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A Comparative Study of Aviation Safety Briefing Media: Card, Video, and Video with Interactive Controls

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Abstract

Passengers' safety knowledge is a key factor in determining the chance of surviving any life- or injury-threatening situation that could occur in civil aviation. Aviation regulations require airlines to provide safety briefings to inform passengers of safety procedures on board. The safety briefing card and the safety briefing video are the two media that airlines routinely employ on board to this purpose. Unfortunately, research on aviation safety briefing media has cast serious doubts about their efficacy, urging researchers to better understand what makes safety briefing media effective as well as improving their effectiveness. This paper contributes to such goals in two different ways. First, it proposes the introduction of interactive technology into aviation safety briefings for improving their effectiveness. Second, it illustrates a controlled study that compares the effectiveness of three safety briefing media: the two briefing media that airlines currently employ on-board (safety briefing card and safety briefing video) and a safety briefing video extended with basic interactive controls. The results obtained by the study highlight a superior effectiveness of the two video media over the card media for aviation safety briefings. Moreover, the video with interactive controls produced improvements over the card in a larger number of effectiveness measures than the traditional video. The paper includes a discussion of factors that can explain the better results obtained with the video conditions, and in particular the video with interactive controls, and of possible additional extensions to increase the interactivity of aviation safety briefings.

Keywords: aviation; cabin safety; safety briefings; interactive technology; instruction; learning

1. Introduction

Passengers' safety knowledge is a key factor in determining passenger's response to an emergency (Chang & Liao, 2009; Muir & Thomas, 2004; Thomas, 2003; Edwards, 1990), and a knowledgeable passenger has a much better chance of surviving any life- or injury-threatening situation that could occur during passenger-carrying operations in civil aviation (FAA, 2003). For these reasons, aviation regulations require airlines to provide safety briefings to inform passengers of safety procedures on board, e.g., 14 CFR 121.571, 125.327, 135.117 (FAA, 2014). The safety briefing card and the safety briefing video are the two media that airlines routinely employ on board to this purpose. Unfortunately, interviews of aircraft accident survivors (NTSB, 2000; Chang & Yang, 2011) as well as accident reports, e.g. (NTSB, 2010), have cast serious doubts about the effectiveness of current safety briefing media for passengers, urging researchers to better understand what makes safety briefing media effective as well as improving the effectiveness of current media.

In particular, two major issues have been raised. One is lack of attention to safety briefings in a large proportion of the flying public. Indeed, passengers' surveys (Corbett and McLean, 2007) as well as accident investigations (NTSB, 2000; 2010) report that passengers who attend to safety information on-board are between 30% and 40%. The other major issue is lack of comprehension and recall of the safety information provided by the media. Studies with participants who were asked to examine safety briefing cards (Corbett & McLean, 2007; Corbett, McLean, & Cosper, 2008; Weed, Corbett, & McLean, 2013) showed little understanding of the received safety information. Studies with participants who were asked to watch safety briefing videos (Seneviratne & Molesworth, 2015; Thehrani & Molesworth, 2015) reported "alarming" recall rates of the received safety information, and called for improvements of how safety information is delivered to passengers to make it more understandable and memorable.

This paper focuses on comprehension and recall issues, and has two main goals. First, we want to propose and implement a possible improvement – the addition of interactive controls - to safety briefing videos. Although the introduction of interactive technologies into aviation safety education has been advocated since 2004 (Cosper & McLean, 2004), to the best of our knowledge, no work exists on making aviation safety briefing videos interactive. Our second goal is to compare the two media currently employed on-board by airlines (i.e., the safety briefing card and the safety briefing video) and the proposed interactive safety briefing video, in a controlled study that considers different aspects of effectiveness.

1.1 Introducing Interactive Controls in Aviation Safety Briefing Media

The In-Flight Entertainment Systems (IFEs) mounted on the seats of an increasing number of aircraft support interactive applications (e.g., interactive movie players, simple games, questionnaires, real-time maps,…), and could provide a first infrastructural opportunity to extend safety briefing videos with interactive features. Unfortunately, such interactive IFEs are typically not available on low-cost carriers, and are more generally available only on selected long-haul flights with any carrier.

A complementary, more promising opportunity is to take advantage of widespread Personal Electronic Devices (PED), such as smartphones and tablets, that most passengers bring on-board. This is not problematic anymore for aviation regulators as the latest regulatory policies (FAA, 2015; EASA, 2014) allow PED use by passengers to all phases of flight. The current trend in the airline industry towards providing wireless connectivity on any aircraft further encourages passengers to use their PED on-board, and the latest surveys clearly highlight passengers' demand of having the same connectivity in the air as on the ground (IATA, 2016). Moreover, PED open up additional, new opportunities for delivering the safety briefings, e.g. the interactive content could be sent to the passenger together with electronic tickets or boarding passes that they already receive on their PED before the flight, or it can be accessed wirelessly after boarding through the airline connectivity services. In the first case, the passenger can even start using the interactive briefings before boarding the aircraft. In both cases, PED make it possible to use the briefings more discreetly than IFEs, allowing a passenger to focus on the content without worrying about being watched by others. Finally, interactive safety briefings could also allow airlines to introduce incentives for encouraging passengers to attend to safety information. For example, passengers could be offered frequent flyer points for attending to safety briefings, and the interactive safety briefing could check that the passenger has gone through all the steps of the procedures, and possibly ask to answer a final comprehension test, before granting the incentive miles.

To design the interactive safety briefing proposed in this paper, we started by considering findings that emerge from research in the learning and instruction community. First, provided that they are intuitive to use, adding basic interactive controls (stopping, restarting, replaying) to a video presentation should improve learning of *procedural skills* (Schwan & Riempp, 2004; Hasler, Kersten & Sweller, 2007; Merkt et al., 2011) with respect to a traditional non-interactive video or to a printed presentation of procedures. This consideration is based on the results of studies concerning concrete procedures that require motor actions such as tying nautical knots (Schwan & Riempp, 2004) or creating origami paper folds (Shyu & Brown, 1995). In addition, in giving recipients more control over the inevitably transient information of videos, we considered the fact that a segmentation of information into small, discrete segments (instead of a steady flow of information) has been shown to be beneficial for learning (Mayer & Chandler, 2001; Hasler et al., 2007). We thus considered each action in each safety procedure illustrated by the briefing as an individual segment. These considerations focused the design of the interactive controls we added to the safety briefing video as follows: after the character in the video presents a segment (a single action) of a safety procedure, the presentation stops automatically, and the user has to touch the screen to proceed with the next segment. This allows the user to adjust the pace of the presentation to his/her individual cognitive needs, supporting self-regulated information processing (Merkt et al., 2011). Then, when the presentation of a safety procedure is complete, our interactive safety briefing offers the user the choice of replaying that procedure from its start or continue to the next procedure (see Figure 1).

Second, a video depiction of a human carrying out a procedure is more effective if the boundaries of each action are made more salient, because they facilitate the process of cognitively segmenting the flow of activity into intelligible units (Newtson & Engquist, 1976; Schwan, Garsoffky & Hesse, 2000). Moreover, research on animations has shown that cueing can help the recipient handle transient information by highlighting relevant aspects of a presentation (e.g. de Koning, Tabbers, Rikers, & Paas, 2007). For these reasons, after the character in our interactive safety briefing presents a segment of a procedure, not only the presentation stops automatically, but we add a graphical cue that highlights what is the contextually important point of interest the user should focus his/her attention on (Figures 2 and 3).

Third, on devices that use a touchscreen for interaction, such as PED and recent IFEs, dragging gestures - instead of simple taps - may positively influence understanding of content (Dube & McEwen, 2015). This recent finding focused the way we designed the interaction that allows users to proceed to the next segment of a procedure. Instead of simply tapping the cue on the screen, the user has to perform a dragging gesture that is contextually connected to the next action in the procedure. For example, if the audio comment in the video has just said that the passenger has to put the oxygen mask on his/her face, the gesture will require to touch and drag the oxygen mask from its position on the screen towards the face of the character on the screen. The graphical cue we add to the video highlights the area from which the gesture starts, and the direction of the gesture: Figure 3 shows an example in which the passenger has to pull the oxygen mask to activate it.

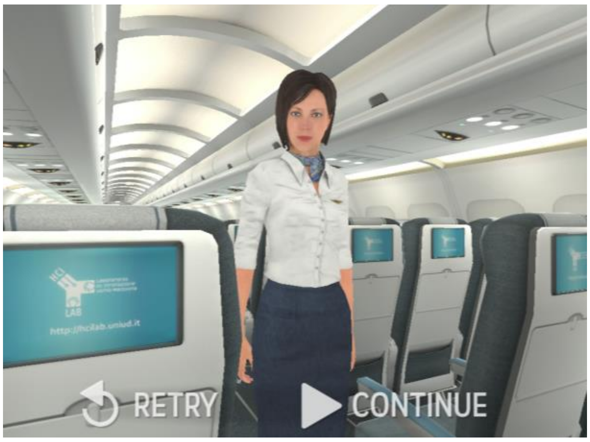

Figure 1. At the end of presentation of a procedure, the user is offered the choice of replaying the entire procedure or continuing to the next procedure.

(a) (b)

Figure 2. (a) Graphical cue that highlights the contextually important point of interest in the video (the door, in this case); (b) After the user has acted on the cue, the animation of the next segment of the procedure starts.

Figure 3. The graphical cue highlights the contextually important point of interest in the video as well as the direction of the gesture with which the user starts the corresponding segment of animation.

In terms of the classification of levels of interactivity proposed by Sims (1997), the interactivity we provide belongs to the category of *object interactivity*, i.e. allowing to touch an object, and get an audio-visual response as a result. However, the addition of gestures extends traditional object interactivity, because the touched object is not activated by a simple, generic “click” or “tap” action, but by a gesture that is related to the real-world action the user has to learn. For example, as mentioned above, it is not sufficient to touch the oxygen mask to see it move to the right position, but one has to perform a gesture towards the specific correct destination of the object.

1.2 Evaluating Safety Briefing Media

Studies of safety briefing media have assessed comprehension with printed booklet tests in which participants had to write what they understood of safety card pictorials (Corbett, McLean, & Cosper, 2008; Weed, Corbett, & McLean, 2013; Corbett & McLean, 2007) or comprehension test forms with headings corresponding to key safety themes, in which participants had to write what they recalled about each theme after watching a safety briefing video (Seneviratne & Molesworth, 2015; Thehrani & Molesworth, 2015).

In our evaluation of safety briefing media, we wanted to assess not only the ability to recall the safety information but also to apply it to the real world, because any instructional technique (traditional or novel) would be of limited value if people could not effectively apply the acquired knowledge to the real world (Carpenter, 2012). To do so, participants in our study were asked to carry out the procedures described by the safety briefing, using real aircraft equipment such as seatbelts, oxygen mask, and life preserver. This way of measuring the effectiveness of the safety briefing media is more indicative of the actual ability to execute the safety procedures appropriately than written tests or interviews about the knowledge gained.

Moreover, we extended the assessment of safety briefing effectiveness by including a measure of attitude change. As pointed out by (Chang & Liao, 2009), in addition to providing passengers with accurate cabin safety knowledge, the methods used by airlines to educate passengers about safety must also cultivate positive attitudes that could affect appropriately passenger’s behavior when an emergency occurs. An important passengers' attitude is self-efficacy, which can be defined as the confidence on one's ability to perform a behavior. According to Social Cognitive Theory (Bandura 1997; Bandura, 2001), self-efficacy significantly determines performance outcomes, and different people with similar skills may perform differently depending on their conviction that they can successfully execute a required behavior. In particular, positive associations between safety training, self-efficacy and attitudes toward safety have been described in the literature, see (Grau, Martínez, Agut, & Salanova, 2002; Katz-Navon, Naveh, & Stern, 2007) for summaries. Increasing self-efficacy is particularly important in aviation safety, because passengers' attitudes about aircraft accidents tend to be pessimistic and fatalistic: passengers believe there is little hope of survival and/or shift the responsibility and capability of their safety to the cabin crew (Muir and Thomas, 2004). Actually, most aircraft accidents are survivable, as clearly shown by surveys of commercial jet airplanes accidents (Cherry, 2013). Moreover, workload and time constraints in aircraft evacuations make it impossible for the crew to provide individual assistance to every passenger, and this requires passengers to take an active role to survive.

In designing the experiment, we took into account that contrasting existing safety briefing media from commercial airlines - as other studies have done - limits the controllability of the experiment due to the potentially large number of confounding variables. For example, the characters displaying the procedures in the contrasted safety briefings can be of different types (e.g. hand-drawn, computer-generated character, real human actors), and even when they are of the same type, there can be many differences in the character features, such as gender, age, body shape, face, hair, clothing, and attractiveness. In addition, there can be differences in the sequence and detail of the provided information. When comparing videos, the number of possible confounding variables extends further to sound and animation features, e.g. differences in timbre and tone of the speaker's voice, speed of speech, facial expressions, complexity and length of the sentences, type of language used. It is well-known that differences in any of the above mentioned variables can have an influence on the effectiveness of a communication, see (O'Keefe, 2015) for a detailed discussion, so it is important to keep them under control as much as possible to investigate possible effects of type of media.

To guarantee such improved level of control with respect to existing studies, the three safety briefing media contrasted in our study were created using exactly the same computer-generated graphics. In this way, the depicted cabin environment, safety equipment, sequences of actions, and the character that demonstrates the actions are the same. Moreover, the two video conditions (traditional and with interactivity) differ only for the addition of the interactive controls: everything else (including animations, facial expressions, voice tone, speed of speech, complexity and length of the sentences, type of language used) are exactly the same.

2. Method

We carried out a between-groups study with three conditions, one for each of the safety briefing media introduced in the previous section (Card, Video, Video with Interactivity). In the Card condition, participants examined a safety card that presented the safety procedures through pictograms based on computer-generated graphics. In the Video condition, participants watched on a tablet a video that presented the safety procedures through animations of the same computer graphics with sound. In the Video with Interactivity condition, participants watched the same video on the same tablet, with the addition of the basic interactive controls described in the previous section.

The three safety briefing media provided information about the following topics prescribed by current regulations (FAA, 2003; 2014), and presented in this order: (i) fastening seatbelts, (ii) using the oxygen mask, (iii) assuming a brace position, (iv) using the life preserver, (v) location of emergency exits, (vi), opening floor exit doors, (vii) opening wing exit doors. The aircraft in the briefing was the Airbus 320 type (Airbus, 2016).

2.1 Materials

The 3D computer graphics objects used in the three safety briefing media were the same, and were created with the 3D Studio Max modeling software (Autodesk, 2016). The animations for the two video conditions were the same, and were created with the MotionBuilder character animation software (Autodesk, 2016). To play the animations we used the Unity 5 graphics engine (Unity Technologies, 2016), and the basic controls for the Video with Interactivity condition were added in Unity by using the C# programming language.

The safety briefing card (see Figure 4) was printed on a 28.3 cm x 26.6 cm cardboard sheet. To choose the size, graphic layout, and the specific computer-generated pictograms to include in the safety briefing card, we examined as a reference the cards currently used by a major world airline.

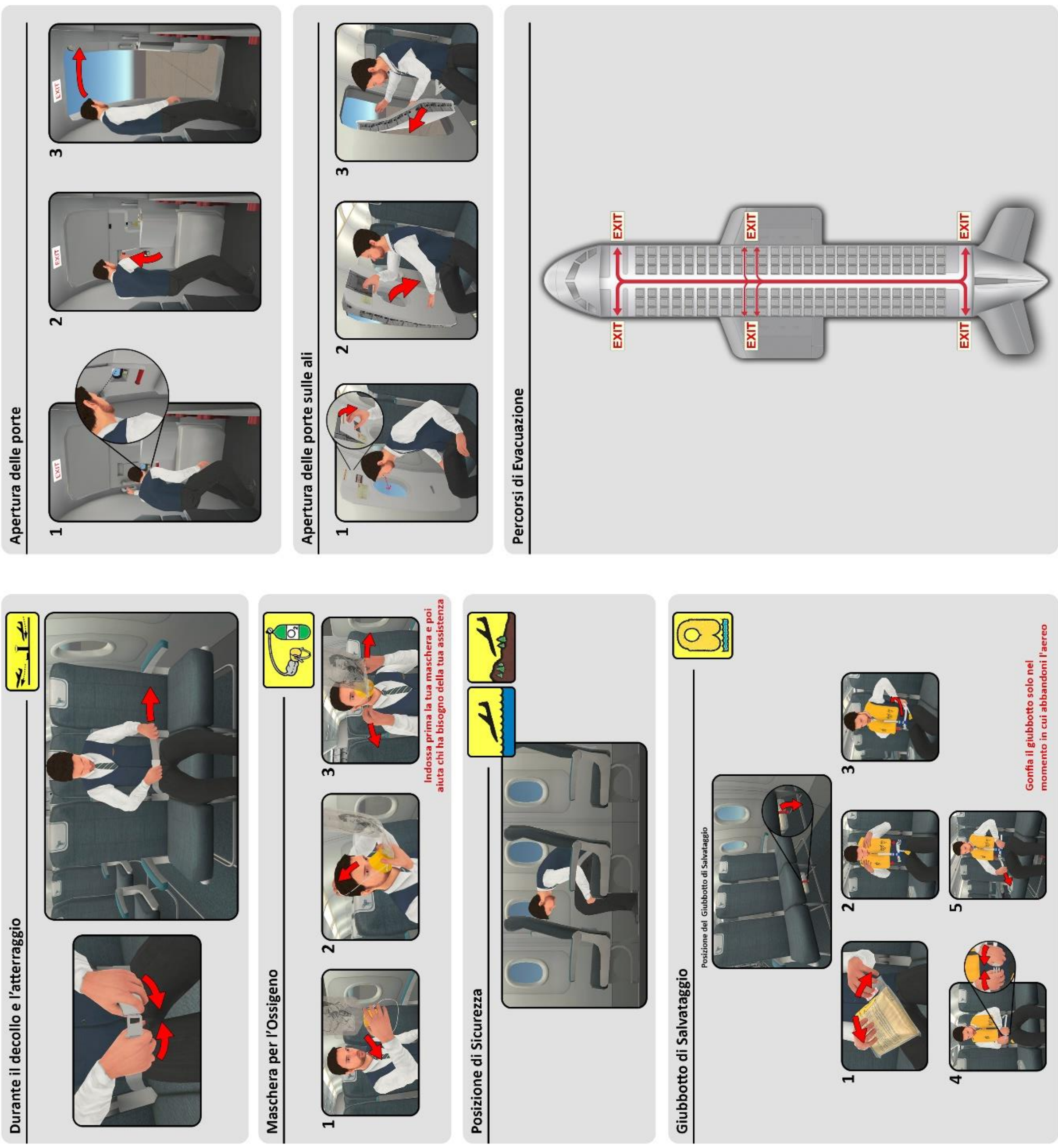

Figure 4. The safety briefing card.

The safety briefing video (with or without interactivity) was displayed on a Samsung Galaxy Tab S2 tablet (screen size: 9.7 inches, resolution: 2048x1536 pixels). Following the typical design choice of safety briefing videos used by airlines, two characters spoke to the passenger in the video. For each procedure of the briefing (seatbelts, brace position, oxygen masks, life preserver, floor exit and wing exit doors), one character briefly introduces the topic in general, while the other (which is the same one depicted in the safety card) demonstrates the procedure. Therefore, in all three media in the study, the same safety procedures are shown by the same character (a male flight attendant). In the two video media, the second character (a female flight attendant) announces which procedure will be demonstrated and when one must execute that procedure; the card provides such information with text and icons (Figure 4) as it is typical of airline safety cards. In recording the character voices, we took into account the indications of (Barkow & Rutenberg, 2002) for the creation of aviation safety briefings, e.g., the voice of the speakers should not be monotone, they should not speak fast, they should use simple, non-specialized language.

For the knowledge application tests, we used real-world seatbelts, oxygen mask, and life preserver of the same type depicted in all three safety briefing media.

2.2 Participants

Recruitment of participants relied on convenience sampling among students at our university. The evaluation involved a sample of 66 undergraduate students (60 M, 6 F). Their age ranged from 20 to 29 ($M=21.64$, $SD=1.58$). We assessed individual frequency of air travel by asking participants to count their number of flights in the last two years, as in (Corbett et al., 2008). We made it clear that each flight had to be counted individually, so for example a round trip from airport A to airport C via a connection through airport B results in four flights. Flight frequency ranged from 0 to 8 ($M=1.47$, $SD=2.18$). Lack of significant differences between the groups was confirmed by ANOVA for age ($F(2, 63)=0.53$, $p=0.95$) as well as frequency of air travel ($F(2, 63)=0.97$, $p=0.82$).

2.3 Measures

2.3.1 Instructions simplicity

We measured participant's perceived simplicity of the instructions received by the safety briefing media by having respondents rate their level of agreement with three items on a 7-point Likert scale (1=not at all, 7=very). The items made the following statements about the provided instructions: "They are simple", "They are easy to learn", "They are easy to carry out". For each respondent, the mean of his/her three answers was taken as the grouped Likert-scale score (Carifio & Perla, 2007; Carifio & Perla, 2008; Norman, 2010) for instructions simplicity.

2.3.2 Instructions efficacy

We measured participant's perceived efficacy of the instructions received by the safety briefing media by having respondents rate their level of agreement with three items on a 7-point Likert scale (1=not at all, 7=very). The items made the following statements about the provided instructions: "They are useful for my safety", "They are effective to face an aircraft emergency", "They allow one to greatly reduce the probability of getting hurt in an aircraft emergency". For each respondent, the mean of his/her three answers was taken as the grouped Likert-scale score (Carifio & Perla, 2007; Carifio & Perla, 2008; Norman, 2010) for instructions efficacy.

2.3.3 Intuitive controls

To assess if the interactive controls offered by the Video with Interactivity condition were intuitive to use, we observed participants while they used the media to take note of any possible difficulties they could encounter or usage errors they could make with the touchscreen interface. At the end of the experiment, we also asked them about any difficulties they experienced.

2.3.4 Knowledge recall and application

We tested participants' ability to recall knowledge and apply it to the real world by having them fasten real seatbelts, wearing a real oxygen mask, physically assuming the brace position, donning a real life vest. We observed participants while they carried out these procedures, and kept track of the number and the type of errors they made in carrying out each of the four procedures. We then tested participants' knowledge about opening exit doors: for each of the two types of doors (wing exit door, floor exit door), they looked at a picture of the door, and had to explain how to open it. We kept track of the number and the type of errors they made in describing each of the two door opening procedures.

2.3.5 Self-efficacy

We assessed participant's self-efficacy with respect to their ability of carrying out the safety procedures. To this purpose, we designed a 6-item questionnaire, based on a typical item ("I feel confident in my ability to…") used in self-efficacy assessment, as indicated in the self-efficacy survey by Schwarzer & Luszczynska A. (2016). Each of the six items referred to one of the different topics considered by the safety briefing: "I feel confident in my ability to…" (i) "wear the oxygen mask", (ii) "assume the brace position", (iii) "fasten the seatbelts", (iv) "don the life preserver", (v) "reach the aircraft exits", (vi) "open the aircraft doors". Each item was rated by participants on a 7-point scale (1=not at all, 7=very). For each respondent, the mean of his/her six answers was taken as the grouped Likert-scale score (Carifio & Perla, 2007; Carifio & Perla, 2008; Norman, 2010) for self-efficacy.

We measured self-efficacy two times: before participants used the safety briefing media, and immediately after they used the media.

2.4 Procedure

Participants were seated at a desk, and filled the initial questionnaire (age, frequency of air travel, and self-efficacy). Then, they received the safety briefing media (Card, Video, or Video with Interactivity) assigned to them. They were told that it was a media that illustrated safety procedures to be used on board an aircraft, and that they could use it for how much time they needed to examine the procedures. We handed the safety briefing media to the seated participants and they kept it in their hands to use it. We informed them that they could not talk or ask questions to the experimenter until they completed their examination of the procedures.

After trying the safety briefing media assigned to them, participants answered the questionnaires about self-efficacy, perception of instruction simplicity, and perception of instruction efficacy. Then, to take the measures described in Section 2.3.4, we asked them to move to another seat that was equipped with real aircraft seat belts, and aircraft life preserver. First, we asked participants to fasten the seat belts. Then, an oxygen mask dropped from above, and we asked them to don it. When they felt they had completed the donning procedure, we asked them to remove the mask, and assume the brace position (the seat was placed in front of a surface that could be reached with the head to assume the position properly). Finally, we asked them to find and don the life preserver. After completing these four procedures, we showed them the pictures of the two types of doors, and asked them to describe verbally the opening procedures (see Section 2.3.4). Finally, we thanked participants for their participation.

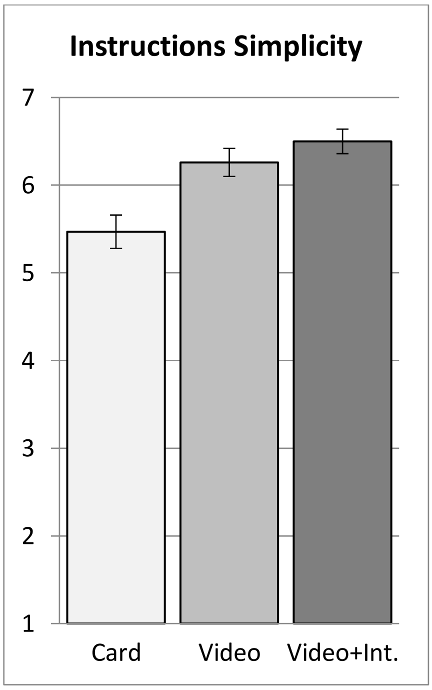

Figure 5. Perceived simplicity of the instructions. Capped vertical bars denote ±1 SE.

2.5 Results

2.5.1 Instructions simplicity

Differences in perceived instructions simplicity (Figure 5) were analyzed with a one-way independent ANOVA, and Fisher's protected t-test for post-hoc analysis, as recommended in (Cohen, 2013) for studies with three groups of the same size. The choice of parametric analysis for grouped Likert-scale items is further motivated by (Carifio & Perla, 2007; Carifio & Perla, 2008; Norman, 2010).

The effect of type of safety briefing media was statistically significant, $F(2, 63)=6.38$, $p<0.001$, $\eta_p^2=0.26$. Post-hoc analysis revealed a significant difference ($p<0.01$) between Card (M=5.47, SD=0.88) and Video (M=6.26, SD=0.76), and a significant difference ($p<0.001$) between Card (M=5.47, SD=0.88) and Video with Interactivity (M=6.5, SD=0.64). The difference between the two video conditions did not reach significance ($p=0.29$).

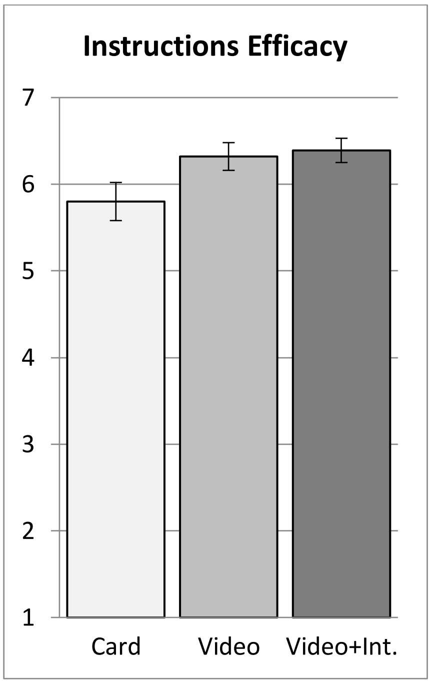

Figure 6. Perceived efficacy of the instructions. Capped vertical bars denote ±1 SE.

2.5.2 Instructions efficacy

Differences in perceived instructions efficacy (Figure 6) were subjected to the same type of statistical analysis used for instructions simplicity. The effect of type of safety briefing media was statistically significant, $F(2, 63)=3.20$, $p=0.048$, $\eta_p^2=0.09$. Post-hoc analysis revealed a significant difference ($p=0.048$) between Card (M=5.47, SD=0.88) and Video (M=6.26, SD=0.76), and a significant difference ($p=0.023$) between Card (M=5.47, SD=0.88) and Video with Interactivity (M=6.5, SD=0.64). The difference between the two video conditions did not reach significance ($p=.76$).

2.5.3 Intuitive controls

All participants in the Video with Interactivity condition were immediately able to interact with the controls on the touchscreen without any prior training or explanation. This observation was confirmed also by the final interview, in which participants did not report any difficulties with the interactive controls.

2.5.4 Knowledge recall and application

Differences in the number of errors for each of the four executions of safety procedures in the real-world (seat belts, oxygen mask, brace position, life preserver), and each of the two verbal descriptions of door opening (wing exit, floor exit) procedures were analyzed with Kruskal-Wallis test. When the test returned a significant result, post-hoc analysis was performed with separate Mann-Withney tests between pairs of groups, and the appropriate alpha adjustment (0.05 divided by the number of separate Mann-Withney tests, i.e. alpha = 0.05/3 = 0.017), as recommended in (Cohen, 2013).

For one of the procedures (fastening seatbelts), although Video with Interactivity obtained the best mean (Card: M=0.82, SD=0.66; Video: M=0.73, SD=0.83; Video with Basic Interactivity: M=0.50, SD=0.67), the analysis did not reveal a statistically significant effect. For all other knowledge tests, a main effect of type of safety briefing media was found, as we illustrate in detail in the following.

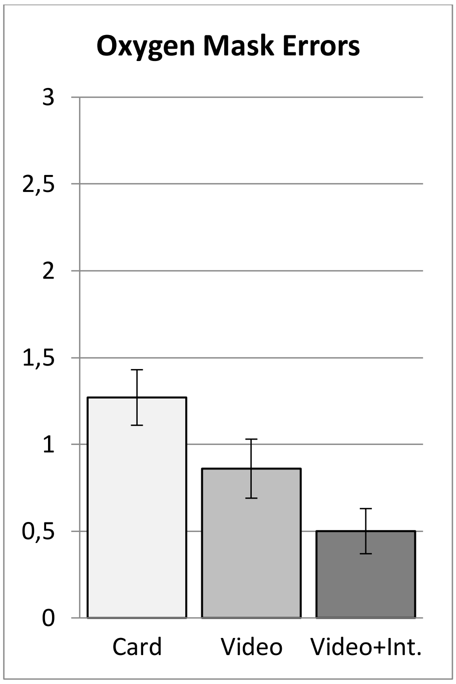

Figure 7. Means of the number of errors in the oxygen mask procedure.
Capped vertical bars denote ±1 SE.

Oxygen mask procedure. Figure 7 illustrates the means obtained for the three conditions in wearing the oxygen mask. The effect of type of safety briefing media was statistically significant, $\chi^2(2)=10.73$, $p<0.01$. Post-hoc analysis revealed a significant difference ($Z=-3.29$, $p=0.001$, $r=0.50$) only between Card ($M=1.27$, $SD=0.77$) and Video with Interactivity ($M=0.50$, $SD=0.60$). Post-hoc comparisons between Card and Video ($p=0.12$), and between Video and Video with Interactivity ($p=0.11$) did not reach significance.

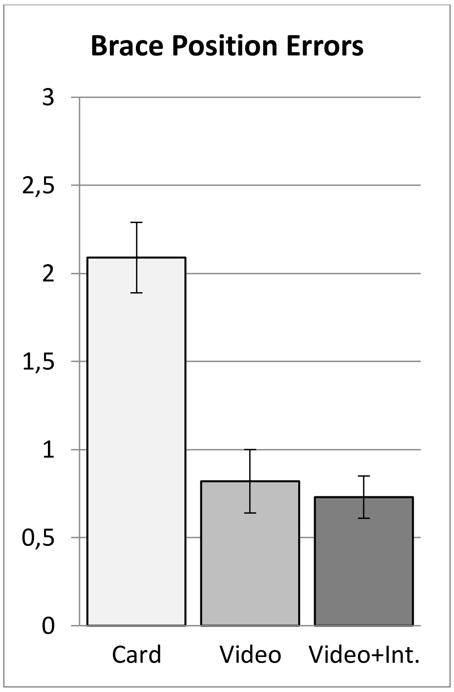

Figure 8. Means of the number of errors in the brace position procedure.
Capped vertical bars denote ±1 SE.

Brace procedure. Figure 8 illustrates the means obtained for the three conditions in assuming the brace position. The effect of type of safety briefing media was statistically significant, $\chi^2(2)=25.35$, $p<0.001$. Post-hoc analysis revealed a significant difference ($Z=-3.94$, $p<0.001$, $r=0.59$) between Card ($M=2.10$, $SD=0.92$) and Video ($M=0.82$, $SD=0.85$), and a significant difference ($Z=-4.76$, $p<0.001$, $r=0.72$) between Card ($M=2.10$, $SD=0.92$) and Video with Interactivity ($M=0.73$, $SD=0.55$). Post-hoc comparison between Video and Video with Interactivity ($p=0.86$) did not reach significance.

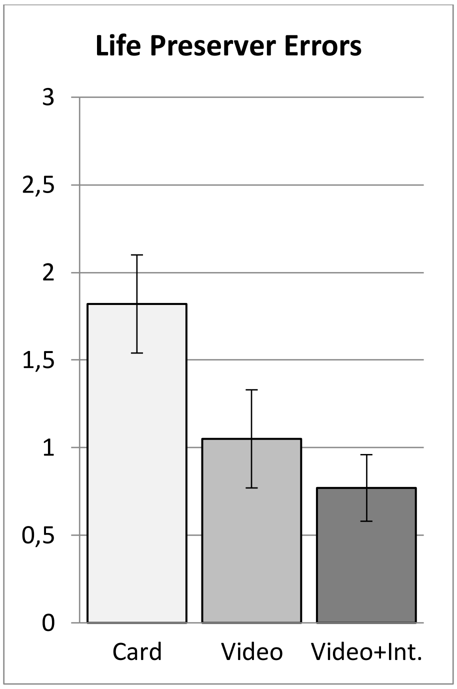

Figure 9. Means of the number of errors in the life preserver procedure. Capped vertical bars denote ±1 SE.

Life preserver procedure. Figure 9 illustrates the means obtained for the three conditions in retrieving and wearing the life preserver. The effect of type of safety briefing media was statistically significant, $\chi^2(2)=10.01$, $p<0.01$. Post-hoc analysis revealed a significant difference ($Z=-3.13$, $p=0.001$, $r=0.47$) only between Card ($M=1.81$, $SD=1.33$) and Video with Interactivity ($M=0.77$, $SD=0.87$). The difference between Card and Video ($M=1.05$, $SD=1.29$), and the difference between Video and Video with Interactivity, did not reach the necessary 0.017 alpha-level for the separate Mann-Withney tests, obtaining $p=0.023$ and $p=0.71$, respectively.

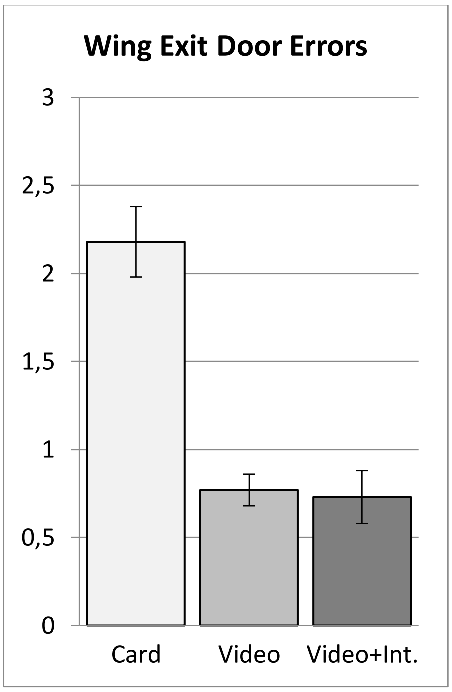

Figure 10. Means of the number of errors in the wing exit procedure.
Capped vertical bars denote ±1 SE.

Wing exit door procedure. Figure 10 illustrates the means obtained for the three conditions in describing the door opening procedure for wing exits. The effect of type of safety briefing media was statistically significant, $\chi^2(2)=29.98$, $p<0.001$. Post-hoc analysis revealed a significant difference ($Z=4.87$, $p<0.001$, $r=0.73$) between Card ($M=2.18$, $SD=0.96$) and Video ($M=0.77$, $SD=0.43$), and a significant difference ($Z=-4.44$, $p<0.001$, $r=0.67$) between Card ($M=2.18$, $SD=0.96$) and Video with Interactivity ($M=0.73$, $SD=0.70$). Post-hoc comparison between Video and Video with Interactivity ($p=0.61$) did not reach significance.

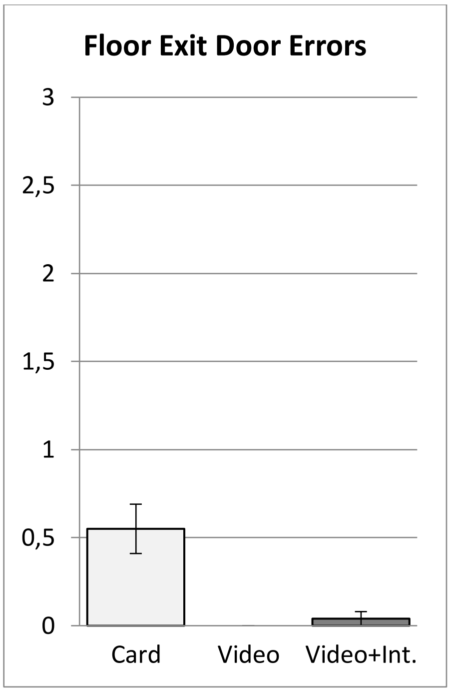

Figure 11. Means of the number of errors in the floor exit procedure. Capped vertical bars denote ±1 SE.

Floor exit door procedure. Figure 11 illustrates the means obtained for the three conditions in describing the door opening procedure for floor exits, which were simpler than wing exits. The effect of type of safety briefing media was statistically significant, $\chi^2(2)=19.63$, $p<0.001$. Post-hoc analysis revealed a significant difference ($Z=-3.54$, $p=0.001$, $r=0.53$) between Card ($M=0.55$, $SD=0.67$) and Video ($M=0$), and a significant difference ($Z=-3.11$, $p=0.003$, $r=0.47$) between Card ($M=0.55$, $SD=0.67$) and Video with Interactivity ($M=0.04$, $SD=0.21$). Post-hoc comparison between Video and Video with Interactivity ($p=0.61$) did not reach significance.

2.5.5 Self-efficacy

Figure 12 illustrates the means obtained for self-efficacy before and after using the safety briefing media. Self-efficacy data were analyzed with an ANCOVA of the after-value, using the before-value as co-variate, as recommended in Cohen (2013) for before-after studies. The choice of parametric analysis for grouped Likert-scale items is further motivated by (Carifio & Perla, 2007; Carifio & Perla, 2008; Norman, 2010).

The analysis revealed a significant effect of type of briefing, $F(2, 62)=4.78$, $p=0.012$, $\eta_p^2=0.13$. Post-hoc analysis with Fisher protected test revealed that only the difference between Card ($M=5.66$, $SD=0.65$) and Video with Interactivity ($M=6.23$, $SD=0.48$) was statistically significant ($p<0.01$). Post-hoc comparisons between Card and Video ($p=0.06$), and between Video and Video with Interactivity ($p=0.43$), did not reach significance.

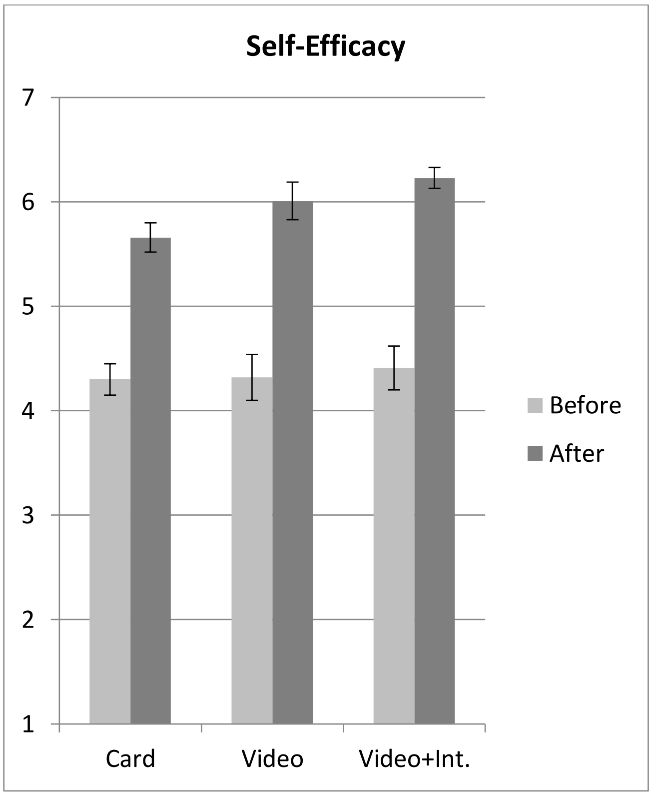

Figure 12. Self-efficacy before and after trying the safety briefing media.
Capped vertical bars denote ±1 SE.

3. Discussion and Conclusions

To the best of our knowledge, our work is the first to propose an interactive extension of aviation safety briefing videos, and to compare the effectiveness of three types of safety briefing media: card, video, and video extended with interactive controls. Moreover, the study we presented was designed to achieve a high level of control on the large number of possible confounding factors (summarized in Section 1.2) that affected previous studies of aviation safety briefing media.

The results of the study showed that the two safety briefing media that used video always obtained better results than the safety briefing card. However, while the Video condition was able to produce a statistically significant difference only on some of the measures (perceived instructions simplicity, perceived instructions efficacy, brace position errors, wing exit door errors, floor exit door errors), Video with Interactivity was able to produce it on almost every measure (perceived instructions simplicity, perceived instruction efficacy, oxygen mask errors, brace position errors, life preserver errors, wing exit door errors, floor exit door errors, self-efficacy). These results highlight a general superior effectiveness of video over card media for aviation safety briefings. Moreover, they indicate that introducing the proposed basic level of interactivity in the video produces additional improvements in effectiveness measures.

Our findings are consistent with the predictions from the literature that points out how adding intuitive basic interactive controls to a video presentation should improve learning of procedural skills with respect to traditional media (Schwan & Riempp, 2004; Hasler et al., 2007; Merkt et al., 2011). The capability of adapting pace of presentation offered by the interactive controls is an especially important factor. Traditional safety briefing videos are mass media presentations that address all passengers together. Unfortunately, the cognitive characteristics of individual members of a general audience vary, including their ability to process and organize information that is presented at a preset rate (Schwan & Riempp, 2004). Lack of adaptability of presentation rate may thus lead to shallow processing or even cognitive overload, as shown by different studies on learning from video media (Wetzel, Radtke & Stern, 1994). On the contrary, in our interactive safety briefing video, each user can adapt the rate of presentation through basic controls that we carefully designed to comprise different facets that have been shown to improve self-paced learning. Such facets are: making interactive controls intuitive to use (Schwan & Riempp, 2004; Hasler et al., 2007; Merkt et al., 2011); segmenting the flow of information into small, discrete segments of activity (Mayer & Chandler, 2001; Hasler et al., 2007); highlighting the boundary between activities (Newtson & Engquist, 1976; Schwan, Garsoffky & Hesse, 2000) and where the user should focus his/her attention in that boundary through cueing (de Koning, Tabbers, Rikers, & Paas, 2007); using contextually meaningful gestures, instead of simple taps on the touchscreen (Dube & McEwen, 2015).

Another factor that can play a role in determining the obtained results is that video conditions can engage the user for a longer time than the card condition. Indeed, although we clearly informed participants that they could take as much time as they needed to examine the procedures, participants who examined the safety card tended to go through its content relatively quickly (M=95 s, SD=35), while the traditional video condition did not allow them to do so because its length was fixed (400 s), and likely provided a better pacing of the information flow that did not allow users to take shortcuts or consider single elements for an insufficient time as one can instead do with the card. The Video with Interactivity condition allowed users to personalize the pace, resulting in a further extension of exposure time (M = 449, SD = 27). It is interesting to observe that this average 11.2% increase in exposure time obtained by adding basic interactive controls to the video is mainly due to the stop and restart control at the end of each action in a procedure. The other basic interactive control available, i.e. the possibility of watching again a procedure, was left unused by all but five participants (three of them used it for just one procedure, one used it for two procedures, and one used it for three procedures). In the final interview about the use of interactive controls, some participants mentioned the fact that they felt the illustration of the procedure was clear enough, and thus did not feel the need to use the control to watch a procedure again.

A difference between our study and the real-world experience of boarding a commercial aircraft is that in the latter case passengers are typically exposed to a live pre-flight demonstration conducted by flight attendants. The thrust of the study in this paper was not to model a live pre-flight demonstration on aircraft, but to compare three safety briefing media for effectiveness, leaving the study of combinations of both types of instruction (live pre-flight demonstration followed by the use of a safety briefing media) as a possible next step. It could also be interesting to investigate the knowledge recall and application effects of the present study in real-world, full-scale simulations of an aircraft evacuation, e.g. (Muir, Bottomley, and Marrison, 1996). Unfortunately, such simulations of aircraft emergencies present ethical issues, due to a significant potential for injuries, including serious ones, to the involved participants (Corbett, McLean, and Whinnery, 2003). Progress in the realism of immersive virtual reality could provide a safe and less costly alternative to real-world emergency simulation, and recent studies of virtual fire experiences, which included functional magnetic resonance (fMRI) and psychophysiology measures, are showing that immersive virtual reality can be effective in recreating the stressful situation of an emergency evacuation (Zanon et al., 2014; Crescentini et al., 2016).

A limitation of the study in this paper lies in the nature of the sample, obtained through convenience sampling. The three safety briefing media were evaluated on young participants in the 20-29 age range. This age range is not representative of all possible passenger ages, but it is nevertheless representative of a relevant segment of the adult flying public (CAA, 2015; IATA, 2014) for which safety briefing media are designed, and it is the segment with the highest traveling frequencies in leisure travel (Statista, 2017). However, it must be noted that people in this age range are familiar with using interactive media on touchscreens. It would thus be interesting to repeat the study with people who are unfamiliar with the technology and/or are older adults, to test if the obtained results generalize to this different sample. A research goal that can be pursued with this different type of participants is assessing to what extent the increase in extraneous cognitive load due to the use of unfamiliar interactive technology could reduce the possible effectiveness of the safety briefing media, by limiting the cognitive resources devoted to learning the materials (Hasler et al,, 2007). The sample we studied was also male-dominated. Silver and Perlotto (1997) conducted a study of possible gender effects in aviation safety information comprehension, and concluded that there were no appreciable differences between genders. However, their study considered only safety briefing cards, and it could thus be interesting to extend the investigation to videos with or without interactive controls.

Another research direction worth pursuing is to explore if adding more advanced levels of interactivity could lead to further improvements in effectiveness. As motivated in Section 1.1, the design of the level of interactivity introduced in the safety briefing video for this study gave priority to simplicity. For example, user's gestures make the safety procedure advance to the next action, and there is no possibility to explore different courses of action than the preset one. In other words, there is no possibility for the user to explore the different actions in non-linear ways. An interesting line of research in adding more interactivity could thus be to support free exploration. For example, the interactive safety briefing could allow users to take different actions including wrong ones (e.g., bringing the oxygen mask to the face without first enabling the flow of oxygen), and learn that some choices are errors that lead to failure of the safety procedures. However, while the interactive safety briefing proposed in this paper was immediately and easily used by every participant, the literature highlights how the addition of free exploration inevitably increases cognitive load, and individual executive functions play a role in mitigating such increase (Homer & Plass, 2014), i.e. individuals with higher levels of executive functions receive more benefit from an exploratory simulation that responds to user's choices, while those with lower levels of executive functions receive more benefit from a system-guided approach. This should be taken into account in the design of a more interactive safety briefing that aims at offering exploratory simulation. While certain passengers will quickly take advantage of free exploration, the possibility of additional guidance to set in and help other passengers in the exploration should be explicitly provided by the system. Such guidance can also be adapted to the individual user. As a simple example, the character in the safety briefing could intervene and guide the user only after a certain time of user's inactivity is detected or a specific control (e.g. a question mark icon on the screen) has been touched by the user to ask the character for guidance when (s)he finds it difficult to proceed. This way, the proper trade-off between exploration and guidance might be tailored to the individual user.

Another interactive feature that could be explored is to allow users to choose among multiple viewpoints (Chittaro & Ranon, 2007): since the proposed interactive safety briefing is based on a 3D world that runs on a real-time rendering engine, it naturally supports any change in viewing angles. This way, the user could examine safety equipment (e.g., oxygen mask or life preserver) as well as the actions carried out by the character from the viewpoint that makes them most clear to him/her.

Finally, the introduction of game-like features could help in increasing attention to and usage time of interactive safety briefings. Video games are increasingly considered as a viable safety education tool in diverse safety domains such as road safety (Li & Tay, 2014) or constructions safety (Guo Li, Chan & Skitmore, 2012). In the literature, two studies (Chittaro & Buttussi, 2015; Chittaro, 2016) have experimented the use of video games in aviation safety education, reporting positive learning results. However, the interactive applications described in the two studies are not safety briefings, but survival video games that immerse players in reproductions of serious aircraft accidents. Moreover, as both papers clearly point out, such realistic disaster depictions (which include the scary consequences of the simulated scenarios such as injury and death) makes them incompatible with on-board use. On the contrary, on-board use is a defining requirement for aviation safety briefings, and the possible introduction of game-like features into aviation safety briefings is constrained by such mandatory requirement. Therefore, the above mentioned survival video games cannot be alternatives to safety briefings, but they might play a complementary role: while interactive safety briefings can be used on-board (as well as off-board) by anyone, passengers who are familiar with playing video games, and do not find the survival genre disturbing, can reinforce their knowledge of safety procedures by playing such video games off-board.

Finally, it is worth noting that the approach to interactivity we have proposed in this paper can be technically added to any safety briefing video that displays procedures as sequences of actions. Therefore, considering that the need to effectively prepare passengers for an evacuation is important also in other transportation domains (e.g., cruise ships), it would be interesting to investigate if the proposed approach could go beyond the domain of aviation safety on which this paper has focused.

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