Design and Implementation of a Serious Game to Make Construction Workers Aware of Exposure to Silica Dust in the Workplace

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Abstract. Silicosis is a lung disease due to the inhalation of crystalline silica dust. In the province of Quebec in Canada, it is the third pulmonary occupational disease recognized by the Committee on Standards, Equity, Health and Safety at Work. To date, lung transplantation is the only proven curative treatment. Consequently, prevention remains the best way to fight against silicosis. This requires that workers, at risk of exposure, have adequate training on the subject. For this, passive slide-based training is generally used. The goal of this paper is to operate a Serious Game to facilitate the training of construction workers on the prevention of silicosis and the protection of health in the workplace. We are interested in exploiting this media because we see in these types of games an active and situated problem-solving with probably some social interactions. They can transmit knowledge while entertaining the user in diversified activities. In this article, we report the development project and preliminary evaluation of a serious game in which the player is faced with different situations that involve exposure to silica. The aim is to train and make the player aware of silica, its risks, and its consequences. The results show the ability of this serious game to transmit knowledge about silica dust, the risk that it represents for health, the risk tasks and the protective measures in the workplace, and finally the consequences of the inhalation of silica dust.

Keywords: Serious games · Learning · Training · Action · Silica dust · Silicosis

1 Introduction

Silicosis is a lung disease caused by the inhalation of crystalline silica dust [1]. It is an occupational hazard to workers of multiple industries such as mining, pottery, oil and

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gas and construction, among others, making it one of the most important occupational diseases worldwide [2]. Silicosis destroys lung tissue that can continue to develop even when the worker is no longer exposed to silica dust [3]. In Canada, in the province of Quebec, it was the third pulmonary occupational disease recognized by the Committee on Standards, Equity, Health and Safety at Work (CNESST) [4]. As lung transplantation is the only proven cure [1, 5], prevention remains the best way to fight the disease. The National Institute of Occupational Safety and Health (NIOSH) recommends four main categories of measures that help to control the development of silicosis [6]: (1) Dust Control which consists of canalizing the dust to prevent its propagation in the air; (2) Personal Hygiene which includes responsible worker behaviour to minimize the risk of inhalation of silica dust; (3) Protective Clothing such as a work uniform for workers to use, maintain and store properly; and (4) Air Monitoring which alerts workers to potential dangers so that they may take appropriate measures to limit their exposure to silica dust.

All of these recommendations require the worker to make informed choices based on the configuration of the environment and the controlling factors (e.g. ventilation and humidity). The fight against silicosis, therefore, requires that workers at risk of exposure have adequate training on the subject. Passive slide-based training is generally used for this purpose [7]. In Quebec, such training is provided by Occupational Safety and Health workers in the public health network. In the construction sector, the high mobility of labour and businesses and the lack of a permanent employment link for almost all workers create barriers to disease prevention. Our goal is to operate a serious game (SG) to facilitate the training of construction workers on the prevention of disease and the protection of health.

We are interested in exploiting SG because these types of games require active and situated problem-solving with likely social interaction [8, 9]. Moreover, SGs allow for a learner approach [10] while creating a meaningful environment for learning [11, 12]. By doing so, they can address both cognitive and affective dimensions of learning [13]. Indeed, learning can be defined as ‘an enduring change in behaviour, or in capacity to behave in a given fashion, which results from practise or other forms of experience’ [14]. It is a process of promoting learners’ engagement in activities of knowledge acquisition or behaviour modification [15]. As learning theories have evolved, several researchers have established that action-oriented learning in a specific context would allow for better changes in the learner than passive learning [14–16]. They subsequently proposed factors that would facilitate the acquisition of knowledge through the interactions between the subject and the environment: learning content, learning context, practice, corrective feedback, manipulation of information, and physical and mental activity of the learner, among others [14]. These factors are even more important to consider when using SGs. We are particularly interested in SGs because of their ability to transmit information while entertaining the user in diversified activities through interactions. In the health sector, they can be used for several purposes including training, information, education and awareness.

In this article, we report the project development and preliminary evaluation of an SG in which the player is faced with different situations that involve exposure to silica. Our goal in using this game is that the player becomes well informed of the various means

of prevention to limit the risks of inhalation of silica particles and that he develops an awareness of the consequences that negligence could have on his health and life.

2 Materials and Methods

2.1 Presentation and Objectives

We named the developed tool 'The Four Aces'. It is an SG of four missions to educate construction workers about silica dust. This concept was selected as a result of the average age of the target population [17]. The game environment is a worksite in summer during the day. It is divided into four missions, each associated with an ace from a deck of 52 cards. The goal of the game is to collect all four aces: spade, diamond, club and heart. Each ace thus constitutes the reward for a fully completed mission. Each mission contains only cards of the same colour. Points are awarded to the player for each card won. To be able to move to the next mission, the player must earn at least half of the points (06/12). A time parameter is associated with each mission to stimulate the player's concentration and commitment.

As the goal is to educate workers without frustrating them, we based the game design on the GameFlow model of Sweetser and Wyeth [18]. The principle is to ensure the player a better experience during the game and keep him in a psychological area free from boredom and anxiety. We first ensured that there was a good balance between the challenges of the in-game tasks and the skills of the player. To accomplish this, the tasks given to the players in the game are all associated with construction jargon. Moreover, the game interface and gameplay are made as simple as possible, and controls are easy. Mission goals are clearly defined, and the player receives immediate feedback on his actions in the game. The player does not receive punishment for error. Instead, he is allowed to retry as many times as necessary, as long as there is time left for the mission. At the end of each mission, a summary is given to the player. For players who missed certain cards, correction images are given to them in this summary so that they can still consider their failures and the right answers. So, regardless of whether the player has won the ace[1], he proceeds to the next mission, having learned what was presented to him in the previous one.

For the first three missions, each card is associated with a specific task, action or situation that can be found on a construction site. In the fourth mission, each card is associated with an effect of silicosis. There is, therefore, a total of forty-eight situations of identification, elimination, protection, and awareness regarding silica dust in a worksite.

2.2 Devices and Mechanics

The game must be installed on a desktop computer with a Windows 64-bit operating system to run correctly. Since workers are not necessarily familiar with computer technologies, the operations are simple and consist of simple clicks or click-and-drag with the mouse. For a quick start to the game, an interactive tutorial is presented to the player

[1] The ace is won if the score is 12/12, and the player can even go to next mission with a score of 06/12 without winning the ace.

at launch (See Fig. 1). This approximately two-minute tutorial constitutes learning by action. It assembles all the manipulations and forms of instructions that the player will have to use throughout the game.

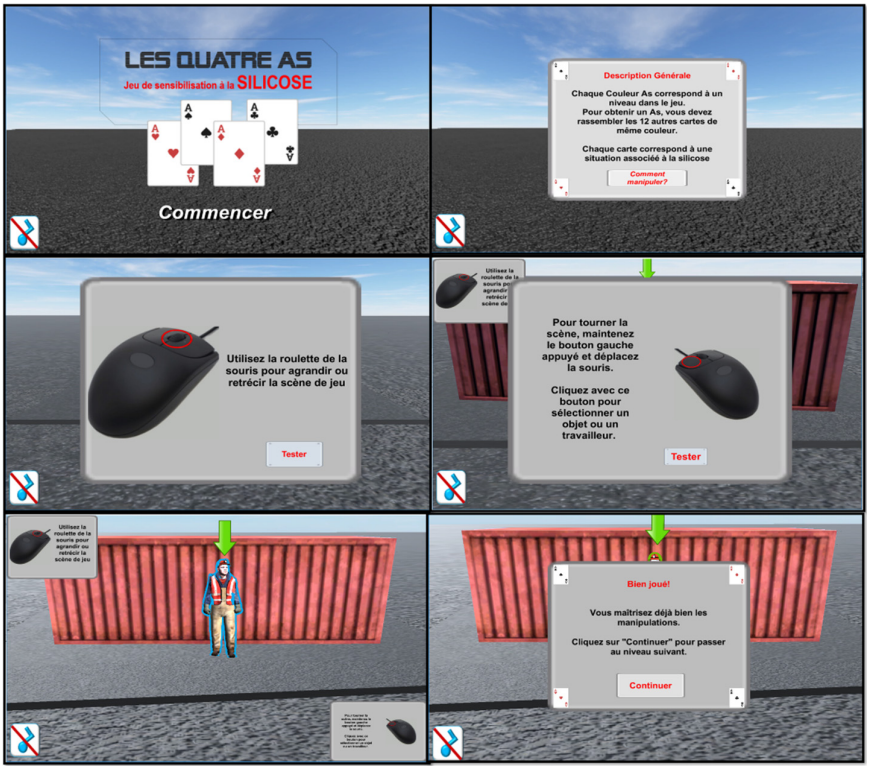

Fig. 1. Serious game (SG) tutorial

2.3 Missions of the Game

The four missions of the game are described below.

Ace of Hearts – Identification: Identify the Risks of Inhaling Silica Dust
This mission lasts at most ten minutes and is associated with heart suit cards. In this mission, the player is invited to identify situations in which one is likely to inhale silica dust in the worksite. For this, the player must go through the virtual worksite and find the twelve workers who do not meet workplace safety standards. Each situation found allows the player to obtain a heart card with which the tool or the situation concerned is associated on the site. To do this, the player must select a card by clicking on it in the upper part of the screen, browse the virtual worksite by clicking and drag with the mouse to find and click on the "non-standard" worker associated with the image engraved on the card.

The order in which the player resolves this mission is not important (he can start with any card). The different risk situations for inhaling silica dust, and the corresponding cards are as follows: 2 of hearts – aspiration without a protective mask; 3 of hearts –sweeping that raises dust without a protective mask; 4 of hearts – bush-hammering without a protective mask; 5 of hearts – concrete mixing without a protective mask; 6 of hearts – inactive standing worker without a protective mask in a dusty area; 7 of hearts – abrasive jet without a protective mask; 8 of hearts – demolition of the slab using a jackhammer without a protective mask; 9 of hearts – grinding without a protective mask; 10 of hearts – cleaning the tool with a sandblast without a protective mask; jack of hearts – perforation of a wall without a protective mask; queen of hearts – concrete sawing without a protective mask; and king of hearts – blowing without a protective mask. Figure 2 shows some of the situations within this mission.

Fig. 2. Some situations of mission 1 in the SG

Ace of Spades – Elimination: Eliminate the Risk of Inhaling Silica Dust

This mission lasts at most height minutes and is associated with spade suit cards. The player must resolve twelve situations associated with ways to eliminate the risk of inhalation of silica dust on a work site. The situations are presented in a scrolling fashion with an average duration of forty seconds each. In each situation presented to him, the player must use the indicative text to click on the action to be performed to eliminate the risk of inhaling silica dust. These situations and the associated cards are as follows: 2 of spades – general aspiration; 3 of spades – delimitation of the work area; 4 of spades

– agglomeration of the cement; 5 of spades – aspiration at the source; 6 of spades – humidification of the area; 7 of spades – suction instead of sweeping; 8 of spades – use of a filtration hood; 9 of spades – use of an automated crushing arm in the filtering cabin; 10 of spades – sandblasting with non-siliceous materials; jack of spades – humidification at the source; queen of spades – choice of the right tool between a saw with an integrated vacuum cleaner and a saw without an integrated vacuum cleaner; and king of spades - change of cabin filters. Figure 3 shows some situations within this mission.

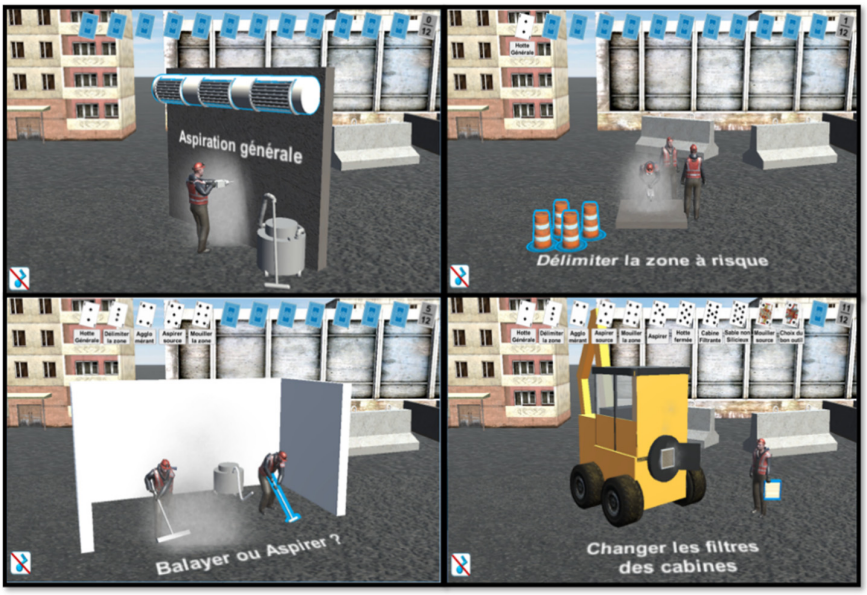

Fig. 3. Some situations of mission 2 in the SG

Ace of Diamonds – Individual and Collective Protection Measures: Protect Yourself and Others from the Risks of Inhaling Silica Dust

This mission lasts at most height minutes and is associated with diamond suit cards.

The aim of this mission is to compel the player to acquire individual and collective protective measures against silica dust in twelve situations, as follows: 2 of diamonds – before working, dress in the protective uniform (wear your work clothes); 3 of diamonds – shave the beard to seal the mask; 4 of diamonds – wear at least one disposable respiratory mask in case of low exposure; 5 of diamonds – wear a respiratory mask in case of strong exposure; 6 of diamonds – wear a respiratory suit in case of very intense exposure; 7 of diamonds – avoid excessive physical effort in a dusty environment; 8 of diamonds – avoid smoking in the workplace; 9 of diamonds – clean the mask; 10 of diamonds – store the mask; jack of diamonds – vacuum all the dust present on the work equipment; queen of diamonds – store work clothes; and king of diamonds – attend safety training.

The manipulations in this mission are the clicks for the situations corresponding to cards 2, 4, 5, 6, 7, 8, 9, queen and king, and the click-and-drag for those corresponding

to cards 3, 10 and jack. In these last three situations, clicking and dragging allow the player to perform actions as in real life. Figure 4 shows some of the situations within this mission.

Fig. 4. Some situations of mission 3 in the SG

Ace of Clubs – Sensitization: Consideration of Silicosis Effects on the Worker's Life

This mission lasts at most two minutes and is associated with club suit cards. The aim is to make the player aware of the consequences of silicosis. With a simple click of the mouse, the player could browse the various clubs' cards and inquire about the information presented to him concerning the consequences of silicosis. This information is presented in the form of animated images. The different situations are as follows: 2 of clubs – degradation of the lungs; 3 of clubs – decline in breathing capacity; 4 of clubs – risk of lung cancer; 5 of clubs – difficulty breathing; 6 of clubs – physical weakness; 7 of clubs – loss of work capacity; 8 of clubs – early retirement; 9 of clubs – financial problems; 10 of clubs – inability to participate in spare-time activities; jack of clubs – loss of family activities; queen of clubs – awareness of the fact that there is no treatment for silicosis; and king of clubs – reduced life expectancy. Figure 5 shows some of the situations within this mission.

At the end of the game, an end scene is presented to the player to congratulate him on what he has just accomplished (Fig. 6).

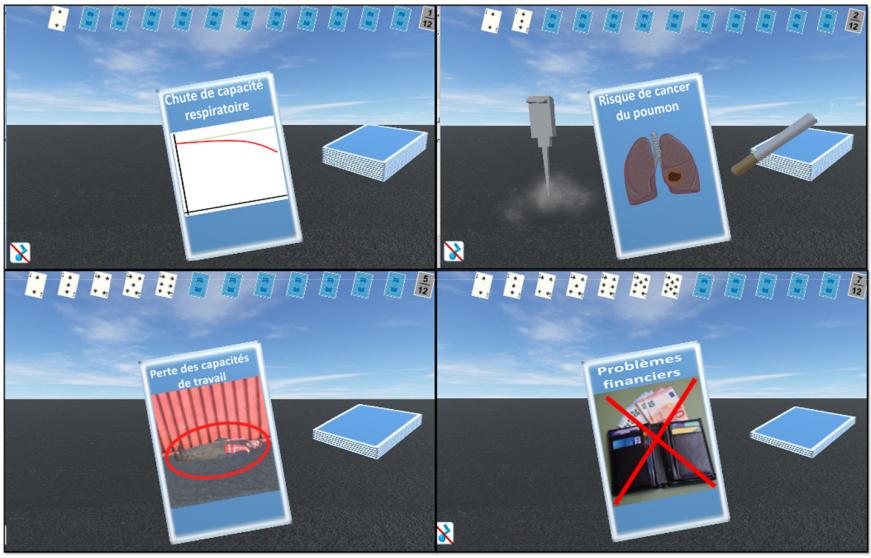

Fig. 5. Some situations of mission 4 of the SG

Fig. 6. Congratulations scene after the SG

3 Preliminary Evaluation and Results

In this section, we present the preliminary results of the test we conducted to assess the usability of this game. We focused on the ease of use of the mechanics, the ease of

learning the knowledge we desired to communicate, and the average time taken by the participants to finish the game while having acquired the expected learning.

3.1 Participants

Participants were five community health student interns from the Faculty of Medicine and Health Sciences at the University of Sherbrooke. They were not familiar with the construction sector.

3.2 Procedure

To better appreciate the effectiveness of this SG, we compared the participants to themselves to solve the problem linked to the absence of a control group. To do this, the participants completed the evaluation questionnaire for the first time one month before the game test. This period allowed us to limit the bias linked to the reproduction of the responses when they must complete the same questionnaire for the second time, after the game test. The questionnaire was divided into three sections, and the type of question proposed was diverse, including multiple-choice questions and open-ended questions.

3.3 Results

We report here the results of this preliminary assessment. Notably, for all the participants, the maximum time spent to complete the game was fifteen minutes.

The First Section of the Questionnaire
The first section concerned the participants' personal information, such as their educational level and their experience with the building sector.

Before the completion of the participation questionnaire, none of the participants had already received training on the risks of silica.

The Second Section of the Questionnaire
The second section concerned a personal estimate of the degree of danger posed by silica dust.

- This section primarily evaluated the knowledge of the participants on silica dust and its health effects. Among other things, participants responded that silica dust could be found in sand, concrete, stone and metal. This last element, which is not entirely correctly designated as containing silica, was underlined by 40% of the participants before playing the game. After playing the game, to this same question, all participants (100%) answered sand, concrete and stone. This answer reflects the fact that the game allowed participants to learn precisely about the elements that could contain silica dust.
- Before playing the game, the participants estimated the level of risk of silica dust on health at an average of 84%. After the game, this average increased to 96%, indicating that participants understood that silica dust could be even more dangerous than they had previously imagined.

The Third Section of the Questionnaire

This section of the questionnaire concerned general knowledge of measures to prevent the inhalation of silica dust on a work site.

- Before the game, participants estimated that wearing a mask could protect workers from silica dust by an average of 84%. After the game, this average increased to 94%, reflecting the extent to which the game helped participants to understand the importance of protection from inhaling silica dust.
- Before the game, participants rated the importance of a workplace silica prevention program at 82%. After playing the game, this was estimated at 96%, reflecting the participants' awareness of training that workers must complete.
- Participants were also asked to identify five tasks that could significantly expose people to silica in the workplace. According to their general personal cultures before the game, the participants listed sanding, drilling, cutting stones, working in the ground, making concrete, renovating, working in mines, working near a conveyor, sawing of stone, being in a factory manufacturing stone, maintenance of such a factory, welding, laying of concrete and laying of sand, among others. After the game, the participants' knowledge seemed to be better circumscribed because their responses were more precise, with appropriate terms such as sanding, sawing concrete, pouring concrete, sweeping with a broom, drilling walls, making holes in the ground with a jackhammer, abrasive jet, sweeping, sawing, being near a source, polishing, grinding stone, casting concrete and sweeping concrete. Once again, knowledge had been successfully transmitted.
- Another point of the questionnaire was for the participants to name five methods to eliminate the production of silica dust at the source. The answers to this question before the game were to use appropriate tools, good ventilation, masks, equipment with protective measures, maximum exposure time, use of alternative material, distance when using the equipment, humidify the stone, adequate ventilation, work outside, vacuum dust, reduce dust production and do not use certain rocks, stones or metals. Once again, after the game, the participants' responses were much more circumscribed, clear and with appropriate terms and expressions such as the use of a filtering cabin, aspirating at the source, humidifying the environment, vent hood, delimiting the workspace, putting a hood, the tool must contain a vacuum cleaner, vacuuming the suits, using other material without silica, humidification at the source, use of a concrete agglomeration, cabin with filter, use of a substrate with low silica concentration and alternative sand.
- Participants were asked to name three steps required to ensure the effectiveness of the filter mask. Before the game, the participants' answers were among others: waterproofness, good use, well adjusted, must not be too wet or soiled, check that there is no break, adjust the mask, wear the mask at the appropriate times, respect the expiration dates, wear the correct size of mask and wear a clean mask. After the game, as for the two previous questions, the answers were more precise: tightness, good use, stored well, shaved the beard well, clean the mask and store it, make sure the mask is properly adjusted, change the cartridges, and use of correct size and model depending on the intensity. Shaving, cleaning, and storage are terms that were mentioned many times.

- The next question aimed to consider the views of participants regarding the need for training to ensure the effectiveness of a respiratory protection program. Before and after the game, the participants were unanimous in answering 'totally'.
- On the last question of the form, participants had to identify 3 possible consequences for workers exposed to silica. Before the game, the answers were: silicosis, lung cancer, asthma, pulmonary silicosis, eye inflammation, pulmonary adenocarcinoma and pulmonary fibrosis. After the game, the participants' responses were more diverse and generalized: silicosis, lung cancer, asthma, lung damage, breathing difficulties, deterioration in the quality of life, lung neoplasia, decrease in life expectancy, financial costs, loss of physical capacity, increased risk of lung cancer, pulmonary silicosis, use of sick leave and loss of functional capacity. This multitude of responses after the game is partly linked to the fourth mission of the game, which presented the consequences of silica dust. However, certain consequences listed by the participants were not part of the content of this mission. We must, therefore, assume that as they were health students, from all that they learned about silica throughout the game, they were able to associate other diseases they knew about with the information that they learned about silica dust.

4 Discussion

4.1 Active Learning Favours the Satisfactory Transmission of Information

The analysis of these results shows the capacity of an SG of 30 min to train and raise peoples' awareness of silica, its risks and its consequences. Indeed, between the evaluation results before and after playing the game, we can observe that the general knowledge of the participants had evolved. We can also see how the participants' answers are "imprecise" before the game and much clearer, more precise and with appropriate terms after the game. This clarity in the responses can be associated with the actions performed to solve the game, and with textual and graphic indications which were used in the game to guide the player. We can find terms and expressions such as abrasive jet and filtering cabin, which are reported exactly as presented in the game. In addition, certain game scenarios such as shaving the beard, cleaning the mask, storing the mask and vacuuming the dust on the coveralls involved an action performed with the mouse as it would be done in real life. To shave the beard, the player had to grab the razor by clicking on it and make shaving movements on the face of the avatar until all the beard was removed. To clean the mask, the player had to take a wipe by clicking on it and simulate cleaning movements on the mask until all the dust was removed. To store the mask, the player had to grab it by clicking on it, and move it to his box, and then move the box containing the mask to the canteen. To vacuum the dust on the work suit, the player had to grab the vacuum cleaner by clicking on it and perform aspiration movements on the avatar suit until all the dust was vacuumed. In participants' responses after playing the game, these scenarios came up repeatedly.

Given that the game aims to raise awareness and, therefore, to transmit new learning and new behaviours to the player, the participants' results confirm the effectiveness of active learning. Indeed, according to the study of the evolution of learning theories, the subject acquires knowledge better and this permanently when he builds it through an

autonomous activity [15]. Already at the base, as we underlined in the introduction, the objective of making an SG for the training and education of workers on the dangers of silica is to be able to transfer this concept of learning into training for a respiratory protection program for workers in the workplace. Thus, all the scenarios of the game 'The Four Aces' involve the worker's activity (identify, select, eliminate). So, interactivity makes this game a different type of media from the slide-based training routinely given to workers.

Another notable result is the response of the participants after the game to the question concerning the consequences of silica dust is that eight of the twelve situations presented in mission 4 were reported as presented in the game. One of the participants had just cited "silicosis" before the test. After the test, he gave three much more elaborate answers, all present in mission 4 of the game: reduced physical capacity, increased risk of lung cancer and development of silicosis. It should be noted that in this game mission, the descriptive text of the consequence was accompanied each time by an animated image. This way of presenting information allowed the participant to integrate knowledge easily.

Finally, all of the answers before and after the game show that this SG had the expected effect on the participants: the ability to identify and eliminate the risks of inhaling silica dust, applying measures of protection against silica dust, and the awareness of the danger that this dust can have on health and human life.

4.2 Participants' Involvement and Observable Behaviours

During the game, we were able to observe the substantial involvement of the participants. For most of the participants, manipulations were very intuitive; it was easy for them to make the association between the input device (mouse) and the tasks they had to perform in the game world, demonstrating a good balance between the tasks, the manipulations, and the skills of the participants.

4.3 Suggestions Made by Participants

At the end of the game, the participants were debriefed, to provide their comments and suggestions for improvement. The positive points noted by the participants were as follows: good tutorial, good graphics, the possibility of going back and correcting mistakes, the scores favoured enjoyment, and the manipulations were easy. However, they suggested adding informational tips to accompany the player better and adding background sound to improve the game feel for the player. They also suggested that the timer be more highlighted for the player. Indeed, some participants did not notice the presence of a "timer" in each mission and were slightly anxious because they did not know how long they had to complete the game. They still completed the game in a much shorter time than what was normally offered to them.

These suggestions have been implemented in the current version of the game. To the suggestion of a background sound, we downloaded free sound effects and integrated them into the game. The informational tips were dynamically added to the game; through the user's manipulations, we detect when the user is incorrect and we inform him, in an informational tip, of what to do. These tips are also used to give positive feedback to the

player when he succeeds in an action. The timer is also more highlighted in the current version of the game.

4.4 Transferability of These Results to the Target Group

This game could produce similar results with construction workers. Indeed, the target audience will have the advantage of knowing the tasks and tools used in the workplace, which could ease the expected learning of good habits that prevent silicosis. However, we have some reservations at the technological level because we cannot attest to their familiarity with computers. Even though we anticipated this by offering the player simplistic in-game mechanics, we could still expect some difficulty in getting started for those people who rarely deal with computers. Nevertheless, these preliminary tests that we conducted reveal a reliable advantage. Indeed, the participants, who are an audience that can be considered technologically skilled, completed the game in less than 15 min while it is intended to be played in 30 min. This margin allows us to hypothesize that those less familiar with the technologies in the target group could still be able to play the game within 30 min and acquire the targeted skills. Therefore, we could consider the possibility of adapting the time allocated to each section of the game to the evolution of the player. In the future, we will study the differences in results between this test group and the target group. We will also be interested in the technological impact on the possible differences that may exist between the two groups. If we realize that there are difficulties for the target group, we could add additional stages to the game to best assist the player.

5 Conclusion

Despite the limitation in the number of participants to this study, this preliminary evaluation allowed us to see that the SG "The Four Aces" was able to effectively transmit learning to people with almost no basic knowledge of silica dust. So, it helps us understand that this could be an effective way to educate workers in the building sector. This game is scheduled to be played in 30 min to comply with the duration of the standard slide-based training. In contrast to the slide-based training, the participant's activity during the game could allow him to better acquire the knowledge by maintaining concentration and motivation.

The project is a SG that should be used by construction companies to train and educate workers on the dangers of silica dust and the protective measures to be observed in the workplace. Thus, just as for the 30 min slide-based training courses that are currently provided, the player must complete this 30 min game during his working hours and will, therefore, be paid during this training. It should also be noted that bosses may need to monitor the performances of their workers in this game, which they could add as a parameter to assess their ability to observe good protective reflexes in the workplace. So, to make the project easily exploitable by these bosses, we have created a data structure in a JSON file, allowing for storage of the player's information as well as his achievements for each game mission. For the next version, we will use the information in this file to provide a graphical interface for managers to track the achievements of their workers

during this SG training. Replayability is, therefore, an important point to underline. If necessary, a copy of the game can be given to employees so that they can practice more at home.

References

1. Leung, C.C., Yu, I.T.S., Chen, W.: Silicosis. The Lancet **379**(9830), 2008–2018 (2012)
2. Greenberg, M.I., Waksman, J., Curtis, J.: Silicosis: a review. Dis. Mon. **53**(8), 394–416 (2007)
3. Ziskind, M., Jones, R.N., Weill, H.: Silicosis. Am. Rev. Respir. Dis. **113**(5), 643–665 (1976)
4. CNESST, Committee on Standards, Equity, Health and Safety at Work 2016–2020
5. Mao, W.-J., et al.: Lung transplantation for end-stage silicosis. J. Occup. Environ. Med. **53**(8), 845–849 (2011)
6. NIOSH: Preventing silicosis and deaths in construction (2014)
7. NIOSH: A Safety & Health Training for Young Workers (2018)
8. Iten, N., Petko, D.: Learning with serious games: is fun playing the game a predictor of learning success? Br. J. Educ. Technol. **47**(1), 151–163 (2016)
9. Menelas, B.-A.J., Benaoudia, R.S.: Use of haptics to promote learning outcomes in serious games. Multimodal Technol. Interact. **1**(4), 31 (2017)
10. Menelas, B.-A.J., Otis, M.J.-D.: Design of a serious game for learning vibrotactile messages. In: 2012 IEEE International Workshop on Haptic Audio Visual Environments and Games (HAVE 2012) Proceedings, pp. 124–129. IEEE (2012)
11. Djaouti, D., et al.: Origins of serious games. In: Ma, M., Oikonomou, A., Jain, L.C. (eds.) Serious Games and Edutainment Applications, pp. 25–43. Springer, London (2011). https://doi.org/10.1007/978-1-4471-2161-9_3
12. Stapleton, A.J. Serious games: serious opportunities. In: Australian Game Developers Conference, Academic Summit, Melbourne (2004)
13. O'Neil, H.F., Wainess, R., Baker, E.L.: Classification of learning outcomes: evidence from the computer games literature. Cirriculum J. **16**(4), 455–474 (2005)
14. Ertmer, P.A., Newby, T.J.: Behaviorism, cognitivism, constructivism: comparing critical features from an instructional design perspective. Perform. Improv. Q. **6**(4), 50–72 (1993)
15. Prince, M.: Does active learning work? a review of the research. J. Eng. Educ. **93**(3), 223–231 (2004)
16. Kamkuimo Kengne, S.A., et al.: Action-centered exposure therapy (ACET): a new approach to the use of virtual reality to the care of people with post-traumatic stress disorder. Behav. Sci. **8**(8), 76 (2018)
17. Sokas, R.K., Dong, X.S., Cain, C.T.: Building a sustainable construction workforce. Int. J. Environ. Res. Public Health **16**(21), 4202 (2019)
18. Sweetser, P., Wyeth, P.: GameFlow: a model for evaluating player enjoyment in games. Comput. Entertainment (CIE) **3**(3), 3 (2005)