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DESIGN EVALUATION OF A FORKLIFT SERIOUS GAME

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─Abstract ─

Forklift training is one of many training programmes which involve heavy machinery or industrial equipment. During such sessions, it is not only the equipment, but also the trainer, trainees and others who may be at risk. Theoretical aspects can be presented without any risk, but practical aspects are dangerous, especially where novices are involved. Novice trainees not familiar with forklift controls, could easily err as they do not always contemplate the outcomes of their driving. It would be ideal if they could undergo training in a risk free virtual environment where they could have the opportunity to learn from their mistakes. Due to advanced technologies in the world we live in, the younger generation find the use of technology interesting while they perceive learning as boring. Serious games provide Technology Enhanced Learning (TEL) which is also fun when learning and gaming are combined. The authors previously investigated how a digital forklift training in a virtual environment would benefit trainees. They consequently embarked on developing a digital-based forklift training game, *OcuLift*™, which could be used in existing forklift training. This paper discusses the multimodal methodology used during this phase of the project

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for the development of a prototype pertaining to the selection of input/output devices, game construction, as well as the rationale for the use of certain gaming elements. The authors tested the game with a local safety training company with sixteen forklift operators who played the game and shared their perceptions.

Key Words: *Serious games, virtual reality, forklift, technology enhanced learning, design research.*

JEL Classification: L86; Information and Internet Services • Computer Software

1. INTRODUCTION

Technology-enhanced learning (TEL) is becoming increasingly popular, not only for saving on training costs, but because it offers trainees a safe and repeatable environment where they may make mistakes; thereby saving their companies accidental losses or even law suits. Trainees could learn from their mistakes by experiencing the outcomes of a bad decision, as well as learning how to prevent an accident. A training programme which is in need of such a TEL conversion is the forklift training programme currently available to warehouse workers in South Africa. Currently, these training programmes are largely paper- and classroom-based, augmented with practical driving sessions. Training typically lasts for a week where day one is strictly based on only theoretical knowledge and three days are then allocated to driving and learning the forklift. On the last day of the week, all trainees are required to complete a written test. This training requires the hiring of external training companies, or in some cases, a company's own qualified training staff. The training sessions take place either on-site or at a remote training centre. Even though such training sessions result in a workforce capable of operating forklifts in a number of environments, the risk associated with the operation of these machines is substantial. Therefore, these operators have to be retested every two years to ensure that their skills are current and that they are competent to complete their tasks at the highest level of safety (De Villiers & Blignaut, 2016).

The authors identified the area of heavy machinery training as conducive for infusion with software-based games in which players are able to make deadly mistakes and yet walk away unscathed. By combining the possibilities of serious games with the technologies of virtual reality, forklift training programs could be updated to reduce the cost of the training and make it more enjoyable to the learners, while the quality of the training is upheld.

In a previous study (De Villiers & Blignaut, 2016), seven qualified forklift operators shared experiences from their forklift training techniques. They also engaged with a number of existing forklift games to determine if they would believe that games could make their training more enjoyable. The participants identified a number of shortcomings associated with the existing games they interacted with. This could be because these games were created for entertaining purposes and not with learning a serious skill in mind. Even though all

participants were excited about training by means of serious games, members of the older generation were not very keen. The main reasons were that (i) the older generation were accustomed to the current methods of training and saw no need for change, and (ii) they were not into gaming.

The Serious Games Institute South Africa (SGI-SA) subsequently developed the first prototype of a forklift training game, *OcuLift*™. The authors presented the serious game to sixteen forklift operators who experienced their first view of what it would be like to receive training through TEL and a virtual reality device. We collected their perspectives on this training method, as well as their experiences with the technical aspects of the game. The aim of this paper is to collect and analyse data on how forklift operators experience the *OcuLift*™ game in order to identify major shortcomings that can be corrected during future development.

2. LITERATURE REVIEW

Since abandoning the development version, the Oculus Rift™ has become more expensive. Also taking into account that Oculus™ does not ship its VR device to South Africa, the cost of procurement remains significant. Furthermore, the VR technologies demand Oculus™ ready computers, which cost significantly more than a standard household PC (Stuff, 2016).

Vogel, Greenwood-Ericksen, Cannon-Bowers, and Bowers (2006) argue that play as a necessary component of motivation is a well-established concept in educational research. Game play has the ability to engage students during learning which could lead to increased learning (Vogel et al., 2006). In terms of TEL, the use of serious games to simulate real world activities has become a primary way in which students learn outside formal schooling (Johnson, Adams Becker, Estrada, & Freeman, 2015). Serious games have become popular as they provide players with authentic learning experiences where entertainment and learning are seamlessly integrated (Charsky, 2010). By incorporating specific training activities into a serious game, players can learn through doing, gain experience, increase their motivation, and create collaboration amongst players (Ribeiro, Almeida, Rossetti, Coelho, & Coelho, 2013; Vogel et al., 2006). Even though the pedagogy of serious games is considered the crucial part of the game, it should however be subordinate to the story and fun factor of the game (Backlund, Engström, Johannesson, & Lebram, 2010; Zyda, 2005). Bellotti, Berta, De Gloria,

and Primavera (2009, p. 1) posit the opinion that "lowering the barrier between education and real entertainment is an important challenge in order to better exploit the potential of computers and reach a demographic that is traditionally averse to learning."

Simulations and games share many characteristics. Where games also comprise wondrous context with different characters and scenarios, simulators encompass specific context. Simulators are particularly effective in teaching of procedures, as they allow players to practise their techniques in a safe environment by replicating the real world (Charsky, 2010; Vogel et al., 2006). Experiential simulators place players in specific roles such as a doctor, lawyer or, ultimately, a forklift operator. The player is required to accomplish certain tasks or goals by making necessary decisions and performing pertinent actions (Charsky, 2010). By adding engaging gaming elements, simulators could enhance motivation as well as facilitate learning (Charsky, 2010). Students participate in student-centred learning environments where they experience scenarios which which could not be created in the real world, owing to constraints like safety, cost or time (Backlund et al., 2010; Monahan, McArdle, & Bertolotto, 2008). According to Dewey (as cited by Huang, Rauch, & Liaw, 2010), students learn by practising what is expected of them in real situations—thereby increasing their skills for real tasks.

In a study of a motor vehicle game-based driving simulator, Backlund et al. (2010) concluded that simulator serious games could enhance learning of driving education. Driving instructors capitalize on the potential of driving simulators when they encourage their students to repeat dangerous driving situations in order to highlight the seriousness of such situations and reinforce in their students how their actions could change the outcomes of tricky situations (Backlund et al., 2010). In a similar study, the use of simulator training also lowered the accident rates of novice drivers (Allen, Park, Cook, & Fiorentino, 2007).

By incorporating VR into games, players are situated within an immersive environment which mimics the real world. Players can experience the learning content first-hand by interacting with objects and events in the artificial world; something not typically provided in traditional classrooms (Huang et al., 2010). The use of VR will increase student interest and motivation, resulting in an increase in student engagement (Huang et al., 2010). Technologies such as virtual reality devices where players can explore the virtual world will increase the

fidelity of training within a serious game simulator. For example, students who trained on a single desktop monitor with a 45 degree field-of-view performed worse than students who trained with a 135 degree field-of-view projected screen (Allen et al., 2007).

3. *OCULIFT*™, THE GAME

SGI-SA developed the first prototype during the first half of 2016. The game is currently limited to a number of learning outcomes which two local safety training companies identified as important from forklift operator training guides (Nirvana Training Academy, 2017). The game comprises eight scenes which instruct the player (trainee) to complete a number of objectives on forklift operations.

Scene 1: The game starts where players find themselves in a 3D training room where the trainees are asked to take a seat. Information boxes display to the user which keys to press in order to move around in the room and interact with objects. The trainer shows a few videos to teach players to use the controls for walking and driving, pre-operation inspections, and the process of completing the fuel log book.

Scene 2: Players find themselves outside the warehouse in the refuelling area with the forklift parked in front of the fuel pump. Another trainer welcomes the players and alerts them that the forklift requires a new oil filter and oil. The players must search for these items in the workshop located in the warehouse. If the players have trouble to collect the oil filter, they are instructed to open the in-game manual where they can view the current training objectives and find an indication of what the spare parts would look like. As soon as the players collect these items, they can place them in the forklift by simply looking at the forklift and clicking the use button.

Scene 3: The trainer notifies the players that the forklift should be refuelled and a pop-up shows the players how refuelling of the forklift is performed. After refuelling, the fuel logbook appears and they then complete all the required fields in the logbook. These fields relate to the forklift number, date, operator name, department name, amount of fuel pumped into the forklift, and the current hour reading on the forklift. The players have the ability to move around in the fuel depot and they should complete the different fields of the log book by finding these relating objects like a calendar or the fuel pump (Figure 2).

Scene 4: This is the first scene where the players start driving the forklift and it is based on a training course that local safety training companies prescribe where the operators have to manoeuvre through a maze of pallets stocked with merchandise. (Systems Development & Training, 2017, p. 107). The players, who are still in the warehouse, are now instructed to get into the forklift and follow the instructor into the warehouse without running over pedestrians, or bumping into stock or shelves. The instructor then walks through a maze of palettes to the back of the warehouse where he awaits the players' arrival. The level restarts when players hit pedestrians, shelves, or merchandise in such a way that they topple over (Figure 2).

Scene 5: The players return to the training room and they are instructed to take a seat and view more training videos. They learn the necessary elements to keep in mind while loading and unloading palettes, as well as how to negotiate corners while carrying a heavy load.

Scene 6: The players are back in the warehouse with the forklift parked nearby in the workshop. The players are instructed to pick up a load from a shelf and place it on a flatbed trailer located outside the warehouse. They can easily locate the load as well as the trailer by means of a flashing red box at each location, as well as a pointing arrow which appears on the bottom left corner of the screen. This scene also restarts as soon as players bump into pedestrians or drop the merchandise (Figure 3).

Scene 7: Scene 7 continues from scene 6. The players are instructed to drive back into the warehouse, pick up a palette from the warehouse floor and place it on the correct shelf. The players use a pointing green arrow located in the bottom left corner of the screen, as well as the flashing red box showing the load and destination. This scene restarts as soon as the players bump into pedestrians or drop the merchandise (Figure 3).

Figure 1: Screen capture of Scene 1 and 2 of the OcuLift™ game, showing the training room and spare parts to be collected

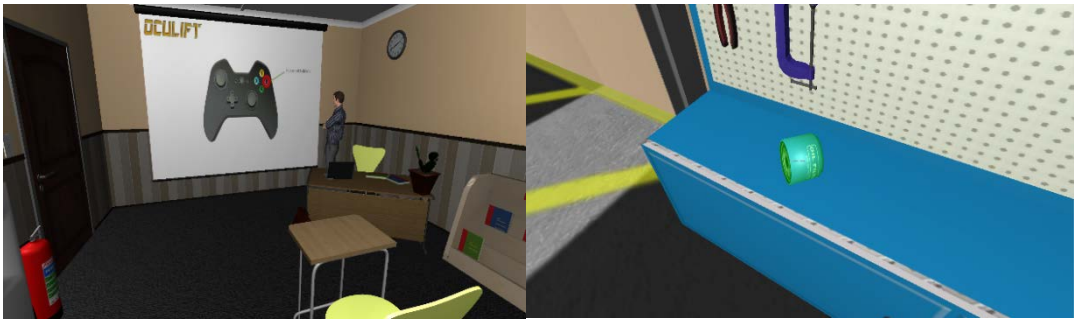
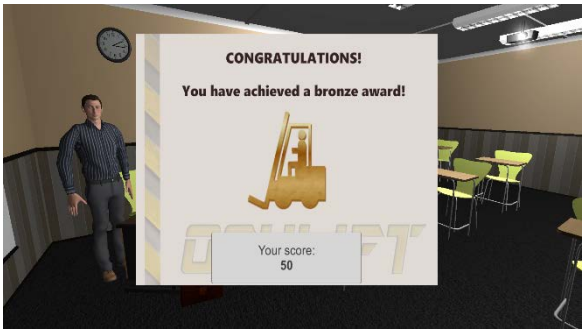


Figure 2: Screen capture of Scene 3 and 4 of the *OcuLift*™ game, showing the fuel log book and the maze of pallets in the warehouse

Figure 3: Screen capture of Scene 6 and 7 of the *OcuLift*™ game, showing transporting of different loads

Figure 4: Screen capture of the receiving of the certificate in the *OcuLift*™ game



Scene 8: On completion of scene 7, players find themselves in the training room where they receive their final score. The players receive a certificate based on their performance, displaying either a bronze, silver or gold stamp. Their final total score comprises a calculation of the number of items dropped, number of restarts and the number of incorrect items selected (scenes 2 and 3) (Figure 4).

The authors selected the Xbox™ controller and the Oculus Rift DK1™ as in- and output devices for the *OcuLift*™ game. The rationale for using the Xbox™ controller rather than the traditional keyboard and mouse was to increase user convenience. While playing with the Oculus Rift™ headset, players find it difficult to locate the required keys on the keyboard or use the mouse buttons. They then have to remove the Oculus Rift™ headset to visually locate the

appropriate mouse or keyboard keys. By using the Xbox™ gaming controller, users already have the device in their hands and interaction is limited to a small number of keys. By showing the players a chart which indicates the keys to press, players can easily identify the keys without having to remove the headset.

By playing in a 3D virtual environment, the player loses accessibility to a mouse cursor which is only visible on a 2D screen (Schemali & Eisemann, 2014, p. 67). After determining where the users specifically look, the menus and buttons were placed within the 3D environment. Users can simply look at the buttons, highlight the specific button, and press the required key on the controller. We also used this method to interact with elements the players had to interact with in the gaming world.

4. METHODOLOGY

The researchers followed a multimodal (Picciano, 2009) design research approach (Amiel & Reeves, 2008) where a project evolves through different phases to ensure that the research outcomes meet the needs of the intended users. The three phases are: (i) needs and context analysis, (ii) design and development of the prototype serious game and formative evaluation of the game prototype, and (iii) a formative evaluation of the serious game with the intended users. Phase 1 was completed during previous research (De Villiers & Blignaut, 2016) where the researchers identified the feasibility of using technology-based forklift training through a literature study and visits to a number of sites where forklifts are regularly used. The current study relates to phase 2 which developed a prototype of the serious game. During phase 3 (a future investigation), inexperienced, experienced forklift operators, and training personnel will formally evaluate the final prototypes of the forklift game. The culmination of these evaluations will provide the researchers with insight as to the unresolved requirements of *OcuLift*™ game, where after the researchers will evaluate the acceptance of the game by a large community of forklift operators.

The research participants of this study comprised trainees who reported for forklift driving training at a local safety training company. The investigation encompassed a total of thirteen first-time trainees (eleven male and two female participants) and three male training instructors who had not played the game before (Table 1). From this group, while eight participants played the game after

receiving theoretical training without any practical training, the remaining five participants played the game after receiving theoretical as well as practical training.

All participants played about thirty minutes with the *OcuLift*™ serious game after which they completed a custom-made questionnaire which comprised two sections: (i) background information (eight questions), and (ii) trainee's perceptions of the value of the game (eleven questions). The researchers established content validity of the questionnaire with researchers from SGI and they also obtained ethical clearance for the use of the questionnaire and the study (Ethics Clearance Number ECONIT-2016-100). After completion of the trainees' theoretical and practical training, the researchers had the opportunity to engage with the participants as two separate focus groups and further explore their perceptions as outlined in Table 2 by asking what the participants liked or disliked in the game; and what they would like to change in the game.

5. FINDINGS

Some participants grappled with familiarising themselves with the game controls and elements and nobody played further than scene 4. This indicates that, although they learnt many aspects pertaining to forklift driving procedures such as pre-operation inspections, completing the fuel log book, driving and manoeuvring the forklift through the warehouse without bumping into anything, nobody reached the point where they could pick up loads and move them to different locations.

Table 1: Background information of participants

Question	Frequency Indicator	%
1. What is your gender?	Male	87.5
	Female	12.5
2. What is your age group?	16-20	6.0
	21-25	50.0
	26-30	6.0
	31-35	19.0
	36-40	13.0
	45+	6.0
3. How many times have you received	Once	69.0
	Twice	0.0

Question	Frequency Indicator	%
forklift training before?	Three times	6.0
	Four times	0.0
	Five or more times	25.0
4. How long have you been working as a forklift operator?	Less than one year	63.0
	1-2 years	6.0
	3-4 years	0.0
	5-6 years	19.0
	7-8 years	6.0
	More than 8 years	6.0
5. What type of forklift do you usually drive?	I do not know	4.5
	Class 1(Electric motor rider trucks)	9.0
	Class 2 (Electric motor narrow isle trucks)	4.5
	Class 3 (Electric motor hand trucks or hand/rider trucks	18.0
	Class 4 (Internal combustion engine trucks with solid tyres)	41.0
	Class 5 (Internal combustion engine trucks with air-filled tyres)	14.0
	Class 6 (Electric and internal combustion engine tractors)	4.5
	Class 6 (Rough terrain forklift trucks)	4.5
6. What types of loads do you usually handle?	Industrial equipment	45.0
	Chemical loads	5.0
	Flammable loads	0.0
	Building materials	10.0
	Food	15.0
	Other	25.0
7. Which games do you play in your free time?	I do not play games	15.5
	Driving games	63.5
	Shooting games	5.0
	Adventure games	0.0
	Gambling games	0.0
	Education games	5.0
	Other	11.0
8. On which devices do you normally play games?	Playstation™	28.0
	Xbox™	17.0
	Smartphone	44.0
	Computer	11.0

Table 2: Participants' perceptions of the *OcuLift*™ forklift driving game

Perceptions	Strongly disagree	Disagree	Agree	Strongly agree
1. By playing the game, I learned the skills to operate a forklift	6.0	6.0	44.0	44.0
2. I like this method of training	0.0	6.0	56.0	38.0
3. All required safety elements are included in the warehouse	0.0	0.0	62.5	37.5
4. I like the experience with the Virtual Reality device	0.0	0.0	62.5	37.5
5. I like handling the forklift in the game	0.0	19.0	44.0	37.0
6. I like handling the stock with the forklift in the game	6.0	6.0	69.0	19.0
7. I like the layout to the warehouse in the game	6.0	0.0	50.0	44.0
8. I would like my friends to also play this game	0.0	0.0	60.0	40.0
9. The game controller is easy to use	6.0	12.5	37.5	44.0
10. The buttons on the menus are easy to use	0.0	0.0	62.5	37.5
11. I am comfortable wearing the Virtual Reality device	0.0	6.0	50.0	44.0

Firstly, the researchers determined if the participants were familiar with digital games, especially driving games, as well as if this had an effect on their perceptions of the forklift driving game. Table 1 indicates that twelve of the sixteen participants indicated that they regularly played driving games, as well as other types of digital games. Six participants indicated that they were familiar with playing games on consoles which used similar controllers as the Xbox™ controller used for the *OcuLift*™ game. While most of the game-playing participants played games on either a computer or smartphone, two participants had never played digital games.

Even though all but one of the participants declared the controller easy to use, many seemed to experience trouble using the Xbox™ controller. Six participants explicitly indicated that the controls were too sensitive, making it difficult to walk around or drive the forklift in the game. They maintained it would be useful to play the game using actual controls found on a forklift. Driving in the game with the Xbox™ controller, they had very little sense of how far the steering was turned and how fast they were going (Table 1). All but one participants agreed that they would be able to learn all the necessary skills required to operate a real forklift by playing *OcuLift*™. The participants liked this new method of training (Table 2).

Since the game designers were not familiar with either the layout of storage warehouses, or the majority of safety elements required in such a work environment, the researchers probed the participants to point out elements they were of the opinion did not belong in the game, or had to be added to the game. Unfortunately, we received no feedback regarding these elements. They all agreed on the safety elements which were incorporated in the warehouse: *It's realistic looking around while driving the forklift*. All but one said that they liked the layout of the warehouse (Table 2).

As the Oculus Rift™ virtual reality device is a new technology, the researchers wanted to investigate the participants' experiences while using the device. All participants agreed that they liked the virtual reality experience the Oculus Rift™ provided. All but one participant felt comfortable while wearing the Oculus Rift™ device. This participant disliked the device as *it made my eyes hurt and I felt disoriented*.

Initially, during gameplay, some participants did not understand that they had to look at a menu button in order to select the button. Once they had mastered this method of interaction with the virtual reality device, they found it easy to select other game elements. After playing the game for a while, all the participants agreed that this method of selecting buttons or elements was easy. A participant described his virtual forklift driving experience as: *Handling of the forklift: sensitivity could maybe be adjustable but the rest is good. Use button for driving and stick just for turning instead of only the joystick for both*.

Except for the few instances of negative feedback, the participants were excited about the prospects of being trained with this new training method, as well as with the new virtual reality technologies they got to experience. While some participants stated that they enjoyed the realistic feel the game provided very much, others pointed out how useful it was to teach them the important aspects of driving a real forklift through a game: *What I liked in the game is that there is a person who tells you what to do. While you are playing you can press the Y button and it will memorise for you. And what I liked is the driving*.

6. CONCLUSION

Even though the authors had expected some negative feedback to this first prototype version of *OcuLift*™, they received valuable feedback that in the near

future will contribute towards improving the next version of the virtual forklift driving game. Although we did not perform an inferential analysis, from the qualitative data we noted no difference between the results of the participants who received practical training before playing the game and those who played the game before they received practical training. This aspect could in the future be tested with larger groups of participants. It was clear the trainees perceived this method of training as useful. Even though some trainees were unfamiliar with the game controllers, they were able to play the game, despite the fact that they found the controls too sensitive. They preferred training with controls similar to those on real forklifts. This provides a huge challenge to the game developers given the diversity of forklift models and controls. We also envisage future forklift games which include a mock-up forklift cockpit. This would vastly increase the fidelity, the learning experience, and also the realism of the virtual reality experience of the game. The developers have to develop realistic *OcuLift*™ controls for a next version of the game for trainees to be able to provide the researchers with improved results on the controlling of the forklift and handling of the merchandise. By also incorporating the latest release of the Oculus Rift™ headset, trainees will find the learning experience even more realistic without experiencing negative side-effects while wearing the virtual device.

Although phase 1 and 2 evaluations related to small groups of participants, phase 3 evaluations should comprise a significant number of participants in order to establish user acceptance and possible technical glitches. However, the researchers believe that the *OcuLift*™ game contributes to incorporating TEL into the training environment and the workplace by making a game replicating the real world full of dangers in such a realistic way that even non-gaming trainees find it easy to navigate the tool and learn from it realistically.

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