivid effect, or solid abstract information, can significantly accelerate individual understanding of the actual consumption and make messages more persuasive (Dillard & Main, 2013; Sheppard, 2012). Research suggests that the strategy of communicating through representative units and household payments of resource usage, such as water and energy, provides individuals with limited recognition (Bowles, 2008; Jeong et al., 2014). Instead, depicting the energy usage in terms of the amount of deforestation or displaying water usage over a year as a number of swimming pools renders the consumption based on factual knowledge more salient and effectively attracts individuals' interest and attention (Jain et al., 2013; Novak et al., 2016; Petkov et al., 2011). Numerous studies have further utilized vivid demonstrations through visualizations such as 3D models, photos, and graphs to provoke greater perceptual responses and even personal conservation behaviors (Pahl et al., 2016; Sheppard, 2015).

Immediacy of the consequence

Immediacy is an attribute of visualization that makes longer-term consequences seem nearer-term through accelerating time (Sheppard, 2005). This approach can provide information about the cumulative negative impact on the environment of activities such as water or energy overconsumption as conspicuous signals that individuals rarely observe directly or immediately. Clear, ominous messages of the future conditions dramatically reduce the temporal gap and make the demonstration of water-conserving behaviors more persuasive (Carlson, 2001). Previous researchers have reported that when people perceive future consumption of resources, they are more likely to reconsider future consequences (Hershfield, 2011; Zimbardo & Boyd, 2008).

Personal relevance to the problem

The facilitation of behavioral modification requires disclosure of the personal relevance of the environmental problem (Anderson, 2012; Bator & Cialdini, 2000; Lowe, 2006; Roczen et al., 2014). Numerous studies have provided such relevancy by showing the water or energy consumption feedback from the daily habitual inaction of individuals (Delmas et al., 2013; Novak et al., 2016). These feedback strategies focus on the outcomes of the specific activities to clarify to individuals that they can influence them (Fischer, 2008; Karlin et al., 2015). Furthermore, when individuals know how to achieve the modifications, they feel more strongly responsible for the problem and are more willing to effect change (Fischer, 2008; Nussbaum et al., 2015).

Experience in immersive virtual environments

Experiential learning is a powerful delivery method to enhance cognitive and emotional and behavioral responses to environmental problems. Studies suggest that the information that is presented by experiential methods is more salient and drives higher attention than that provided in the form of description (Ahn et al., 2014; Karthe et al., 2016; Pooley & O'Connor, 2000; Quay et al., 2013; Weber, 2006). For promoting the perception of environmental degradation, personal experience is recommended as an effective approach to reduce temporal and psychological distance (Larson & Redman, 2014; Redman, 2013). Experiencing negative consequences, such as water scarcity, improves people's attitudes, which are more affectively based (Corral-Verdugo, 2002). Despite the energy of experience-based strategies, real-world experiences of negative environmental consequences are often unavailable or infeasible, so a realistic simulation could provide an alternative solution. Immersive virtual environment technology has been applied in numerous studies to enhance the intensity of experiences.

Immersion

IVET provides a first-person view of a three-dimensional virtual environment in a panoramic display so that users can see, hear, and feel the content with higher vividness and realism (Bailey et al., 2015; Blascovich & Bailenson, 2011). The experience creates an illusion of the physical world, and users can feel the virtual events happening to them (Ahn et al., 2016). Due to the sense of presence, the sensory information and scene simulated in a virtual environment increase the user's attention and engagement, and the experiences tend to be stored as individual memories for the long term (Ahn et al., 2016). The cognitive responses will be recalled and further influence personal attitudes.

Interactivity

Interactivity is defined as a process in which users have the freedom to influence the displayed content and receive real-time feedback on their own actions (Sundar, 2004). A virtual environment provides a higher level of interactivity, allowing users to naturally move their bodies, such as walking or moving their heads, to positively control the information received during the experience (Ahn, 2011; Bailey et al., 2016; Sheppard, 2005). Meanwhile, to respond to the users' actions as in an actual physical environment, the objects in the virtual environment are rendered and controlled with a physics engine. The dynamic experience enhances users' engagement and enthusiasm and further encourages changes in attitude and behavior.

Flexibility

The content of the experience in a virtual environment is boundless. Users can experience scenarios that would be impossible in the real world. For example, a virtual environment can provide sensory experiences of body transfer (e.g., the individual is inside the body of an animal (Ahnet al., 2016), disability (Ahn et al., 2013)), future consequences (e.g., individual see their own aged faces (Oh et al., 2016)) and impossible actions (e.g., being a superhero and saving virtual people (Rosenberg et al., 2013)). The flexibility and extensive control of IVET increases the efficiency of highlighting meaningful messages and making abstract concepts and information concrete. Also, experimenters can easily control the displayed form of the virtual environment and unobtrusively measure every movement made by the users.

Due to the characteristics of IVET, namely, immersion, interactivity, and flexibility, numerous studies suggest that IVET could be a powerful form of persuasive technology for catalyzing personal cognition, attitudes, and behavior changes. IVET can be used to expose users to novel events that can create new beliefs and emotions (Felnhofer et al., 2015; Oh et al., 2016). The effect is caused not only by the levels of interactivity, flexibility and immersion that IVET provides but also by individual differences such as gender and past personal experiences (Ahn et al., 2013; Sandstrom et al., 1998). Experience-learning through IVET has the potential to make the target consciousness easier to achieve while it should be evaluated that personal belief and emotion to the context in virtual environment. Focusing on enhancing pro-environmental attitudes and behaviors, numerous studies have utilized IVET as persuasive technology to increase awareness of environmental issues.

Game design

To examine the hypothesis, we designed a virtual reality water conservation game based on psychological considerations to fill the gap between the individual's habitual behaviors and the negative consequences for the environment. One study showed that game-based learning results in more positive effects than only using virtual worlds or simulations to foster learning. Game-initiated learning is a persuasive design for motivating students and delivering practical experiences (Tsai et al., 2015). The virtual reality game was designed for two participants. One was the major player in the virtual environment. The other one was the assistant and stayed in the physical environment. The two participants needed to cooperate with each other to complete the tasks in the virtual reality game. Below, we describe the psychological considerations and apparatus used in the virtual reality game.

Psychological considerations

The overall considerations in the design of the virtual experience are presented in Figure 1. The content of the virtual reality game corresponded to the key elements of raising consciousness of environmental problems related to water.

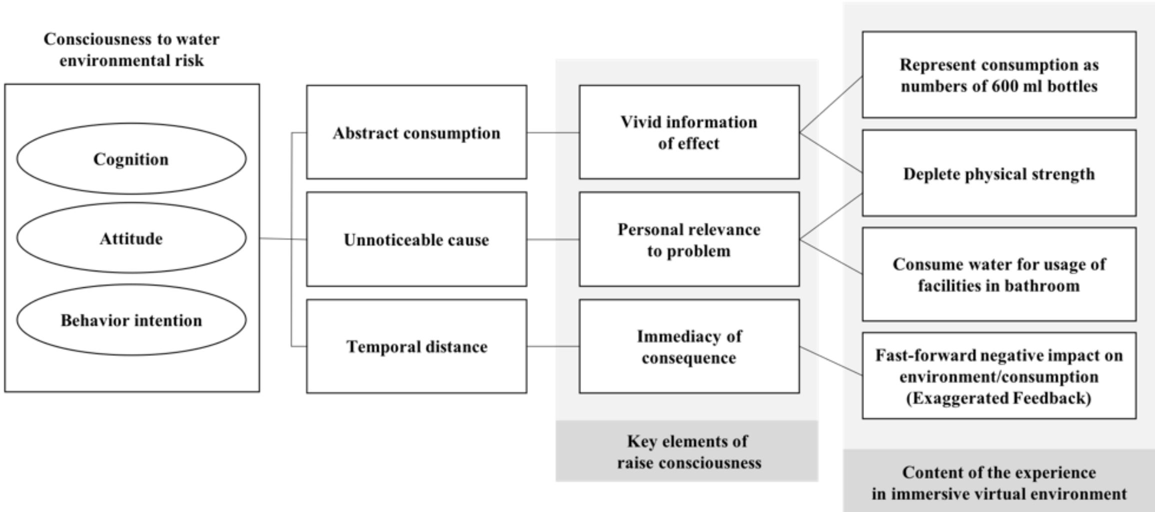

Figure 1. Overall considerations in game design

Relevance of personal behavior

Figure 2 shows the virtual bathroom, including a toilet, shower, and faucet, that was built in the game.

Figure 2. The bathroom in the virtual reality game

In the game, participants were required to exhaust the water in the virtual bathroom for flushing the toilet and taking a shower, after which they received feedback on their water consumption in real time. The design was intended to present a clear connection between specific habitual activities and water consumption to increase the participants' awareness of how their customary behaviors are related to environmental problems.

Vivid water consumption

To make the amount of daily water use more concrete, we utilized 600-milliliter bottles and the consumption of physical energy to represent feedback on water consumption.

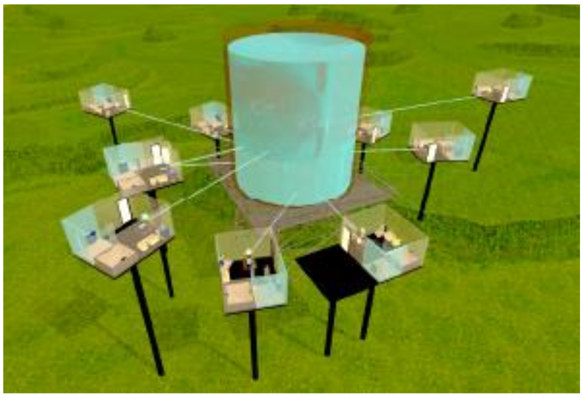

Figure 3. Surroundings in immersive virtual environment, including a central water reservoir, numerous virtual bathrooms, and an oasis

In the game, as shown in Figure 3, a central water reservoir stored the water resource, and numerous virtual bathrooms were located in the oasis. The water could be used after being drawn to a water-storage tank, as shown in Figure 4, in the virtual bathrooms. To build a water scarcity environment, water could be drawn if the assistant in the game, the other player, repeated the physical motion of pumping to fill the water-storage tank little by little. On the other hand, players in one of the bathrooms were allowed one minute to use a 600-milliliter bottle repeatedly to transfer water from a water storage tank (left side of Figure 5) to specific water tanks for flushing the toilet and taking a one-minute shower. After the tasks, the actual water consumption of each activity was visualized as multiple 600-milliliter bottles (right side of Figure 5).

The vivid feedback, namely, 600-milliliter bottles and the drop in the water level of the central water reservoir, could construct the individual's knowledge of the actual amount of water used. Moreover, the personal experience of the effort of transferring water created fatigue, which could cause the individual to reflect on the feedback.

Figure 4. Physical motion of pumping to draw water from the central water reservoir to the bathroom

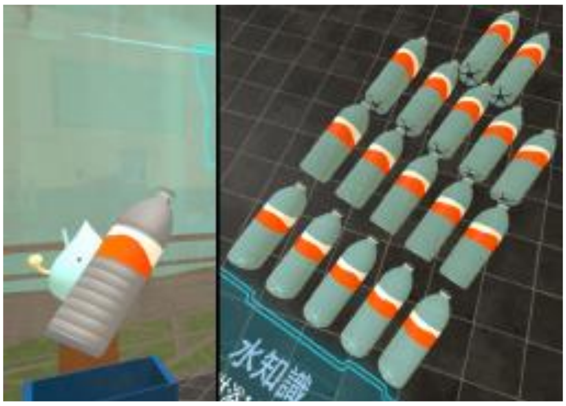

Figure 5. Vivid information presented as 600-milliliter bottles

Exaggerated feedback (EF)

The exaggerated feedback was intended to convey the concept that an individual may unconsciously cause negative consequences, which is hard to be aware of while using water in daily life. Two types of exaggerated feedback were considered in the virtual reality game, those being an accelerated negative impact on the environment (Ambient EF) and an accelerated negative impact on consumption (Direct EF). Ambient EF (Negative impact on environment feedback) was indicated by shrinking of the oasis due to the drop in the water level of the central water reservoir (Figure 6) Direct EF (negative impact on consumption) was indicated by the rapid consumption and exaggerated drop in the water level. The exaggerated feedback was intended to convey the environmental (ambient EF) and water resource (direct EF) effects of the participant's consumption to emphasize the importance of saving water.

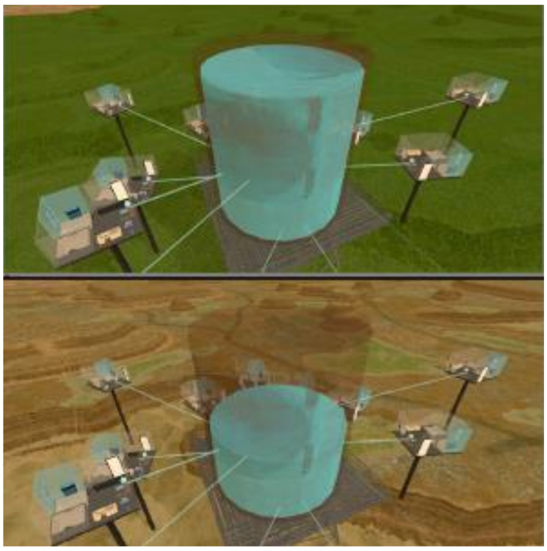

Figure 6. The degradation of surroundings caused by consuming water as ambient EF

A 2x2 between-subjects design was implemented to examine the effects of the two types of exaggerated feedback, negative impact on the environment (low vs. high) and negative impact on the resource (low vs. high), on attitude and behavior intention to conserve water, as shown in Figure 7. In the condition with the feedback of negative impact on the environment, the walls around the bathroom were opaque, so the participants were unable to detect the transformation of the oasis into a desert. To prevent participants from unintentionally becoming aware of the change, the virtual scene would become black-and-white if the participants walked out of the bathroom.

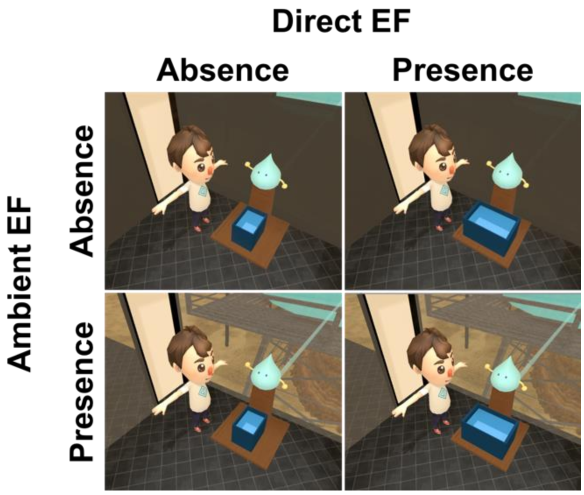

Figure 7. Four experimental conditions in the immersive virtual environment: no EF, only direct EF, only ambient EF, direct and ambient EF

Apparatus

In this study, a head-mounted display system with two integrated hand controllers (HTC VIVE) and a motion sensing input device (Microsoft Kinect) were used, and the virtual game was programmed in the Unity and Steam VR toolkit.

Head-mounted display

While wearing the head-mounted display, the participants experienced a three-dimensional environment from a first-person perspective. The head orientation and position of the participants were tracked by two sensors mounted on the ceiling, so the participants could look and walk around the virtual environment with natural physical movements. To intensify the immersion, stereophonic sound effects, including water flowing and realistic sounds of the desert, were also provided through the earphones. Figure 8 depicts the setup of the experiment.

Figure 8. Participants experienced the immersive virtual environment through (a) a head-mounted display, (b) hand controllers, and (c) earphones

Hand controllers

Figure 9 shows the virtual appearance of the two hand controllers, which allowed users to interact with the virtual environment in real time. The left-hand controller elicited tasks and provided guidance for the participants to finish the virtual experience. After reading and understanding the guidelines, participants could press the button on the controller and continue the game. The right-hand controller was shown as a virtual 600-milliliter bottle, with which participants could transfer the water. During the transfer process, participants received haptic feedback (i.e., vibrations from the controller) while filling the bottle or pouring the water.

Figure 9. Virtual appearance of two controllers for water delivery and guideline text
(e.g., In the above figure the guideline text says : “Now please ask your partners to press the pump to cause water flow into water-stored box.”)

Motion sensing input device

A motion sensing input device was used to detect the physical motions of the game assistant in real time. The game assistant stood at a distance from the device that allowed the device to track the assistant’s movements. Meanwhile, the assistants could view the perspective of the main player on a 27-inch display. Figure 10 shows the overall experimental setup of the virtual reality game.

Figure 10. Overall experimental setup: (a) Game assistant stood in front of the Kinect sensor (b) Main player wore the head-mounted display to perceive the virtual environment

Methodology

The experiment was conducted in two phases in order to investigate whether the virtual reality game and exaggerated feedback could decrease the individual’s temporal distance from the environmental risk of overconsumption of water to improve the behavior intention to reduce water usage.

Participants

Participants aged 16 to 17 (*M* = 16.30, *SD* = 0.46) years old were recruited from a senior high school in Taipei. The sample (*N* = 165) consisted of 15 female and 162 male students. Students were recruited to participate in an event, Online to Onsite (O2O), for promoting water resource education at the National Taiwan Science Education Center (NTSEC), and all provided informed consent prior to participation. The event lasted for four days, and about 40 students attended each day.

Procedure

The experiment was conducted in two phases. Phase One was conducted on the day on which students participated in the event, and Phase Two was completed approximately one month after the experimental treatment. In Phase One, all participants attending the event on the same day, about 40 students, finished a written pretest to measure their baseline levels of attitude, behavior intention to conserve water, and habits of water usage in a meeting room at the NTSEC. Later, the participants were divided into four groups and assigned to one of four exaggerated feedback conditions in the immersive virtual environment, as follows: without EF (*N* = 37), only ambient EF (*N* = 42), only direct EF (*N* = 45) and ambient direct EF (*N* = 41). Two participants, a major player and an assistant, cooperated in each round of the experiment. As shown in Figure 11, the virtual experience consisted of two parts, a training mission and a main mission. The main mission consisted of three tasks of consuming water.

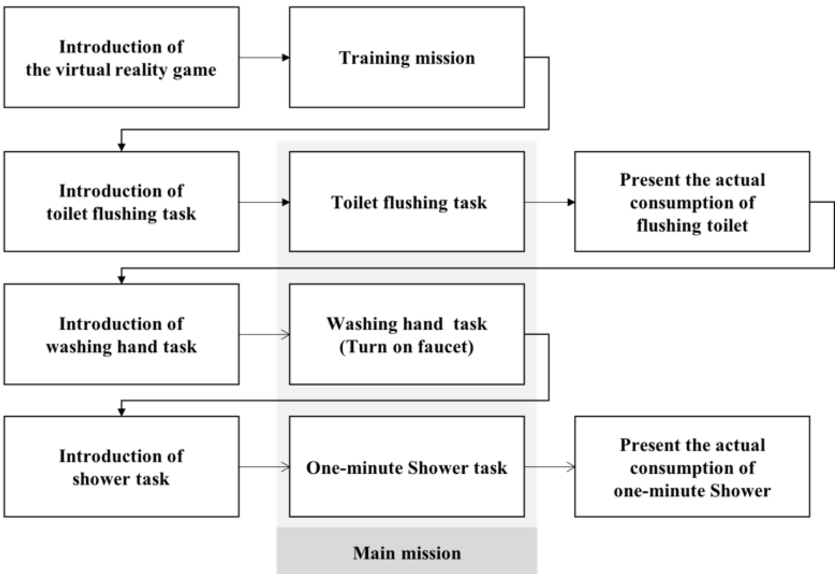

Figure 11. Flow chart of the water conservation virtual reality game

The duration of the overall experiment was about 7 to 10 minutes for each participant. At the start of the experiment, the major player was provided with guidance on playing the game to ensure the equal accessibility of the IVET to each participant. The main player stood in the virtual bathroom and viewed an introduction of the game background, as follows: “You are located on an oasis suffering from a scarcity of water resources. We need your energy to deliver the water to complete missions that will make the daily water-consumption facilities work normally.” Then the major player and the assistant completed the training mission, one instance of transferring the water with a 600-milliliter bottle, to ensure that the participants were familiar with the procedure of the virtual reality game. After the game demo, the major player viewed the message, “During the mission, the avatars in other bathrooms will consume water simultaneously.”

Next, the main player stepped into the part of the main mission, which involved depleting their physical energy to afford the habitual water usage. Progression of the virtual simulation is presented in Figure 12. First, the player was instructed as follows: “Please fill the water tank of the toilet in 1 minute and flush the toilet one time”, and then the mission began. At the end of the task, the system examined the water level of the specific water tank, the time left, and the amount of water spilled to report the final game score to the player. The player was also informed of the actual consumption per toilet flush, represented by the number of 600-milliliter bottles.

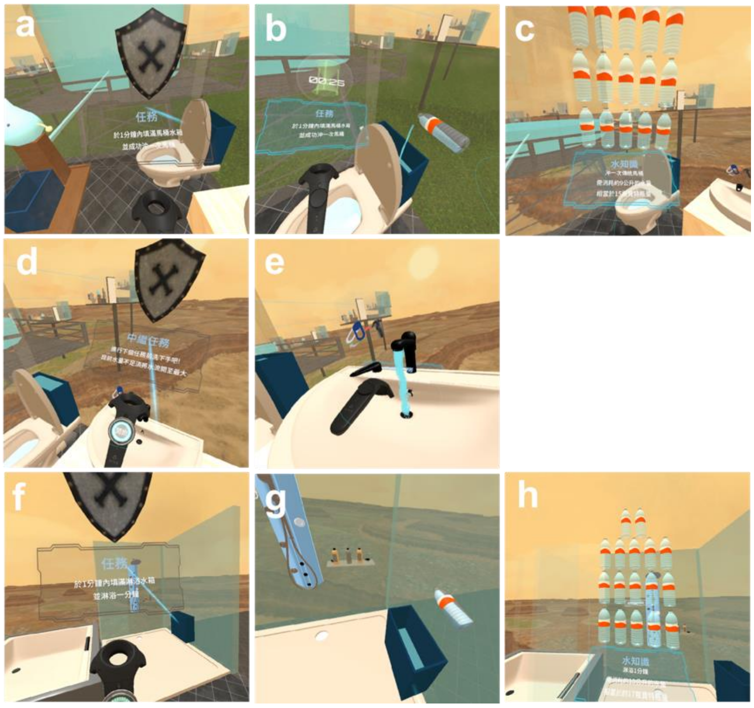

Figure 12. Screenshot of the series of missions in the virtual bathroom:(a) directions for toilet flushing task (b) toilet flushing task (c) presentation of actual consumption of toilet flushing as bottles (d) directions for washing hand task (e) washing hand task (f) directions for shower task (g) one-minute shower task (h) presentation of the actual consumption of a one-minute shower as bottles

Then the player was instructed to turn on the faucet to wash their hands by the message, "You have succeeded to flush the toilet. Why don't you wash your hands?" During the hand-washing task, the player was not asked to turn off the faucet. The player had complete freedom to control the flow of water throughout the game. Finally, the player filled the water tank of the shower in 1 minute and took a one-minute shower, the procedure of which was identical to that of the first task. The final score of each player was recorded and ranked on a scoreboard, and the top five scores were shown at the end of the game. After the virtual experience, participants were then guided to fill out a written questionnaire that measured the level of immersion and collected written feedback on the participants' feelings and emotions during the game. In Phase Two, one month following Phase 1, the participants completed a written delayed posttest investigating their changes in attitude, behavior intention to conserve water, and habits of water usage in their high school classrooms.

Measures

There were five measures in this study: cognition of daily water consumption, attitude toward water usage, self-reported behavior intention to conserve water, extent of tightening of the virtual faucet, and presence in the virtual environment. The first three items were measured before the virtual game (Time 1, pretest) and one month later (Time 2, delayed posttest). The other two items were measured and recall of the virtual experience was tested after the participants had finished the virtual game. The questionnaire was self-developed under the guidance of researchers or according to previous research.

Cognition of water consumption

Two multiple-choice questions were used to access personal cognitive correctness of daily water consumption. These questions were developed based on the context in the virtual game, where the water consumption of flushing a toilet and that of taking a one-minute shower were vividly displayed. One question was, "How much water is consumed if a non-water-saving toilet is flushed one time? (1) 1–4 liters (2) 5–8 liters (3) 9–12 liters (4) 13-16 liters." The second question, on the water consumption of a one-minute shower, was provided in a similar pattern. The responses to the two questions were scored as correct or incorrect. The final value of this measurement was the total number of questions that participants correctly answered.

Attitude toward water usage

Seven 6-point interval scale items (1 = strongly disagree, 6 = strongly agree) were used to gauge participants' attitudes toward water usage, including responsibility and emotion, based on previous work (Peçanha de Miranda Coelho, Veloso Gouveia, Silva de Souza, Lemos Milfont, Barros, & Nogueira, 2016). Two example items are "I think if I do my best, I can improve or solve the water issue," and "I feel guilty when I forget to turn off a tap." The Cronbach's alpha (reliability) of the seven items was 0.63.

Water saving behavior intention

Six 6-point interval scale items (1 = strongly disagree, 6 = strongly agree) were used to gauge participants' intentions to reduce water usage, such as by shortening their shower time or actively dealing with water leaks from a toilet or faucet that was not turned off. Two additional items asked participants to report their personal habits of daily water consumption. One item was, "In general, for how long do you shower? (1) less than 5 min (2) 6–10 min (3) 11–15 min (4) 16–20 min (5) more than 21 min." The other one was related to the frequency of reusing water resources. Three choices, "always," "sometimes," and "rarely" were provided. Linear transformation was applied to combine different point scale data. The Cronbach's alpha of the eight items was 0.75.

Extent of tightening the virtual faucet

In the process of experiencing virtual environment, participants were asked to turn on the faucet for washing hand and then were allowed to continue the game. However, we did not force participants to turn off the faucet that would keep virtual water flowing and wasted. Participants had freedom to deal with the sewage by actively turn off the faucet before the end of the game. The extent of tightening the virtual faucet was measured in percentage and the final number that could be considered as behavior intention in short-term was recorded.

Presence in the virtual environment

Presence was measured with three four 6-point interval scale items (1 = strongly disagree, 6 = strongly agree), which measured participants' subjective perceptions of the realism of the mediated virtual experience and whether exaggerated feedback intensifying the negative consequences could cause a lower personal perception of presence. The questions were adapted from Ahn et al. (2014); Bailenson et al. (2005) to assess the presence in the virtual environment. For example, the items were "It feel like I visited the water scarcity place." "I feel the experience of pouring water is real." The presence was immediately evaluated after participants finish the game. Reliability for the eight items was Cronbach's alpha = 0.63.

Recall

After finishing the virtual game, the participants were encouraged to recall their cognitive and affective responses in the process of the experience and to write them down on paper. They were provided two open-ended questions: "Which scenario made the greatest impression?" and "How did you feel after the virtual experience?" The written responses were organized according to several key points and are presented in the results section.

Results

We analyzed the data recorded in the virtual reality game and questionnaire results to answer our two research questions. We focused on the overall effect of the virtual reality game and investigated the impact of exaggerated feedback with measures.

Effect of vivid and personally relevant experience in a virtual environment

Paired *t*-test between pretest and posttest was used to determine whether the virtual experience incorporating vivid and personally relevant information had effects on the personal cognitive, affective, and behavioral domains. As Table 1 shows, overall, participants' changes in cognition (M_1 = .39 (*SD* = .23), M_2 = .60 (*SD* = .30)), attitude (M_1 = 4.16 (*SD* = .83), M_2 = 4.20 (*SD* = .92)) and behavior intention (M_1 = 4.07 (*SD* = .66), M_2 = 4.24 (*SD* = .73)) were positive. The paired t-test also indicated statistically significant differences in the personal cognitive (t = -3.389 (*SE* = .43), $p < .01$) and behavioral (t = -3.63 (*SE* = .36), $p < .01$) domains before and after the experimental treatments. On the other hand, no significant effect (t = -.886 (*SE* = .49), $p > .05$) of the virtual experience on overall personal attitude was revealed.

Table 1. Descriptive statistics and pair *t*-test for overall effect of virtual reality game

	Time 1	Time 2 (after one month)	*t*-value	*p*-value
	M (*SD*)	*M* (*SD*)		
Cognition to water consumption	.39 (.23)	.60 (.30)	-3.389	.001**
Attitude to water usage	4.16 (.83)	4.20 (.92)	-.886	.337
Water saving behavior intention	4.07 (.66)	4.24 (.73)	-3.63	.001**

Note. $^{**}p < .01$.

Effect of exaggerated feedback

Descriptive statistics of all measures that were analyzed according to different condition resulted from direct EF and ambient EF are presented in Table 2 To investigate the effect of exaggerated feedback, two-way analyses of variance (ANOVA) was run with direct EF and ambient EF as the between-subject variable; and extent of tightening virtual faucet, the change of cognition, attitude and behavior intention between pretest and posttest and personal presence in virtual environment as independent variable. The results from the ANOVA are shown in Table 3.

Table 2. Descriptive Statistic for measures according to ambient and direct EF

Condition	1	2	3	4	5	6	7	8
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	M_1 (*SD*)	M_2 (*SD*)	M_1 (*SD*)	M_2 (*SD*)	*M* (*SD*)
Overall not direct EF	.43 (.50)	.39 (.59)	.61 (.69)	4.12 (.53)	4.20 (.43)	3.98 (.68)	4.20 (.57)	4.54 (.81)
Overall direct EF	.50 (.50)	.40 (.54)	.62 (.62)	4.19 (.61)	4.21 (.51)	4.15 (.64)	4.27 (.60)	4.47 (.86)
Overall not ambient EF	.55 (.50)	.46 (.57)	.67 (.67)	4.28 (.55)	4.21 (.54)	4.20 (.66)	4.25 (.63)	4.60 (.84)
Overall ambient EF	.39 (.49)	.33 (.54)	.55 (.63)	4.04 (.57)	4.19 (.39)	3.94 (.64)	4.23 (.54)	4.41 (.83)
Not direct, not ambient EF	.49 (.51)	.54 (.65)	.65 (.70)	4.20 (.53)	4.20 (.51)	4.17 (.66)	4.20 (.60)	4.67 (.79)
Direct, not ambient EF	.60 (.49)	.40 (.50)	.69 (.55)	4.34 (.57)	4.22 (.57)	4.23 (.66)	4.29 (.66)	4.55 (.88)
Not direct, ambient EF	.38 (.49)	.26 (.65)	.57 (.68)	4.05 (.53)	4.20 (.35)	3.82 (.67)	4.20 (.56)	4.44 (.82)
Direct, ambient EF	.39 (.49)	.39 (.50)	.54 (.67)	4.03 (.61)	4.20 (.43)	4.07 (.60)	4.26 (.52)	4.39 (.84)

Note. 1 = The extent to tighten virtual faucet; 2 = Cognition to water consumption baseline; 3 = Cognition to water consumption post; 4 = Attitude to water usage baseline; 5 = Attitude to water usage post; 6 = Water saving behavior intention baseline; 7 = Water saving behavior intention post; 8 = Presence in the virtual environment.

Table 3. Two-way ANOVA for overall measures to evaluate the effect of EF

Condition	1			2			3			4			5		
	F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
A	.59	.44	.004	.005	.946	.000	.255	.614	.002	.857	.356	.05	2.164	.143	.013
B	4.048	.05	.025	.052	.821	.000	5.034	.026*	.03	6.596	.011*	.39	.038	.845	.000
C	.42	.52	.003	.762	.186	.011	.499	.481	.003	1.255	.264	.008	.584	.446	.004

Note. A= Change with direct EF; B = Change with ambient EF; C= Change with direct & ambient EF1 = Tighten virtual faucet; 2 = Personal cognition improvement; 3 = Personal attitude improvement; 4 = Personal behavior intention improvement; 5 = Presence in the virtual environment. $^{*}p < .05$.

Extent of tightening of the virtual faucet

As Table 2 shows, participants in the only direct EF condition had the highest behavior intention to turn off the virtual faucet, with a mean of the extent of tightening the virtual faucet of .60 (*SD* = .49). Comparing the overall direct EF condition with the not overall direct EF condition, it is likely that direct EF had a positive impact on the short-term behavior intention to save water. In this study, no significant effects of direct EF ($F = .59$, $p > .05$, Eta-squared = .004) or interaction effect ($F = .42$, $p > .05$, Eta-squared = .003) were found.

Improvement of cognition, attitude and behavior intention

With regard to the long-term effect of EF, results showed a significant effect of ambient EF on enhancing personal water conservation attitude and behavior intention. The improvement of individual attitude and behavior intention was greater after exposure to ambient EF than to not ambient EF. Table 3 presents statistically significant effects of ambient EF were found for personal attitude improvement ($F = 5.034$, $p < .05$, *Eta-squared* = .03) and personal behavior intention improvement ($F = 6.596$, $p <. 05$, *Eta-squared* = .39). No significant interaction effect ($p > .05$) was found for attitude improvement ($F = .499$, *Eta-squared* = .003) or behavior intention improvement ($F = 1.255$, *Eta-squared* = .008).

Presence in the virtual environment

Presence in the virtual environment was higher without EF ($M = 4.67$, $SD = .79$) than with EF, including the only direct EF condition ($M = 4.55$, $SD = .88$), only ambient EF condition ($M = 4.44$, $SD = .82$), and direct ambient EF condition ($M = 4.39$, $SD = .84$) as Table 2 shows. However, the effect of EF on presence was not significant. The results indicated that EF did not dramatically decrease the personal feeling that the virtual experience was genuine.

Immediate recall of virtual experience

Recall was collected from two open-ended questions immediately following the virtual reality game. The responses mainly fell into three categories: engagement, realism, and awareness. Engagement-related responses, comprising about 52% of the response, was focused on the entertainment and accessibility of the virtual game. Examples of responses are, “It was really interesting!” “The task in the game was a little difficult,” and “The experience was very attractive to me.” About 38% of the feedback (35% positive, 3% negative) depicted the realism of the virtual game, such as “The experience was more realistic than expected,” “It was just like being located in an environment suffering from water scarcity,” and “Pouring water in the virtual environment was realistic.” Such responses can be regarded as support for evaluating the personal presence. About 10% of the responses was classified as awareness. These statements were expressions of personal emotion about the exaggerated virtual experience and cognition regarding conservation of water issues, such as “The experience gave me a quite shock” and “Although the game was really fun, it informed me of the importance of saving water.”

Discussion

Reason for positive effects of the virtual reality game

The purpose of the present study was to create virtual experiences that exposed individuals to vivid information in hopes of increasing the behavior intention to conserve water. Thus we evaluated the effects of a compelling immersive virtual environment on behavioral changes, echoing earlier studies on climate change communication by demonstrating that interactive immersion in a virtual environment was more persuasive and would likely motivate behavioral intent (Sheppard, 2005). We compared personal levels of cognitive, affective, and behavioral responses to water conservation issues one month after the mediated virtual experience with outcomes from the pretest. Overall, the vivid and personally relevant experience enhanced students' cognition, attitude, and behavior intentions by respectively 53.84%, 1.02%, and 4.17%. Significant positive effects on cognition regarding water consumption and behavior intention to conserve water were found.

The results indicated that the experience of depleting one's physical energy to afford daily water usage in the virtual environment may successfully convey to individuals a strongly vivid message. The vividness caused by making abstract water consumption concrete with 600-milliliter bottles and even the direct experience of water transfer in the game facilitated students' clear comprehension of the actual amount of water consumed every day. Moreover, regarding the significant effect on increasing behavior intention, it is possible that the familiar scene, using water resources in a bathroom, provided the specific cause of excessive consumption and then raised awareness of personal relevance to the water conservation issue. The open feedback, such as "From an objective perspective, I am surprised that daily water consumption is so high" and "We always consume a lot of water unconsciously," also provided similar results. Therefore, seeing vivid causes and clear effects, the students were more willing to engage in water conservation behaviors. Similar to earlier studies summarized in Larson and Redman (2014), the current study launched programs and conducted experiments attempting to transform behaviors toward conservation and sustainability. The central idea was to raise awareness that would lead to corresponding responses and reflections by presenting contextual issues regarding environmental protection. Previous studies (e.g., Dillard & Main, 2013; Sheppard, 2012) have utilized the "vivid effect," referred to as exaggerated feedback (EF) in our work, to significantly accelerate individual understanding of the actual consumption and make messages more persuasive. Also, 3D models, photos, and graphs have been developed to provoke greater perceptual responses and even personal conservation behaviors (Pahl et al., 2016; Sheppard, 2015). We also took advantage of the fact that "exaggeration is a malleable concept." Specifically, the "exaggerated feedback" was proposed with the hypothesis that it had the "power" to trigger many aspects of human beings' cognition and behavioral responses. On the other hand, the overall attitude toward water usage was not significantly improved. The lower effect may have been due to the change in personal attitude not being largely determined by vivid and personally-related information, which will be discussed in the next subsection.

Reason for positive effects of exaggerated feedback

Two kinds of exaggerated feedback, direct EF and ambient EF, were controlled in the experimental treatments. In the following, to answer Q2, we explore the effects of exaggerated feedback during the process of experiencing a virtual environment (at Time 1) and one month later (at Time 2) according to corresponding independent measures.

Immediate effects

The immediate effects of exaggerated feedback were investigated with the personal intention to turn off the virtual faucet. Although participants exposed to direct EF tended to tighten the faucet, the outcomes had no significant differences from the no direct EF condition. A reasonable explanation is that there was no pretest treatment to evaluate the baseline of individual water saving behavior in the virtual environment. The baselines of attitude and behavior intention in the separated groups, with and without ambient EF, were validated to have a significant difference ($p < .05$), as was the difference ($p < .05$) in attitude baseline in the direct EF and no direct EF conditions. The results showed that, without controlling for students' prior behavior in the virtual immersive environment, the outcomes of this experimental treatment were changeable.

Delayed effects

The results of this study show that ambient EF and accelerated environmental degradation directly caused by personal behavior can stimulate a pro-water-conservation attitude and behavior intention. The experience with ambient EF somehow had a lower level of realism than that of the no EF condition, but it did not dramatically increase personal disbelief in the water conservation issue. One deduction might be that the open feedback about realism was nearly all positive in the exaggerated condition. With enough presence in the experience, students' affective responses, including their guilt over wasting water and sense of responsibility for water conservation, were prone to be evoked by emphasis on the change in the virtual ambient environment, which facilitated the intention to modify their behavior. The open feedback from students also generated the expected reflections, such as "The situation in the virtual game could happen in the near future, so we should be more engaged in water conservation," and "Quite shocking! It made me understand the inconvenience in a water shortage area."

Unexpectedly, no effects of direct EF on cognition, attitude, and behavior intention were found. It is likely that direct EF, achieved through exaggerating the water consumption while the participants filled the 600-milliliter bottles, did not make the immediacy of the negative consequences salient. Compared with ambient EF utilizing the wrap-around display of virtual reality, direct EF was less intuitive for participants and did not direct their attention to the negative consequences of their behavior. To provide access to mental processes through direct EF, related basic knowledge should be provided as a baseline to heighten the contrast with exaggerated outcomes.

We specifically focused on how to implement exaggeration in designing virtual reality games to influence participants' attitude and change behaviors in facing issues in environmental education. Unlike the tools and facilities used in previous studies, the new science and technology of VR was used in this study to provide a more vivid visual presentation with the goal of raising the individual's personal relevance and immediacy in responding to water resource issues. Previous studies have shown that individual behaviors may directly cause negative consequences for many aspects of water resources, indicated as direct EF in the current study. Here we further elaborate the effect by examining the impact on the environment as a whole, indicated as ambient EF. Parts of our experiments had relatively small significant outcomes, possibly due to the nature of the virtual reality games. Participants inevitably were resistant to some extent, perhaps feeling that these exaggerations were simply designed to force them (or made it easy for them) to choose from one or another situation. However, the unique contribution of our study is that it integrated and applied the concept of exaggeration in game design in the environmental education field.

Conclusion

In this study, to bridge the perceptual gap between behavior and actual consequences in water conservation education, we developed an immersive virtual water conservation game as persuasive technology for experiential learning. The virtual reality game, which involved using one's physical energy to deliver water for use in a bathroom, provided individuals access to vivid and personally relevant experiences of water consumption. The virtual experiences allowed participants to better process their understanding of actual water consumption and increase their engagement in water conservation.

Furthermore, focusing on the temporal distance of the water conservation risk, exaggerated feedback in the embodied environment was suggested in this study, and it was applied to emphasize that individual behaviors of daily water usage may directly cause negative consequences on water resources (direct EF) and the environment (ambient EF). The evidence revealed that participants exposed to the ambient EF with the immediacy of the degradation of the virtual environment tended to have higher levels of affective response and intention to modify their behavior for conserving water, whereas the direct EF did not provoke similar responses. We found that ambient EF, achieved by gradually degrading the virtual surroundings while the water was being exhausted, was more intuitive and salient than direct EF, thus leading to success in evoking emotions and raising personal awareness of the water conservation issue.

In summary, this study contributes a novel experiential intervention in water conservation education. The intervention utilized the characteristics of IVET, namely, immersion, interactivity, and flexibility, and the self-designed context in the game achieved the key elements: consciousness of the water conservation issue, vivid effects, personally-related information, and immediacy of consequences. Furthermore, the use of exaggerated feedback in a virtual environment appears to be an effective strategy for promoting intention to actively engage in pro-environmental activities.

Limitation and future work

A lingering question is the connection between each response to virtual experience, which remains unclear. The current study found positive impacts of the virtual experience and exaggerated feedback on cognition, attitude, and behavior intention, but the psychological model, such as cognitive effects on attitude or behavior intention, and the extent of responsibility and emotion aroused, should be investigated in detail.

Regarding the experienced context in the virtual environment, the current study mainly assessed participants to loss frame that stimulated individual guilt and anxiety to increase concern about environmental issues. Although the virtual reality in this study may have made it clear to the participants what daily behaviors cause excessive water consumption, which in turn showed individuals how to avoid the negative consequences, no elements for raising positive emotion were included in the intervention. The effectiveness of a gain frame with exaggerated feedback should be investigated and compared with the negative one in the future.

Limitations of the experiment design were noted in two aspects: the sample and the frequency of intervention. The sample, consisting of 90% male senior high school students, limits the generalizability of the results. Gender can cause differences in the access to virtual reality technology. Indeed, measures of personal daily behaviors in the physical environment were lacking in this study. To yield further insight into the effectiveness of the water conservation virtual reality game, future research should recruit a wider range of participants from different populations. In addition, the outcomes of repeated interventions and measurements of the environmental behavior have to be considered.

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