# Changing User's Safety Locus of Control through Persuasive Play: an Application to Aviation Safety

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**Abstract**. Virtual risk experiences have been proposed in persuasive technology as an approach to change people's attitudes and behaviors concerning safety topics. This paper advances the investigation of virtual risk experiences in different directions. First, we extend the study of their effects to safety locus of control, which is an important predictor of an individual's attitudes and behaviors with respect to risky situations. Second, we explore a design that relies much more on play than previous virtual experiences of risks in the literature. Third, we extend the investigation of persuasive technology to a topic in aviation safety (i.e., assuming a proper brace position during an emergency landing) that has never been approached before with an interactive system and we analyze if a novel game-based approach can be effective in fostering awareness of this fundamental safety action. Our study shows that the proposed persuasive game produces noteworthy results in terms of learning safety knowledge and improves players' attitudes towards aircraft accidents, increasing their internal safety locus of control and decreasing the external one.

**Keywords:** safety, persuasive games, virtual risk experiences, locus of control, aviation safety, brace position

## 1 Introduction

Virtual risk experiences [5,6,18,31] have been proposed in persuasive technology as an approach to change people' attitudes and behaviors with respect to safety topics. This approach could be effective in persuading people to change because it enables them to observe the link between cause and effect [11], it can provide immediate feedback by showing the positive consequences of recommended behaviors and the negative consequences of dangerous behaviors [5], and those consequences can be simulated in vivid ways that can contribute to make them more memorable [18].

Studies of virtual experiences of risk carried out so far focused on measuring effects on attitudes towards risks deriving from threats such as climate change [18], floods [31] structure fires [6] and aircraft evacuations [5]. In this paper, we aim at advancing the investigation of virtual risk experiences in different directions. First, we extend the study of their effects to safety locus of control, an important predictor of an individual's attitudes and behaviors with respect to risky situations. Second, we explore a design that relies much more on play than the previously cited virtual experiences of risks. Third, we consider a topic in aviation safety (i.e., assuming a proper brace position during an emergency landing) that has never been approached before with an interactive system and we analyze if a novel game-based approach can be effective in fostering awareness of this fundamental safety action.

The paper is organized as follows. In Section 2, we discuss previous work in persuasive technology for aviation safety and how the present research differs from it. Section 3 motivates and illustrates the importance of the safety locus of control construct. In Section 4, we present in detail the persuasive game application we created. Section 5 and 6 respectively illustrate the experimental evaluation and the obtained results, while Section 7 concludes the paper and introduces future work.

## 2 Related Work

The primary purpose of aviation safety education is to provide aircraft passengers with accurate cabin safety knowledge and cultivate positive passengers' attitudes to appropriately affect their behavior when an emergency occurs. As shown by the study in [4], the level of aviation safety education an aircraft passenger has does affect her knowledge, attitudes and behaviors. Safety awareness can lead passengers to efficient behaviors and being responsible for their own safety; therefore, improving passenger safety education increases the probability of their survival in an emergency [20,26].

Current approaches to passenger education are based on the safety card in the seat pocket and the flight attendant presentation to which passengers are exposed after boarding the aircraft. Unfortunately, as discussed in reports of the US Federal Aviation Administration (FAA) [7] as well as other papers in the literature [20,26], passenger attention to safety cards and briefings is poor at best, and the few passengers who pay attention have little knowledge and understanding of the information received. Reports conclude that safety and survival information needs to be presented and made available in substantially improved and creative ways [8,20].

Persuasive technology is a natural candidate to address this problem, but to the best of our knowledge the only study to date of persuasive technology for aviation safety was the one we described in [5]. In that work, a simple 3D world allowed users to partially experience a specific pre-scripted evacuation scenario, which started with an in-flight announcement that an emergency landing was going to be attempted and ended when the player got out of the plane. Progress in the scenario was determined at some choice points in which the player had to choose an action (for example, retrieving his/her luggage or leaving it on the plane). Choosing the right action made the scenario progress, otherwise the player was left where (s)he was and the question was asked again. The negative consequences of wrong choices were described by a very brief text, and not simulated with graphics and sound to avoid scaring the player. The way users chose actions was very basic too: a text menu appeared on the screen and the player had to push keys on the computer keyboard to choose an option. The study conducted on 26 participants showed that playing the game (which required 2-3 minutes to complete) improved to some extent knowledge of the evacuation procedure and also self-efficacy (the participants' belief in their ability to carry out the evacuation procedure). Finally, the study checked if living the virtual experience had effects on the perception of vulnerability and severity of aircraft evacuation risks. While vulnerability did not change, an undesired decrease in severity was found, probably due the fact that the virtual experience was specifically designed not to be scary and did not show any kind of damage and adverse effects on the players' avatar.

The present project differs from the previous research in a number of ways. From the point of view of aviation safety, we focus on educating passengers about how to accurately perform a specific action (assuming a brace position), while the previous study focused on an abstract procedure in which complex actions such assuming the brace position reduced to simply choosing a single menu option. From the application point of view, we aim at creating more playful dynamics, in which the user does not simply choose options from a menu but can actively play with his/her avatar body, posing it in a wide range of different postures and seeing how this affects it in an accident. We also aim at providing much richer feedback. First, unlike the previous application that did not show any negative consequences, we fully simulate and show them to players with realistic graphics and sound. Second, after showing the possibly scary consequences, we provide hints to help the player avert them. Since our aim is to make the game available for public campaigns, we devoted particular care to obtaining a graphic and audio quality higher than typical research prototypes. Finally, we extend the study of the game effects to locus of control, an important construct in psychology and in safety, which we introduce and discuss in the next section.

## 3 Locus of Control and Safety

Locus of control, a construct originated from Rotter's social learning theory [22], can be defined as the degree to which a person perceives that the outcomes of the situations (s)he experiences are under his/her personal control. With respect to a given situation, an individual's locus of control can have an internal orientation (the individual perceives that she can exert control over the outcome of the situation) or an external orientation (the individual perceives that the outcome of the situation is due to external factors, such as fate, chance or the actions of other persons).

The importance of locus of control in safety was highlighted by several studies, which showed that it is a predictor of safety-relevant attitudes and behaviors. In particular, an internal orientation is usually associated with safer attitudes and behaviors. For example, in the domain of road safety, Hoyt [12] found that car passengers with an internal locus of control are more likely to wear seat belts, while Montag and Comrey [19] related drivers' internal locus of control with safer driving. Interestingly, a recent study [13] showed that drivers' locus of control can be influenced by training and by observer feedback, and the changes in drivers' locus of control can predict change in driving behavior. This suggests that the simulations people can live in a virtual risk experience and the feedback the application can provide users with are worth of study as possible techniques to change users' locus of control, in addition to improve their knowledge about the considered risky situation.

Wuebker [29] focused on locus of control in the industrial safety domain, proposing the Safety Locus of Control Scale. The results of her study indicated that externally oriented employees had significantly more accidents than employees with internal safety control beliefs. Moreover, accidents and injuries suffered by externally oriented employees were more serious than those of internally oriented employees. Jones and Wuebker [17] focused on hospital workers, confirming the relation of the Safety Locus of Control Scale with occupational accidents in that domain too.

Hunter [14] adapted the Safety Locus of Control Scale to measure aviation safety locus of control in pilots and found that civil aviation pilots with a more internal orientation were involved in fewer hazardous events. A study of airline pilots by You et al. [30] reinforces these findings, showing that locus of control influences safe operation behavior. Hunter and Stewart [15,16] extended the investigation of locus of control to U.S. Army aviators, developing the Army Locus of Control Scale and finding significant associations which are consistent with research conducted on civil aviation pilots. In particular, aviators with a more internal control orientation experienced fewer accidents than aviators who were low on that construct.

Improving safety locus of control seems to be particularly important also in the domain of air passengers' safety. Indeed, it is known that passengers tend to look at aviation emergencies with attitudes that are consistent with an external rather than an internal orientation, e.g. shifting the responsibility and capability of their safety to the cabin crew [20] or falsely believing that most aircraft accidents are unsurvivable [25]. This way of thinking is dangerous for the negative effects that an external orientation has on safety attitudes and behavior, and it is also unfounded for different reasons. First, in an emergency, the crew cannot provide individual assistance to every passenger, due to the workload and time constraints of the evacuation. Moreover, crew members could be injured or incapacitated, and this would require passengers to take an even more active role to survive. Second, passengers' pessimistic beliefs about survivability are contradicted by facts: a survey of commercial jet airplanes accidents conducted by Boeing [1] indicates that the majority of them is survivable, and a recently released FAA report [3] confirms and reinforces that conclusion.

Therefore, persuasive applications aimed at passengers, in addition to informing them about the correct actions and emergency procedures, have to address explicitly the issue of changing passenger's attitudes towards his/her role in the emergency and his/her actual possibility of exerting control on the outcomes. The goal of the study in the present paper is to determine if a playful virtual risk experience and the feedback that it provides can, as we hypothesize, be effective in changing users' locus of control as well as improving their knowledge about the considered risky situation.

## 4 The Persuasive Game

A fundamental action that passengers can take to contribute to their survival in aircraft accidents is to assume an appropriate "Brace for Impact" position. This is an action in which passengers pre-position their bodies against whatever they are most likely to be thrown against, significantly reducing injuries sustained [25]. The purpose of our persuasive game is to allow players to become familiar with the action of assuming a brace position in all of its details as well as improve their locus of control with respect to the risk posed by an emergency landing. The game is meant to be used in public campaigns conducted on the Web, so that users can conveniently play it on their computers, to familiarize with the brace position well before boarding a plane.

In designing the application, we organized gameplay in four steps. First, the player poses a 3D virtual passenger. In particular, the player sees the passenger seated in the cabin of a flying aircraft, from a third-person perspective. As shown in Figure 1, four distinct icons are associated to different body parts of the passenger. The player can freely drag each icon with the mouse to easily move the corresponding body part and pose the 3D character. The rationale for choosing this interface was that it supports a "puppeteer" metaphor in which the user pulls the strings connected to the head, hands and feet of the virtual passenger to pose it. Such kind of metaphor should be immediately familiar to users. Moreover, the point-and-click interaction technique (through which users move the icons to "pull the strings" in the game) is typical of many computer applications and should thus require no learning effort. The application invites the player to pose the passenger in a position (s)he believes to be safe for an emergency landing, but the player is allowed to pose the character in any position, including the most dangerous ones.

Second, when the player has finished posing the character, a hard emergency landing is simulated in real-time, after the user clicks the "Crash" button in Figure 1. The simulation is not pre-scripted: it is physically based so each player's try can have slight or major differences from a previously seen one, depending on the initial body position of the virtual passenger. The aim of the simulation is to vividly show the consequences of assuming a wrong position on the passenger's body as well as allow the player to discover experientially which positions do not produce such negative consequences. Figure 2 shows two instants in a specific simulation.


**Fig. 1.** Posing the virtual passenger.

**Fig. 2.** Real-time crash simulation.


**Fig. 3.** Slow-motion replay with damage highlight.

Third, since the impact in the real-time simulation occurs in a very short time as in real life, a slow-motion replay (similar to those shown in the media for car crash tests) is also presented to allow players appreciate details that cannot be noticed in a real-time simulation. To make the slow-motion replay more dramatic, we show it in greyscale and use color red to highlight the parts of the body which get injured as they impact the front seat surfaces (see Figure 3). Ominous sounds such as crash landing sounds and sounds of breaking bones are also played at the proper instants.

Fourth, we complete the illustration of the outcome of each game try with a detailed damage report (see Figure 4). Following the recently proposed idea of using visualizations of internal damage to human body parts obtained through medical imaging for persuasion purposes (see e.g. [24]), we do not only highlight in red the externally visible damage in the virtual passenger body but we enrich the report with x-ray visualizations that show internal damage in the affected body parts. We also follow fear appeals strategies of persuasion [21,23,28] that highlight how scaring the participant is a good tactic as long as the intervention also presents a simple and effective way of averting the depicted negative consequences. To do so, after highlighting each negative consequence on the passenger's body, we provide a short, clear and simple hint about how to avoid it (as shown in the left part of Figure 4 and described in the figure caption). This is meant to educate and reassure the player but is also an implicit incentive to retry again the game to see if one can do better next time. A prominent "Retry" button is displayed to conveniently restart from the character-posing phase.

To choose a correct brace position for our application, we first analyzed official normative information about brace positions [27], which derived from dynamic impact tests conducted in the 80's and 90's. We then considered the latest research conducted in 2013 by the FAA [25], after the injuries sustained by passengers in several recent commercial airline accidents (e.g., US Airways flight 1549) highlighted a need to review brace position effectiveness to determine if the recommended positions were still appropriate for today's passenger seats. As a result, we adopted the optimized brace position recommended by that research.

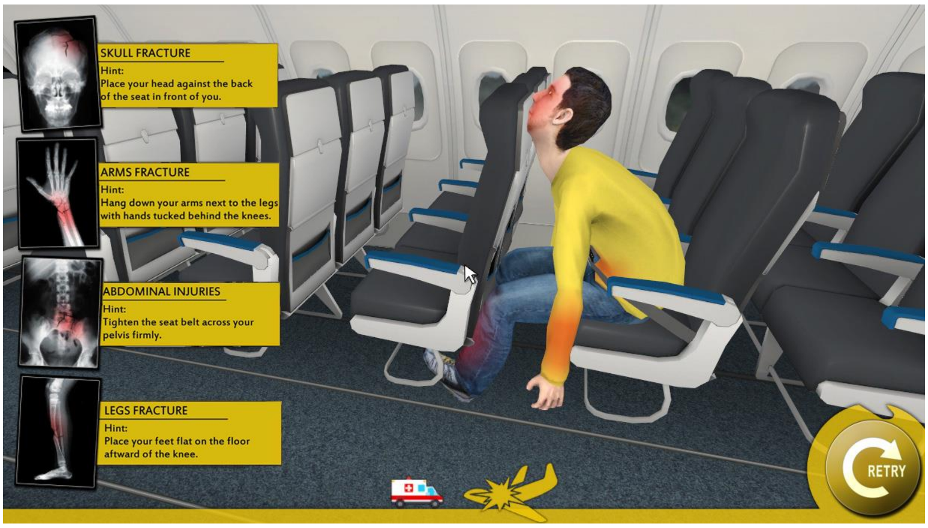


**Fig. 4.** Damage report and hints. The four hints in this scenario are (from top to bottom): (a) "Place your head against the back of the seat in front of you", (b) "Hang down your arms next to the legs with hands tucked behind the knees", (c) "Tighten the seat belt across your pelvis firmly", (d) "Tuck your feet firmly on the floor behind your knees".

## 5 Method

### 5.1 Participants, design and measures

We recruited 24 participants (11 male, 13 female) through personal contact. Participants were volunteer university students and people from various occupations who received no compensation. Their age ranged from 19 to 55 (M=30.50, SD=13.51).

We assessed video game use by asking participants to rate their frequency of video game use on a 7-point scale (1=never, 2=less than once a month, 3=about once a month, 4=several times a month, 5=several times a week, 6=every day for less than an hour, 7=every day for more than one hour). Mean rating was 3.38 (SD=1.86). Frequency of air travel was assessed by asking participants for their number of flights in the last two years. Answers ranged from 0 to 10 (M=2.63, SD=3.28).

To measure participants' knowledge about the brace position, we used 4 questions that asked them to describe where and how to position (i) hands, (ii) feet, (iii) safety belt, (iv) head. To avoid suggesting possible answers (e.g., as a multiple-choice questionnaire would do), participants were asked to answer orally the 4 questions and the answers were recorded.

To measure participants' locus of control with respect to emergency landing situations, we created a 12-item questionnaire, adapting items from the Aviation Safety Locus of Control Scale [14] by changing the context from the pilot's to the passenger's one. The items we used include statements such as "Surviving is a matter of luck, chance or fate" and "Most injuries and deaths are inevitable" to measure external orientation, or "Passengers can prevent injuries if they follow safety procedures" and "Some injuries are due to errors made by passengers" to measure internal orientation. Each item was rated by participants on a 7-point Likert scale (1=strongly disagree, 7=strongly agree). Answers to items for internal orientation (resp. external orientation) were averaged to form a reliable scale, Cronbach's alpha=.78 (resp .77).

We also measured risk perception by using the 6 questions employed by [9], changing the name of the risk into "emergency landing": vulnerability to risk was assessed by having respondents rate their vulnerability on 3 items (e.g., "how high do you believe your risk of being involved in an emergency landing is?") and severity of risk on the 3 other items (e.g., "how harmful would the consequences of an emergency landing be?"). Ratings were given on a 7-point Likert scale (1=not at all, 7=very). Answers to items for vulnerability (resp. severity) were averaged to form a reliable scale, Cronbach's alpha=.75 (resp .94).

Based on the considerations we described in Sections 3 and 4, we hypothesized that playing the game should increase player's knowledge about the brace position, increase his/her internal safety locus of control and decrease the external one. For risk perception, we did not expect changes in vulnerability since that should be more related to the traveling habits of participants. However, considering the vivid and possibly scary visualization of bodily damage to the player's avatar which is central to the studied game, we did expect an opposite trend with respect to [5]: playing the game could increase perception of risk severity, and we were interested in exploring to what extent this increase might occur.

### 5.2 Procedure

The study does not involve coercion or deceit and respects applicable professional code of conduct. Participants were told they were going to try a video game meant to illustrate the brace position passengers should assume during an emergency landing. They were told that they could use the game for as much time as they wanted without minimum or maximum limits. First, participants filled the demographic, locus of control, risk perception questionnaires, and answered the knowledge questions. Then, they played the game on a 15.6 inches LCD monitor with stereo speakers, without receiving any previous training or illustration of the game from the experimenter (this was done to check that the user interface was intuitive and immediately usable as planned). All the instructions for playing the game were contained in a brief text displayed as a starting screen. The text said: "You are going to face an emergency landing! Click and drag the 4 yellow icons with the mouse to choose a position you think is safe. When you're done, press CRASH!". When participants decided to stop playing, they filled the locus of control and risk perception questionnaires and answered the knowledge questions for the second time.

# 6 Results

The means for number of correctly answered knowledge questions are shown in Figure 5. Differences were analyzed with a non-parametric Wilcoxon test and confirmed our hypothesis: after playing the game, there was a statistically significant ($Z=-4.40$, $p<0.001$) and noteworthy increase in the number of correct answers which reached a value extremely close to the best one, moving from 1.08 ($SD=.58$) to 3.92 ($SD=.28$). In particular, 22 out of 24 participants reached the maximum number of correct answers (4), while the number for the remaining 2 participants was 3.

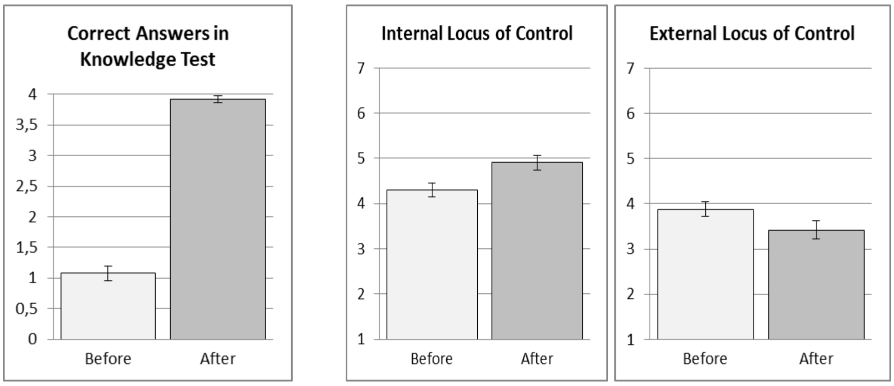


**Fig. 5.** Number of correctly answered knowledge questions and locus of control, before and after play. Capped vertical bars denote ±1 SE.

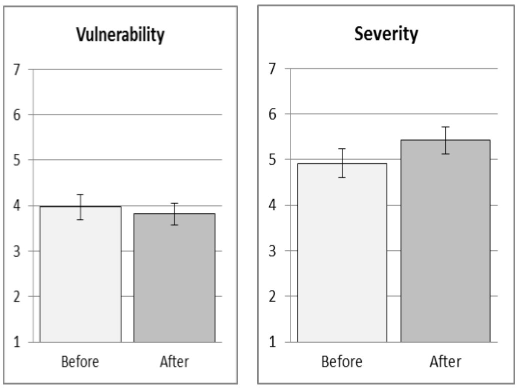


**Fig. 6.** Risk perception: vulnerability and severity, before and after play. Capped vertical bars denote ±1 SE.

Figure 5 also illustrates the means for locus of control. Differences were analyzed with ANOVA and confirmed our hypothesis: after playing the game, there was a statistically significant ($F(1,23)=17.05$, $p<0.001$) increase in internal orientation, which rose from 4.30 ($SD=.80$) to 4.91 ($SD=.77$). Consistently, there was a statistically significant ($F(1,23)=7.58$, $p=0.01$) decrease in external orientation, which moved from 3.88 ($SD=.98$) to 3.42 ($SD=.98$). In other words, participants felt the outcomes of an emergency landing were more under their personal control after playing the game.

The means for risk vulnerability and severity measures before and after the experience are shown in Figure 6. The obtained differences confirmed our hypothesis: after playing the game, there was no significant change in vulnerability perception, while there was a statistically significant ($F(1,23)=5.40$, $p<0.05$) although small increase in severity, which rose from 4.92 (SD=1.59) to 5.42 (SD=1.43).

Most participants (22) played the game for a time that varied between 145 and 389 seconds (M=241.38, SD=71.84). The remaining 2 participants played instead for a considerably larger time (579 and 728 seconds, respectively). Similarly, the number of tries of the simulation was for most players (22) between 2 and 5 (M=3.18, SD=.85), while for the remaining 2 players it was respectively 6 and 8. We checked if there possibly was a significant correlation between time played and the improvement in knowledge (difference between final and initial knowledge score) obtained by participants, and found no such correlation. Time played was instead positively correlated ($r(24)=.57$, $p<.01$) with participants' age: the older the participant, the more time (s)he took to play the game.

## 7 Conclusions

This paper extended research on the persuasive effects of simulated experiences of risk for aviation safety education in different directions. First, the experiment showed that a persuasive game that simulates a risk experience can be a very effective educational tool: the results in learning we obtained are much larger than the previous study on persuasive technology for aviation safety education [5] and extremely close to the ideal outcome. Overall, playing the game for an average time of just 4 minutes resulted in full learning of the safety content for all but two players. Second, the experiment showed that playing the game improved important players' attitudes towards aircraft accidents, increasing their internal safety locus of control and decreasing the external one.

The fact that the game slightly increased perception of risk severity, while the previously studied application [5] obtained the opposite effect, is consistent with our design choice of vividly showing the consequences of the accident on the passengers' body, while the previous application deliberately omitted to show them. The better results obtained in our study seem to support our different approach. We showed possibly scary visualizations of negative consequences of wrong actions, but we always accompanied them with simple hints to avert the depicted consequences. We illustrated the details of the recommended action with a simple interface that all participants were able to use immediately and provided clear simulations that highlight the effectiveness of right player's choices. The fact that all but two players fully learned all those details is an indication that we have likely succeeded. Moreover, the change in safety locus of control towards a more internal orientation indicates that participants felt more control over the outcome of an emergency landing after going through a sequence of virtual risk experiences with the game.

The results we have obtained go in a positive and opposite direction with respect to the previously mentioned limitations of traditional solutions, i.e. safety cards and briefings. We are anyway working at repeating the study with a group that is exposed to a traditional approach instead of the novel persuasive application, to precisely determine how large the differences between traditional and persuasive solutions to aviation safety education can be.

Another limitation of the study is that it considered only short-term effects. A longitudinal study aimed at measuring retention of knowledge and attitudes is needed.

After a few minor cosmetic improvements, our application has now entered a public beta-testing phase on Facebook (http://apps.facebook.com/learntobrace). Public accessibility of the game will also allow us to conduct remote evaluations that could possibly involve large, international and varied samples of players and to study their behavior in more naturalistic ways than laboratory studies.

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