The Influence of Virtual Reality Maintenance Training on Spatial Awareness and Learning Comprehension

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Management Summary

This research took a closer look at the effectiveness of Virtual Reality in technical maintenance training on radar systems. For technical training of this kind good spatial awareness and system comprehension are essential key learning goals. This report investigated the effect of Virtual Reality on spatial awareness and system comprehension in defence maintenance training in comparison with traditional 2D classroom training using Power Point presentations and 2D computer programmes. An experiment was used to compare both conditions upon spatial awareness and system comprehension using *performance, awareness state* and c*onfidence level* measurements.The experiment was of exploratory nature generating quantitative, observational and qualitative data. Further, 17 participants were trained in Virtual Reality to remember 10 different system hardware item locations inside a radar system plus basic functionalities. As control, 15 participants were trained using traditional training means training the exact same 10 item locations. One week later all 32 participants were asked to take a memory-recall test on the actual system. Both trainings were created based on the concept of memory palaces. A memory palace is a technique making use of an environment as memory stimulator. Information are mapped spatially stressing the exposed individual to create a mental map of the obtained information in a certain environment. That map can later be recalled cognitively and can be highly efficient in spatial awareness training.

Performance measures were used to determine the measurable and observable difference in test groups while the awareness state of the participants and the confidence level of recalled test objects were cognitive support measures to performance and of self-indicating nature.

This study found an increased performance with reference to spatial awareness of the test group using Virtual Reality for training as well as an increased system comprehension ability of the same group in comparison with the group that was exposed to traditional training means. Ambiguous findings concerning confidence levels and awareness states in relation to recall performance could be identified in this research. In other words, the relation between ones confidence level or mental awareness state did not always show an actual effect on the ability to recall hardware items correctly, nor did it show an effect of the latter on system comprehension. However, overall Virtual Reality training led to higher awareness states and confidence levels across all individuals under the scope of this experiment.

It can be concluded that Virtual Reality can be of help when training tasks require spatial awareness and system comprehension however what must be considered with that statement is the fact that the way Virtual Reality is used to train must be optimised and remains subject to further investigation. This research report is able to provide practical implications providing new insights in the usage of Virtual Reality in training and theoretical implications, adding to the existing literature about *spatial awareness*, *confidence level* and *awareness state measures* in relation to Virtual Reality. Moreover, this research provides additional information to literature about the effectiveness of virtually designed learning environments for spatial awareness training in the defence industry.

Keywords: Cognitive mapping, Memory palace, Spatial Awareness, Spatial memory, Training, Virtual Reality

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Introduction

The influence of Virtual Reality maintenance training on spatial awareness and learning comprehension

To navigate around familiar environments, a human must use spatial memory as part of spatial awareness by recalling information obtained at an earlier point in time (Krokos, Pleasant & Varshney, 2018). As also the norm in general defence system maintenance trainings, also in radar maintenance training it is often required to acquire spatial memory in order to be able to orientate oneself and engage fast with the environment (Stone, Craid-Daley & Besssell, 2019). Spacial knowledge of hardware and software system items is one major part aspirants in the defence industry must train during their traineeship. For example the location of safety equipment and system safety functions must be known from memory. Often there is no time to first search for the location of the latter (Thales Nederland, 2019). The memory required for this kind of environmental orientation is argued in research to derive from a cognitive map (Franz & Mallot, 2000; Eichenbaum, 2017). That cognitive or mental map is an inner visualisation of routes and environmental relationships including object-environment relationships (Tolman, 1948). Mental maps are used to recall spatial and locational knowledge (Stone et al., 2018). A map might be created by exposure to the real environment or origins from symbolic abstractions of the environment (Stone et al., 2018; Burgessm Mguire & O'Keefe, 2002). According to Hartly, Lever, Burgess and O'Keefe (2013), the creating of a mental map is trained most when a sense of body position, movements and acceleration is provided. The ideal scenario for stimulating those senses is the actual real-life environment however especially in the defence sector, training on the actual radar system is often limited which results in a lack of spatial awareness training for trainees (Thales Nederland, 2019).

To create and recall spatial maps, memory palaces are often used (Kroks et al., 2018). Memory palaces are meant to map attributes onto a cognitive model of the environment eventually helping the human brain to recall locations of objects within a certain environment (Kroks et al., 2018; Eichenbaum, 2017). Often times in radar maintenance training mental maps are trained with 2D memory palaces that come in the form of interactive computer programmes supported by traditional power point presentations (Thales Nederland, 2019). However, research has proven that 2D memory palace training is not as effective as training in the actual 3D environment (Kroks et al., 2018). Therefore, this research seeks for a new way of training spatial awareness.

Memory palaces are more effective when body senses such as position, movement or acceleration are used to create the map (Badariah, Coxon & Watten, 2010). Immersive visual reality provides according to several researchers such as Hartley et al. (2013) or Eichenbaum (2007), the possibility to stimulate those senses. Over the past decade, Virtual Reality (VR) has gained immense attention across a diverse industry spectrum in regards to its potential to transform human learning (P. Wang, Wu, J. Wang, Chi & X. Wang, 2018; Huang, Rauch & Liaw, 2010). VR works with 3D data creating computer generated realistic environments immersing the user into a mimicked real-world scenario triggering senses such as movement or position of oneself (Huang, Rauch & Liaw, 2010; Quevedo, J. S. Sánchez, Arteaga, Álvarez, Zambrano, V. D. Sánchez & Andaluz, 2017). The decrease in cost and the corresponding increase in availability of VR equipment and software for the consumer market has opened up the possibility to include VR technology in products and services on a feasible and sustainable basis (Sherman & Craig, 2018). One major future application area for VR is the educational sector including both, formal and informal education for schools and organisations (Saidin, Abd halim, Yahaya, 2015). The positive impact of VR on education has been repeatedly reported in literature and leads back to studies conducted as early as (1995) by Bell and Foegler. The common conclusions from several research studies is that Virtual Reality has the ability to manipulate and interfere human feelings and behaviours which is the reason for its powerful learning effects (Górski, Bun, Wichniarek, Zawadzki & Hamrol, 2017).

Due to its immersive nature, Virtual Reality can deliver realistic and effective learning experience and especially for specific tasks which are difficult, risk related or expensive to train, offer a safe and accessible alternative (Huang, Rauch & Liaw, 2010). Training on actual radar systems can be risky, expensive and only limited available and trainees have to travel far to reach the system. VR training could bridge that gap of time, space and inflexibility by providing an adaptable and immersive learning mean which is unrestrictedly available and yet suitable to let individuals get familiar with the space of the system.

Hence, virtual reality environments as memory palaces are a promising alternative to increase spatial awareness through the new level of immersive mental mapping.

In order to ensure training effectiveness when developing VR training, not only the technological aspects matter but a clear definition of the training programme is of major importance (Borsci et al., 2015; Arthur, Bennett, Edens & Bell, 2003). This research study includes a basic information recall measure to investigate the suitability of VR in training programmes where the focus lies on learning contents and explanations. This research paper aims to contribute to the theoretical and practical understanding of VR in training on radar systems conducted for *Thales Nederland. Thales Nederland* operates in the Defence, Security and Public Transportation sector (Thales Nederland, 2019).

An in between subject experiment aims to investigate the effect of virtual reality (VR) on spatial awareness by measuring the location-based recognition memory of individuals trained in an immersive virtual reality environment. To test the effectiveness of VR in strengthening spacial awareness, comparisons are made with traditional passive 2D presentation leaning. Compared and measured are the recall performances of research participants under both groups, supported by also looking at the awareness state and confidence level of the participants. Moreover, this research examines the recall ability of system functionalities in regards to system comprehension as learning measure.

The guiding main question for this research is as follows:

Does *Virtual Reality training influence spatial awareness differently in comparison with a passive 2D presentation training and if so, to what extent*?

To also gather data on the learning comprehension of virtual reality compared to traditional passive presentations, the following second question is formulated:

To what extent differs the learning effect in terms of system comprehension of virtual reality training from the learning effect of 2D presentation training?

Literature review

Spatial memory

Spacial memory describes a system that recalls environmental information of spatial nature. The cognitive process of remembering spatially starts with encoding information, followed by storing, recognising and embodying those information (Madl, Chen, Montaldi & Trappl, 2015). In practice humans encounter spatial memory most often when the feeling of " I remember where I saw this" occurs (Krokos, Plaisant & Varshney, 2018). Moreover, spatial memory is needed to plan navigational steps to arrive at a desired location mostly in reference to where a certain object is located (Bolton, Ellen & Bass, 2007). In other words, spatial awareness is a crucial cognitive skill to find way's within an environment and remember locations of objects and in what relation those objects stand to each other (Krokos, Plaisant & Varshney, 2018). Spatial memory is one element of general spatial awareness. Spatial memory is needed to achieve spatial awareness of one's environment.

Spatial awareness is described in cognitive psychology research as the awareness of space surrounding an individual (Gardner, 2006) and is also part of overall cognitive perception by the brain (Bolton, Ellen & Bass, 2007).

Spatial awareness is one main component of situation awareness (Wickens, 2002). Situation awareness can be described as the human perception of environments and its components and happenings (Endsley & Bolstad, 1994). According to the model of Endsley (1989) which can be seen in Figure 1., situation awareness consists of several levels ranging from recognising the relationship between objects and the recognition of objects within an environment, over the functioning of those objects to the cause and effect information about those objects predicting the future status (Endsley & Bolstad, 1994). The model provides a good overview of several factors influencing decision making in environments.Those factors are situation awareness, Individuals abilities, Pre conceptions and objectives and workload. This research does not investigate the whole model of Endsley (1988) but uses his research arguing that situation awareness consists of three levels, which is the relevant information distracted from this model for this research.

As described, situation awareness is a major influencer for situational decision making with its presented three different levels of situation awareness. Level one of situation awareness, the recognition of object relationships and object locations within an environment, is equivalent to the description of spatial awareness. Spatial awareness identifies the awareness of oneself in a certain space and the ability to recall objects in relation to oneself (Wickens, 2002; Endsley, 1989). Hence, spatial awareness refers to level one of situation awareness in Endsley's (1989) model.

With reference to the model, spatial memory is is needed to achieve spatial awareness which is in turn one aspect of situation awareness demonstrating one factors needed to take decisions within environments (Figure 1, Appendix 1.).

Spatial memory describes the cognitive process required to remember different locations and relationships between objects. (Bodenheimer, 2007). Spatial memory is the part of the brain encoding the spatial information needed for spatial awareness (Bodenheimer, 2007). According to research spatial memory forms after the exposure to a certain environment (McNamara, Hardy & Hirtle, 1989; Bodenheimer, 2007). Hence, spatial memory is essential for navigation and decision making in environments. According to Newman, Caplan, Kirschen, Korolev, Sekuler and Kahana (2006), the human brain remembers the general layout of an environment and then assigns so called "*target locations*" within that environment to create a mental map. That is because it is assumed that the human brain needs target locations of a cognitive map to activate spatial memory and therefore, possesses spatial awareness (McNamara, Hardy & Hirtle, 1989). The concept of mental maps is further described in the following section of this report.

Cognitive mapping

In cognitive psychology it is argued that spatial memories are collected cognitively in a so called *mental or cognitive map* (Yates, 1992). Spatial memory is needed to navigate and recall a certain environment. A cognitive map refers to a distinct form of mental model, created by ones brain mapping out objects and object relations within a certain experienced environment (Chun & Jian, 1998). The mental map allows navigation between different *target points* within the environment and in relation to the awareness of oneself within the environment (Newman, Caplan, Kirschen, Korolev, Sekuler & Kahana, 2007). Cognitive mapping relies on two different concepts: remembering of environmental layout and *target point* identification (Newman, Caplan, Kirschen, Korolev, Sekuler & Kahana, 2007; Chun & Jian, 1998). Individuals map objects within a certain space in relation to other objects, forming a layout of the environment by using objects as landmarks making both concepts complimentary (Bolton, Ellen & Bass, 2007).

However, in research it is apparent that cognitive mapping is not a single predictor for spatial memory and awareness. More it is one variable in the latter which can be influenced by factors such as prior experience or individual cognitive abilities (Endsley & Bolstad, 1994; Chun & Jian, 1998). Nevertheless, cognitive mapping is a well researched concept used to generate spatial memory and awareness. In order to stimulate mental mapping, memory palaces are often used to create spatial memory.

Memory palaces are a well known technique used to recall information by mapping them spatially (Krokos, Plaisant & Varshrey, 2018). Those information are mapped mentally and associated with the environment (Endsley & Bolsrad, 1994). The idea is to recall certain information by visualising the environment the information was obtained in (Krokos, Plaisant & Varshrey, 2018). For example the recall of certain item locations within an environment can be trained by the usage of mental palaces. It is essential to this technique that one is experiencing the environment, the palace, in a sense of being present (Krokos, Plaisant & Varshrey, 2018; Slater, 2009). Memory palaces also called the *method of loci*, relaying on the brain's ability to organise concepts in a spatial manner (Yates, 1992; Gardner, 2006). Memory is recalled by cognitively imagining the layout of a space and the corresponding *target points*.

Based on the evidence provided above, this research paper uses the concept of memory palaces in order to increase spatial memory and awareness in maintenance training through mental mapping.

Virtual Reality in human training

Research on Virtual Reality in technical training using a fully immersive approach has gained increased attention in the past years compared to other VR means such as VR environments for desktop devices. Between 2012 and 2017, 47% of research studies within VR have been identified to discuss the the topic of immersive and intractable virtual environments (Wang et al., 2017). However, as of 2019 scholars are debating over the effectiveness of VR in training. A limited amount of experimental research papers can be identified addressing the effectiveness which highly correlates with the tremendous costs attached to create, test and evaluate such expensive technology (Borsci, Lawson & Vroome, 2015; Mantovani, Castelnuovo, Gaggioli & Riva, 2003).

However, evidence can be found in literature that Virtual Reality possesses the ability to motivate trainees, increase participation and eventually strengthen the learners motivation when technical tasks or procedures are performed in VR (Wang et al, 2017; Sherman & Craig, 2018). Furthermore, according to several scholars including Borsci et al. (2015) or Gavish, Gutiérrez, Webel, Rodríguez, Peveri, Bockholt and Tecchia (2015), VR in technical training can reduce costs on a sustainable level by eliminating travel and equipment costs, by being more effective in using a learning-by-doing approach and by increasing efficiency through adapting the learning environment to the learner needs. Moreover, Virtual Reality for technical training increases concentration and functions as a good measure of environmental awareness and orientation, as concluded by Sacks and Pikas (2013) who conducted a study on VR safety training.

In technical training, VR is used by educators to train several things whereas not all training goals are equally suitable for VR training means. The main training areas for VR in technical training are; Visualisation and spatial orientation in complex on-the-job environments, reasoning in complex situations, performance of procedures, achieving certain goals by following predetermined steps in the correct order and the observation of detailed and/or hard accessible technical parts (Borsci et al., 2015; Wang et al., 2017; Quevedo, 2017).

What kind of learning goals are translatable into VR while maintaining training effectiveness and how other factors such as the level of trainee expertise or the degree of information exposure influence the effectiveness of VR training, remains subject to further investigation and is not extensively researched in literature therefore, demonstrating a research gap (Mantovani et al., 2003; Yuviler-Gavish, Yechiam & Kallai, 2011). This research marks a starting point exploring the effect of VR training on spatial awareness and basic learning contents comprehension.

Virtual Reality for spatial memory and awareness training

Several researchers including Stone, Craid-Daley and Bessell (2019) argue that immersive virtual reality provides a better memory palace and therefore, better spatial memory and awareness compared to non-immersive 2D devices. In literature it is discussed that immersive virtual environments for example displayed by a head-mounted device, support spatial awareness due to the high stimulation of vestibular and proprioceptive human senses (Krokos et al., 2018). Those senses refer to the body position and feelings of movement and acceleration. Certain distinct brain mechanisms are involved in spatial memory creation. Speed, direction and movement of oneself actives so called *grid cells* in the entorhinal cortex. Moreover, looking in a certain direction triggers *head-direction cells* in a brain part called medial parietal cortex. *Boundary vector cells* or *border cells* are triggered by environmental boarders and horizons. The *hippocampus* inside the brain is activated when spatial orientation is desired, imprinting the environment space internally (Burgess, 2008). Hence, it is evident that body movement and memory are closely related (Madl, Chen, Montaldi & Trappl, 2015). VR can stimulate human senses by providing a fully immersive experience of the environment mimicking the real-world environment. Realistic body movement possibilities within VR hold therefore the potential to activate the brain cells responsible for memory recall (Krokos, Plaisant, Varshrey, 2018; Mania, Badariah, Coxon & Watten, 2010).

Virtual reality stimulates spatial memory and eventually awareness by providing a virtual environment that matches the real-world environment allowing for pattern matching in later recall scenarios (Endsley & Bolstad, 1994). This pattern matching refers to the ability of recognising layout and target points in an environment that looks alike the reference environment but is visited at a later point in time (Madl, Chen, Montaldi & Trappl, 2015). Thus, VR's great visual and spatial information potential can also provide perfect conditions for the creation of a memory palace since one important factor for the memory palace technique is the feeling of *presence* by the individual.

As mentioned in the previous section, a memory palace is used to create cognitive maps of an environment which can be later cognitively recalled to recollect spatial memory and consequently, increasing spatial awareness (Bodenheimer, 2007). Virtual reality forms spatial representation in a realistic way which is assumed to lead to better spatial knowledge compared to training techniques which are less realistic and immersive such as 2D spatial training. This can be supported by the outcomes of a study conducted by Krokos, Plaisant and Varshrey (2018) looking at the effects of several immersion levels on spatial knowledge. The in-between subject study compared a 2D desktop environment with a more immersive 3D environment by creating a memory palace. The study found that the spatial knowledge of those individuals which were exposed to a more immersive environment, showed 8.8% better spatial knowledge. The researchers explain as reason for that, the usage of human senses in the 3D environment and the spatial awareness in relation to oneself within the environment compared to a 2D environment which does not trigger those factors (Krokos, Plaisant & Varshrey, 2018).

Despite the leading evidence for the effectiveness of Virtual Reality immersive environments in spatial memory research, the research area must be explored more in depth (Mania et al., 2010; Benford & Fahlén, 1993). It remains unclear how and to what extent individuals create mental maps from virtual environments and how those cognitive maps stimulate memory recall in the real-world environment (Mania et al., 2010; Krokos, Plaisant & Varshrey, 2018).

Therefore, this research paper chooses to investigate the possibility of Virtual Reality in maintenance training in the defence sector as possible enhancer for spatial memory and awareness of the environment.

Spatial awareness - Theoretical understanding and different measurements

Measuring spatial awareness has been tackled in several ways by researches thought the past decades. A universal and acknowledged measurement and definition is not present at this time (Salmon, Stanton, Walker & Green, 2006).Based on that fact, this section aims to define the way spatial awareness is perceived and used in this research and aims to provide a better understanding of the measurement techniques used in this study based on existing literature.

Most spatial awareness measures are part of situation awareness measures (Endsley, 1994). Situation awareness and therefore spatial awareness can be measured using several different approaches depending on the way spatial awareness is defined and perceived (Salmon et al., 2006; Zheng, McConkie & Tai, 2004). Situation awareness measurements find their origin in the military domain where situation awareness is highly crucial to the success of the operation (Endsley et al., 2000). Nowadays situation awareness and spatial awareness measures are used across several domains including the automotive or entertainment industry.

Possible angles to approach the topic are for example the measurement of the processes conducted to achieve situation awareness or on the contrary, the measurement of the direct awareness or human behaviour via performance measurements (Gugerty, 1997). It has to be said that each approach can lead to a different measurement of spatial awareness (Salmon et al., 2006). In literature those different approaches are reported as the process versus product debate (Smith & Hancock, 1995).

Besides the different approaches also different theoretical perspectives including the three-level model as one pat of the whole model by Endsley (1989), the activity theory model by

Bedny and Meister (1999) and the perceptual cycle model of Smith and Hancock (1995) exist in literature.

Usually a deeper elaboration of measurement levels is subject to the methodology of a conducted research however in this research paper, spatial awareness measurements are closely related to the theoretical view one is taking on the matter and therefore, it was decided to elaborate on several measurements eventually providing understanding on the way spatial awareness is taking up and treated in this explorative research.

Under the light of this research paper and final research goal, the part of Endsley's (1989) model that refers to situation awareness, the three-level model (Figure 1., Appendix1.) fits best with the theoretical understanding of spatial and situation awareness as already introduced in the previous part of this literature review. According to the researcher, situation awareness is internally build and consists of three different hierarchical levels; (1) the perception of the elements in the environment, which is labelled as spatial awareness in this report, (2) the comprehension of the element meaning and (3) the projection of the future status of the element (Endsley, 1995). According to Endsley (1989), those levels form a situation assessment base used to take a decision. The complete model my Endsley (1989) describes more factors such as individual ability, objections or workload as influencing factor for decision making in an environment however, this research only extracts his conception of situation awareness at this point. Future research may want to consider the remaining factors in relation to Virtual Reality.

This research paper builds spatial awareness and learning measures upon the theoretical foundation of the three-level approach for situation awareness by extracting level 1 (the perception of the elements in the environment) as definition for spatial awareness in this research (see section ‘Spatial Memory’) and level 2 (the comprehension of the element meaning) as theoretical foundation for learning effect measures. The relation between both levels and its mutual contribution to situation awareness in Endsley’s (1989) understanding match well with the aim of this research, wanting to measure object location but also system comprehension.

It is important to note that situation awareness is influenced by several factors such as experience, design or prior training and should therefore not be solely measured by cognitive measures (Mania, Troscianko, Hawkes & Chalmers, 2003).

Following the theoretical understanding of the topic by the view of Endsley (1989; 1995), several measurement techniques can be implemented ranging from subjective rating techniques, questionnaires or freeze techniques to performance measures. Each measure has its advantages and disadvantages and is situational dependent (Salmon et al., 2006).

Since this research paper aims to investigate the effectiveness of Virtual Reality for spatial awareness as the level 1 of the situation awareness measure model by Endsley (1989), a basic understanding of the difference in individual spatial performance comparing VR training with traditional training is required to form an exploratory foundation for this research.

Hence, the right choice for this research is a performance measure measuring performance accuracy, assessing spatial awareness by measuring relevant aspects of human performance during an awareness test usually consisting of the conduction of several tasks under observation (Salmon et al., 2006). The tasks to be performed differ per context and therefore, the aspects indicating spatial awareness differ accordingly and have to be defined per measure

(Gugerty, 1997). One example for a spatial awareness performance measure is 'orientation' (Wickens, 1992). Generally, task performance measures are of non-intrusive nature and simple to obtain. However, it has to be considered that performance measures as subject to research bias such as the prior experience of the individual undergoing the measure (Salmon et al., 2006).

In an experimental setting performance measures are often supported by observer rating techniques. Observer rating techniques refer to the observation of an individual by a subject matter expert while performing a certain task. The observer assesses the individual's spatial awareness by the usage of aspects referring to spatial awareness as for example the initial orientation of one in the environment. A typical bias for observer rating techniques is the lack of knowledge on the observing end (Salmon et al., 2006; Endsley, 1995).

To receive an subjective but possibly enriching assessment of situational and therefore spatial awareness, self-rating techniques are often used (McGuiennes, 2004). Self-rating techniques make use of related rating scales hence in the case of this research, individuals would need to self-report their individual spatial awareness mostly as a post-test measure. The major downside of this measure is described in literature as the questionable recall ability of participants post to the actual test (Salmon et al., 2006).

Other situation awareness measures include process indices (Smolensky, 1993), real-time probe techniques such as the SPAM method by Durso et al. (1998) or a quantitative analysis of the matter (McGuinnes, 2004). Despite the great usefulness of those situation awareness measures, none does fit the purpose of this research.

Considering the theoretical approach this paper is taking, spatial awareness is treated as one factor of situation awareness (Endsley, 1989) hence, the most suitable measurement for this research is a performance measure since it is very suitable to evaluate the performance of the end 'product' by analysing the **performance accuracy** in the light of predefined relevant aspects of human performance indicating spatial awareness. That makes spatial awareness measures more flexible and distractible from situation awareness which is not given for most other measures (Mania et al., 2003; Stone et al., 2010). Especially due to its great flexibility, performance accuracy measures fit well the explorative nature of the research aim in this paper.

Hence, **performance accuracy** marks the first independent spatial awareness measure of this research. Moreover, this is well supported by additional cognitive measuring techniques such as self-rating techniques and observer rating techniques (Salmon et al., 2006).

Awareness state in spatial awareness

As stated in the previous section, a stand alone performance measure as cognitive measure is often times not sufficient. Thus, to support the measure of **performance accuracy**, self-rating measures can be used. One self-rating measure concerning spatial awareness is a cognitive measure of **awareness state** (Mania et al., 2010). Awareness state indications can provide a more elaborate insight in the cognitive processes during performance recall (Mania et al., 2006; Bolton, 2009). In the bigger picture, this research aims to explore the effect of Virtual Reality on spatial awareness. That effect is measured by reporting general performance as main measure however, according to existing literature, it is also advised to look at awareness states when assessing spatial/situation awareness.

Gardiner (2000) reports in his study that a subjective measure of awareness state is of essential importance to research since a traditional performance measure cannot lead to a conclusion on the awareness state one believes to be in (subjectivity aspect).

Several researchers such as Mania, Wooldridge, Coxon and Robinson (2006) or Mäntylä (1997) report variating awareness states by consistent performance accuracy forming more evidence for the importance of **awareness state** as explanatory support measure for performance accuracy (exploratory nature). The awareness state scale used in this research is taken up from the research of Mania et al. (2003) and ranges from ‘guess’, ‘familiar’ and ‘know’ to ‘remember’, enabling individuals to express how they have achieved spatial memory and recollection of objects (Mania et al., 2003; Mania et al., 2006). The occurrence of awareness states such as ‘remember’ and ‘know’ was first reported by Tulving (1985) and since then taken up in spatial knowledge research frequently. Table 1. summarises how the scale is to be understood.

Awareness State	*Definition**
Guess	The answer is not known, a guess is made.
Familiar	The exact answer is not known but but the matter seems or feels familiar, especially in comparison with alternatives.
Know	The answer is known without visualisation.
Remember	The object can be visualised and recalled in relation to its position inside the environment.

Table 1. *Awareness states scale, *Mania et al. (2003); Endsley (1994)*

In summary it can be said that **awareness state** is an essential component taken up in prior research when evaluating spatial awareness as part of situation awareness.

Confidence level of spatial memory recall

Confidence level in research is often argued to be another expression of memory and awareness state measures (Dunn, 2004). However, several studies including Gardiner (2001) or Hamilton & Bolton (2002) are indicating opposing patterns when awareness state measures and confidence measures where taken on the same matter. Another example is the study by Gardiner and Java (1990) in which two experiments were conducted, presenting two groups the same stimuli (words or non words) but with providing once an awareness state scale and once a confidence level scale with the conclusion that the awareness states differed per stimuli while the confidence levels did not. Hence, in literature no concise conclusion can be drawn about the relationship between confidence level, awareness state and memory recall. Despite that fact, confidence level remains reported often in combination with awareness state as for example by Mania & Chalmers (2001) to investigate differences in mental processes. In cognitive research confidence measures are taken to understand and identify memories better (Wixted & Squire, 2012).

Moreover, Dunn (2004) argues that it must be investigated whether awareness state measures are just another form of confidence level measures or vice versa, or if both concepts measure different memory components. Therefore, this research takes up **confidence level** as supportive subjective component for **recall performance** and **awareness state**.

Virtual reality and object comprehension - Learning effect

This research investigates the effect of VR on spatial awareness as discussed in previous sections, but also on the system comprehension ability VR training can provide. To understand comprehension in relation to spatial awareness the model of Endsley (1989) is taken up again.According to the model of Endsley (1989), comprehension of the items in once environment is next to spatial awareness, another important factor of situation awareness. Especially in the defence system industry good situation awareness is essential (Stone et al., 2010). Endsley (1989) describes object comprehension as one level deeper compared to spatial awareness. Object comprehension refers to the understanding of the functionality of the objects in ones surrounding (Endsley, 1989). In research it is argued that those object functionalities can be learned through Virtual Reality by forming a realistic representation of the environment which increases the learning effect due to more rememberable experience (Mania et al., 2010). This study takes an explorative approach to investigate to what extent Virtual Reality can stimulate the comprehension of system parts in maintenance training for the defence sector, marking an essential skill this kind of training must deliver (Thales Nederland, 2019). Spatial awareness and comprehension build two of three factors of situational awareness (Endsley, 1989), measured in this research. For the future, the third factor referring to the relationship between objects in an environment might be considered as the technology used in this research matures.

The following table, Table 2. provides an overview of the variables measured in this research. In total this research amounts to four dependent variables indicating the two independent variables: Spatial awareness and System comprehension. Table 2. Also reports the measurement techniques used in this research to operationalise the measurements of the dependent variables. Lastly an overview of the essential literature per independent variable is provided. The table (Table 2.) helps to understand the theoretical foundation for this research and how prior literature is used to address the questions this research stresses. Measurement techniques are subject to prior understanding of concept definitions which demonstrates the reason for a display of the latter under the theoretical framework and not under the scope of the methodology section.

*Dependent Variables**	*Measurment Techniques*	*Independent Variables*	*Theoretical foundation*
Performance accuracy	1. Observations: Observing spatial awareness through reporting spatial aware behaviour (Salmon et al., 2006; Stone et al. (2010). 2. Quantitative measures: Reporting objective differences between and within conditions (Bolton & Bass, 2007). 3. Qualitative data: Self-rating and open questions to capture how spatial awareness/ memory was achieved and training mean experienced (Koriat & Goldsmith, 1994; Mania, 2010).	Spatial awareness/ memory	Endsley (1995), Endsley & Bolstad (1994), Gugerty (1997), Mania et al. (2003),Mania et al. (2006), Bolton & Bass (2007), Salmon et al. (2006) , Koriat & Goldsmith (1994), Stone et al. (2010).

*Dependent Variables**	*Measurment Techniques*	*Independent Variables*	*Theoretical foundation*
Awareness state	Subjective performance support measure indicating awareness level of item recollection (Mania et al. (2003); Mania et al. (2006).		Mania et al. (2010), Mania et al. (2003), Bolton & Bass (2007)
Confidence level	Subjective performance support measure indicating the level of confidence of item recollection (Mania et al. (2003); Gardiner (2000).		Gardiner (2000), Bolton & Bass (2007)
Item meaning recall	1. Quantitative measures: Reporting objective differences between and within conditions (Bolton & Bass, 2007). 2. Observations: Observing spatial awareness through reporting spatial aware behaviour (Salmon et al., 2006; Stone et al. (2010) 3. Subjective performance support measure indicating the level of confidence of item recollection (Mania et al. (2003); Gardiner (2000).	System comprehension	Mania et al. (2010), Mania et al. (2003), Endsley (1989), Endsley (1995)

Table 2. *Independent and dependent variables. * Please see the theoretical framework section for further elaboration of those terminologies.*

In order to answer the two main research questions presented in the introduction of this report, consequently the following four sub research questions are formulated based on the context of Thales Nederland, the exploratory nature of this research aim and the theoretical foundation presented in this section:

1. Will the performance accuracy indicating spatial memory, be different when using Virtual Reality as training mean compared to the recall ability of individuals undergoing passive 2D presentation training, and if so to what extent?

2. In what relation does awareness state stand to performance accuracy for spatial awareness ?

2. What conclusions can be drawn from the relationship between performance accuracy and reported confidence level?

3. Does Virtual Reality training influence basic system comprehension differently than traditional 2D training?

Research design

This section frames the design constructed for this research. The methodology presents an outline of the research procedure and major approaches applied in order to answer the leading research questions; Does *Virtual Reality training influence spatial awareness differently in comparison with a passive 2D presentation training and if so, to what extent?* And*, to what extent differs the learning effect in terms of system comprehension of virtual reality training from the learning effect of 2D presentation training?*

The design is based on a mixed-method research approach including an in between subjects experiment delivering observational, qualitative and quantitative data. It crosses an exploratory and explanatory starting point aiming to deliver practical as well as theoretical implications enriching the knowledge base in the field of Virtual Reality training, spatial awareness and learning comprehension.

Participants

The target population for this research marks every individual that could possibly undergo Virtual Reality training for maintenance on systems in the defence sector. The total number of individuals within that sample amounts to N = 32 individuals. It was aimed to divide all participants equally among two experiment groups however eventually, the division settled for 15 participants in Group 1 and 17 participants in Group 2. From all 32 individuals three identify as female and 29 as male with an age range of 17-63. The sampling pool was derived from *Thales Nederland* employees from various departments including Product Management, Human Resource, Engineering, IT and Training. The degree of technical skills and experience varies throughout the experiment group.

Sampling procedure

The sampling for this research relied on convenience sampling due to practicalities and time restrictions. The major pre-condition to be eligible as a research participant demonstrated that the individual has never been inside the SMARTL radar system or has seen the SMARTL radar system as 3D model in Virtual Reality. All individuals were briefed about the experimental design and possible experiment safety concerns and data sampling procedures were clarified. Consent forms have been handed out and signed by all participants hence, all participants agreed with the research conditions.

Research design

The research in this study was conducted by the means of an experimental set up. The goal of this study was to investigate whether virtual reality enhances the trainees spatial awareness and comprehension of hardware system parts and items within the space of the SMARTL radar system. All participants were assigned at random to one of two experimental conditions. Condition 1, the control condition refers to the traditional way of learning spatial awareness for SMARTL radar training, a passive presentation on a 2D projector given in a standard classroom setting supported by an internal learning software namely Hardware

Navigator. Condition 1 was assigned to half of the total sample however due to practicalities, Group 1 ended up with 15 participants. The other 17 participants were assigned to condition 2, the intervention condition. Condition 2 appointed for immersive Virtual Reality learning. Under both conditions, the participants learn about the basic functionality of 10 different system hardware items and their spatial location within the SMARTL radar. The 10 points of attention were arranged within the environment of the SMARTL system based on the principle of mental palaces (see Theoretical Framework of this report).

All research participants were first trained and after a period of 7 days all 32 experiment participants were asked to fulfil a memory recall test within the actual physical real system environment. The participants were tested upon *performance accuracy*, *awareness state*, *confidence level* and *item comprehension*, marking the dependent variables of this research. Those variables measured *spatial awareness* and *system comprehension* as independent variables allowing for comparison between VR training and traditional maintenance training.

The experiment consisted of two different conditions characterising each one way of maintenance training for the SMARTL radar system. The aim of this research was to investigate which of the conditions delivers better spatial awareness and system comprehension. The table below (Table 3.) provides an overview of the different conditions.

	Experiment Conditions	
	Condition 1	*Condition 2*
Number participants	15	17

	Experiment Conditions	
	Condition 1	*Condition 2*
Name	Group TR (Traditional training).	Group VR (Virtual Reality training).
Training mean	Power Point presentation and 2D computer programme displaying pictures and outlines of the SMARTL radar system.	3D model of SMARTL radar system displayed in Virtual Reality using a head-mounted device (HMD).
Training Duration and setting	Approximately 30 minutes in a group setting.	Approximately 15 minutes in an individual training setting.

Table 3. *Experiment conditions*

Experimental manipulations

Both conditions (Group TR and Group VR) received different training sessions hence, different experimental manipulations. In the following both manipulations are explained and examples are provided. For a better impression of the training sessions please refer to the appendixes of this report (Appendix 2. & Appendix 3.).

Group TR

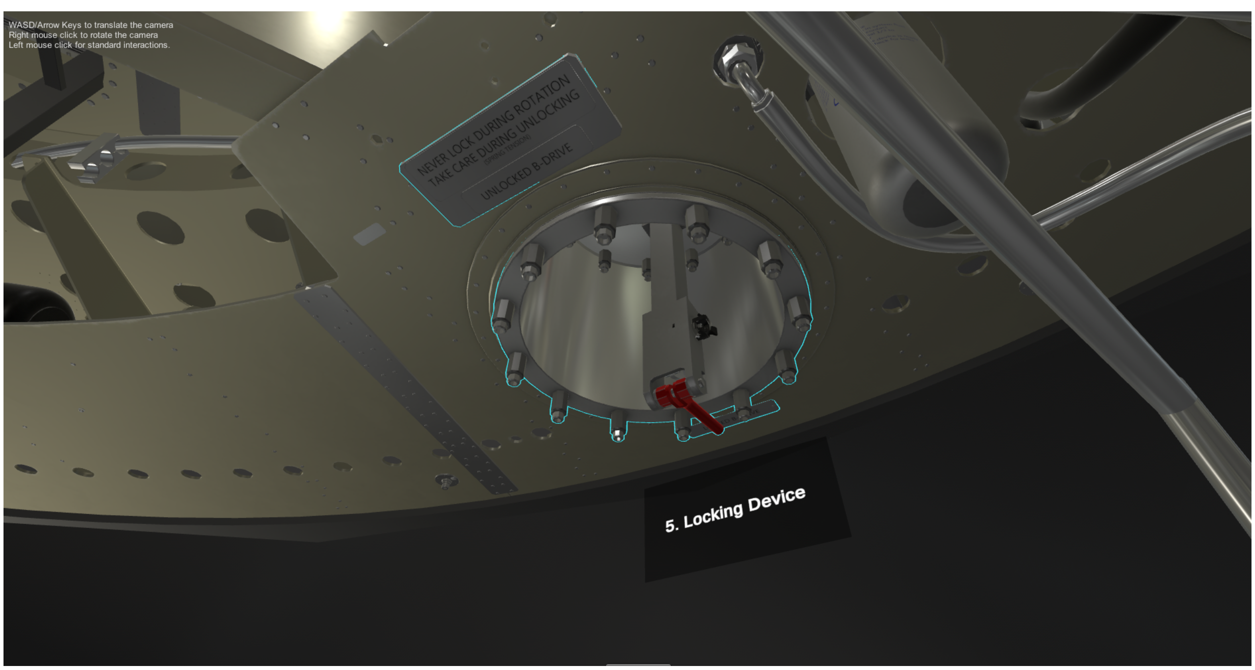
The training sessions for Group TR participants took place exactly 7 days before the actual test on the real radar system. In total four traditional trainings were given on three different days to cover all 15 participants of Group VR. The sessions were video recorded and a timer was used to ensure equal quality however, due to practicalities all trainings provided for this group lasted between 28.4 and 31 minutes. The trainees of this training session got assigned one computer each and the researcher was seated in front also with a computer. Each individual had the 2D computer programme (Hardware Navigator) in front on the computer and the researcher used a Power Point presentation to walk the participants through the 10 different hardware items inside the SMARTL radar which were trained during the session. Parallel to the Power Point the researcher explained the different item locations and functionalities with the usage of the computer programme giving each participant the opportunity to follow what the researcher did on their individual computer. The explanations of the items were normed for Group TR and Group VR and came in the form of 10 simple one or two lined explanations of each hardware item. This kind of training is usually used to train people on the SMARTL radar system in spatial awareness and also item comprehension (Thales Nederland, 2019). In order to ensure a realistic traditional training set up subject matter experts from *Thales Nederland* were interviewed and included in the creation of the traditional training intervention. This condition marks the control condition of this research paper. 'Appendix 2.' provides examples of the Power Point presentation used and 'Picture 1.' shows an example screen of the computer programme used for training. The training took place in a real classroom inside the training centre of *Thales Nederland* in Hengelo, The Netherlands.

Picture 1. *Example 2D Hardware Navigator (computer programme)*

<u>Group VR</u>

Group VR received likewise to Group TR also the training session exactly 7 days before the experiment test (derived from the research of Mania et al., 2010). The training for all 17 participants had to take place individually and each VR session lasted for 15 minutes. The training mean was a Virtual Reality space based on a realistic model of the SMARTL radar system demonstrating a memory palace. Each participant got a Head Mounted Device and one controller for maximum immersion. The 17 training sessions were spread throughout three different days.

Each VR training session started with a basic introduction to the functionalities inside the VR world e.g. the moving around and the required physical body movement. Inside the 3D virtual space of the SMARTL radar system, all 10 hardware item parts were highlighted with blue and accompanied by a number and a label making them recognisable for the trainees. The researcher walked the participants through the VR world from item 1 to item 10 and provided the basic description of the item verbally. All descriptions provided matched the descriptions provided to Group TR. After the observation of all 10 items the researcher repeated all items and encouraged the trainee to recollect each of them for him or herself. With that, the training ended. This condition demonstrated an alteration to the traditional way of system training and marks the intervention of this research paper. Picture 2. shows an example screenshot of the 3D virtual memory palace.



Picture 2. *Example VR Group item inside Virtual Reality training*

Measures

An experimental memory-recall test was performed to measure whether Virtual Reality training performs differently in comparison with traditional training for radar systems. The latter was measured via the two independent variables in this research, spatial awareness and system comprehension. The test took place inside the SMARTL radar system over a period of three days. Each participant was asked to recollect four of the 10 learned different hardware items and recall the basic functionality of the items. The researcher used a head camera to record each test session. The sessions ranged between approximately 16 minutes and 25 minutes.

To measure spatial awareness and system comprehension during the test a mixed method study was used with an underlaying exploratory approach. During the experiment test, observational data was gathered which is of qualitative and quantitative nature measuring and exploring performance and item comprehension. Supporting that, two quantitative subjective measures were used (Awareness State and Confidence Level) to strengthen the predictive power of this research for spatial awareness and item comprehension of both experiment groups. Both support measures were self-rated by each participant during the test. Next to that, four questions (Q1-Q4) were asked post to the test on the radar system to support performance and item comprehension measures with qualitative data aiming to produce explorative outputs. Also those come in the form of qualitative and quantitative data. The following table (Table. 4) provides an elaborative overview of each measurement level.

Measurements		
Dependent variable corresponding measurements		*Independent variable*
Performance accuracy		Spatial Awareness
Observations	Observations were taken by the researcher during the test drafting out behavioural patterns indicating performance in relation to spatial awareness (Stone et al., 2010; Mania et al., 2006).	
Items recalled	This is a quantitative performance measure making both test groups comparable upon objective performance (Koriat & Goldsmith, 1994).	
Questions	Four questions were asked to the participants post to the recall test asking about recognisability of items and environment (self-rating scales), strategy used to remember the items and level of preparation for the test through the training provided accordingly. The latter two questions are of strong exploratory nature and open ended hence, providing a mix of qualitative data indicating spatial awareness and comprehension item meaning (Mania et al., 2003).*	
Confidence level	This is a quantitative support measure using a confidence self-indication scale ranging from ‘low confidence’ to ‘certain’ (Mania et al., 2010).	
Awareness state	This is a quantitative support measure using an awareness state self-indication scale ranging from ‘guess’ to ‘remember’ (Gardiener 2000; Mania et al., 2003).	
Item meaning recall		Comprehension item meaning
Observations	Observations were taken by the researcher during the test drafting out behavioural patterns indicating item meaning recall in relation to comprehension of item meaning (Endsley 1989)	

Questions	*Please see 'Questions' above.
Item meaning recalled	This measure is quantitative count of recalled item meanings making both test groups comparable upon item meaning comprehension (Salmon et al., 2006; Koriat & Goldsmith, 1994).
Confidence level	This is a quantitative support measure using a confidence self-indication scale ranging from 'Low confidence' to 'Certain' (Mania et al., 2010).

Table. 4 *Measurements dependent and independent variables*

For a more elaborate explanation on the origin of those measures please see the theoretical framework section of this report. For the data gathering sheet used during the experiment test please see the appendices of this report (Appendix 4.).

Data analysis

The data analysis was build on several programmes and techniques. First of all the test part of the experiment was recorded with a Go-Pro camera attached to the researchers head. As a backup, the researcher filled in an observation sheet per participant (see Appendix 5. for sheets), during the test and afterwards during the interviews. Those sheets come as a hard copy and were used together with the video material gathered to analyse the performance, confidence level, awareness state and item recall comprehension. That was done by quantitative and qualitative data analysis. To receive quantitative performance data the statistical programme SPSS was used to generate descriptive statistics (e.g. contingency tables) aiming to identify relationships between the variables within this sample. In order to test the data upon significance a statistical significance test was performed. Due to the nature of the data a Chi Square test was preferred however not possible due to the small sample size of this experiment. Therefore, a Fisher's exact test was used to indicate statical significance instead. This test only functions as support measure and does not accept or reject any research findings since the test works with exact p-values, outcomes might be conservative and therefore, not a sufficient solution to label its reliability with confidence.

Moreover, to report observations and interview data, a sheet was created in the computer programme "Numbers", containing one table per participant and the qualitative text codes accordingly to the observed text. The same document contains also a clear overview of the main observations per test group and basic quantitative frequency tables. Eventually the "Numbers" sheet and the SPSS output functioned as foundation for this research reports results, conclusions and discussion section.

Results

The following section provides an overview of the results collected in this paper. The research aimed to explore the influence of Virtual Reality training on spatial awareness and system comprehension. Group TR consisted of 15 participants and Group VR consisted of 17 individual research subjects.On average, people trained in VR recalled 2.9 out of 4 items compared to 2.6 items recalled by people trained traditionally.Moreover, in this research it was observed that the VR group recalled most frequently three items from the test making 52.9% of the whole VR test group. Also the TR Group recalled most frequently three items however with an percentage of 46.7% using the whole TR Group as 100%. Looking at four items recalled and therefore all, the VR Group performed 10.5% better. It was observed that 23.5% of the VR Group and 13.3% of the TR Group recall 4 items during the test. However, the relationship between group and item frequency recalled was not significant (p = .354, 2-sided, Fisher's exact test).

	Items recalled total in percent	
	Group TR	*Group VR*
1 item recalled	20 %	0 %
2 items recalled	20 %	23.5 %
3 items recalled	46.7 %	52.9 %
4 items recalled	13.3 %	23.5 %
Total	100 %	100 %

Table 5. *Items in total recalled per group*

Spatial awareness

In order to measure spatial awareness in this research, *performance accuracy*, *awareness state* and *confidence level* were reported. *Performance accuracy* consists of quantitative data (descriptive and inferential) in terms of item recall count and qualitative data which was based on behavioural observations. *Awareness state* and *confidence level* were reported as quantitative measures (descriptive and inferential) supporting reasoning and providing insight in the quantitative measure of *performance accuracy*. To test the statical significance of the quantitative measures next to descriptive statistics also a statistical test is performed. Due to the fact that the data obtained in this research is of categorical nature and the sample size is rather low (N = 32), a Fisher's exact test is chosen as statistical significance indicator. However, this statistical test functions only as orientation in this research due to its high level of discreteness. The test does not determine the rejection of any hypothesis indicated in this paper but has to be red in combination with other research measures. This mixed method approach led to the following research outcomes.

Performance accuracy

To measure *performance accuracy* in this research quantitative measures were supported by qualitative observations upon performance behaviour indicators. In total N = 32 participants were subject to these measures. The quantitative measures are converted into percentages however the observational data is expressed in numbers of people which is why the unequal distribution of the groups must be taken into account (Group TR = 15 participants, Group VR = 17 patricians).

Item 1

Item one was recollected within the VR Group by 47.1% of all individuals whilst in Group TR, item was one found by 33.3%. Of all tests, item 1 was recollected 61.5% by people from Group VR. In this research, Fisher's exact test indicated a statistically not significant relationship of Item one recollection and group (p = .447, 2-sided).

	Item 1 recollected	
	Group TR	*Group VR*
Yes	33.3 %	47.1 %
No	40 %	17.6 %
Partially	26.7 %	35.3 %
Total	100 %	100 %

Table 6. *Item one recollected per group*

All participants from both groups (Group VR = 17, Group TR = 15) went upstairs towards the item location right away. Hence, initial orientation towards the item location in the entire environment was good and similar among both test groups, always considering the differing amount of research subjects per group. 11 of Group TR and 10 participants of Group

VR started counting for the exact item location right away after arriving above deck. From Group TR, one person went straight towards the item location without counting and arrived at the right item location. In contrast, six participants from Group VR did the same stressing the fact that Group VR showed higher spatial awareness. Ten participants of Group TR were able to point out the right compartment of the TRXL location and also 11 of Group VR. However, as stated above in the table, Group VR had the higher overall recall percentage (47.1%). Four individuals from Group VR mentioned in particular that they remember the location from the training. Furthermore, six participants from Group TR remembered the right counting system while also six remembered the right counting system from Group VR. Considering that Group TR consisted of 15 participants and Group VR of 17, Group TR does seemed to do better on remembering the right counting system.

Item 2

Item two shows that 82.4% of all VR Group individuals were able to find item two during the test. In contrast, 66.7% of all TR Group participants recollected item two during the rest. Hence, there is a 15.7% performance difference between Group VR and Group TR in this research. Performing a Fisher's exact test it became apparent that this difference is not significant (p = .209, 2-sided).

	Item 2 recollected	
	Group TR	*Group VR*
Yes	66.7 %	82.4 %
No	33.3 %	11.8 %
Partially	0.0 %	5.9 %
Total	100 %	100 %

Table 7. *Item two recollected per group*

The most remarkable observation of item two refers to the initial orientation and therefore the spatial awareness concerning the item recollection. Of Group TR, eight participants thought that item two is located downstairs and 13 participants had very bad initial orientation, they did not know where the item location is, indicating bad spatial awareness. In contrast to Group TR, Group VR performed remarkably different.Two people thought the item is located downstairs from which one person explains that she mixed up the items and returns back upstairs and points out the right item location right away.Moreover, 12 individuals from Group VR went straight away to the right item location in the environment and showed very good initial orientation. In general, once a research subject reached the right overall item location (upstairs, PDU rack) the specific item location was pointed out either very quickly or right away (counts for both test groups). Hence, the general location of the item rack was located very differently by both groups while the exact item location on the rack was located similar well by both groups. It was apparent that Group TR showed overall bad initial orientation but once the item rack location was found the right item could be recalled, which led to a high percentage in reported item recalls by Group TR. From Group VR, four people pointed out a wrong but similar looking rack upstairs inside the antenna as item two location. Seven people of Group TR pointed out a different hardware part at least at first or as final answer.

Item 3

Item three shows a high recollection accuracy for both groups. 88.2% of Group VR and 80% of Group TR were able to find item three. Thus, Group VR delivered 8.2% higher performance during the test in this research. Consulting Fisher's exact test, the relationship between test group and the recollection performance of item three is not significant (p = .319, 2-sided).

	Item 3 recollected	
	Group TR	*Group VR*
Yes	80 %	88.2 %
No	20 %	5.9 %
Partially	0.0 %	5.9 %
Total	100 %	100 %

Table 8. *Item three recollected per group*

Both groups showed good initial orientation, 11 people of the TR Group and 15 people of Group VR knew that the item is located between upstairs and downstairs at the "Bearing Drive" of the radar making both groups similar successful in recollecting the location initially. 9 individuals of Group TR and 13 of Group VR needed a very short amount of time or found the exact item location on the “Bearing Drive” right away. Five people took moderately long to recollect the exact item location from Group TR and two people from Group VR. Moreover, six people of Group VR indicated that they remember the look of the item. Three people from Group TR and three people from Group VR pointed out a different item from the training as item three which means that Group VR performed slightly better (Group VR = 17, Group TR = 15). The overall positive orientation and therefore spatial awareness of both groups is in line with the high item recall percentages (80% for Group TR and 88.2% for Group VR).

<u>Item 4</u>

Item four shows similar high recollection percentages as item three, being recollected right by 81.3% of all participants (N = 32). In this research, 82.4% of all Group VR participants recollected item four correctly. Comparing that with Group TR, Group TR shows 2.4% lower recollection performance with a recall percentage for item four of 80%. There was no statistically significant association found between test group and recollection of item four (p = .053, 2-sided, Fisher's exact test).

	Item 4 recollected	
	Group TR	*Group VR*
Yes	80 %	82.4 %
No	20 %	0.0 %
Partially	0.0 %	17.6 %
Total	100 %	100 %

Table 9. *Item four recollected per group*

The observed performance measures for both groups were similar. 10 participants of Group TR and 15 participants of Group VR recollected straight away the location of the item in the environment (downstairs, VPC cabinet), indicating a slight better performance by Group VR (Group VR = 17, Group TR = 15). Four Group TR participants took a moderate long amount of time to locate the exact item inside the VPC while in contrast five VR Group individuals took a moderate amount of time to identify the exact item. Moreover, three people of Group TR indicated that they can remember the location of the VPC but not the exact item location inside the VPC (SVU). Three individuals of Group VR reported the same, meaning that Group VR performed slightly better considering the differing number of research subjects per group.

Self-rating performance measures (Q1 and Q2)

In order to grasp more data supporting performance measures in this study, two self-rating scales were used for all participants (N = 32). Scale Q1 asked the participants to indicate whether they have been able to recognise system hardware items (asked and not asked items in the test) based on the training they have received one week ago. Scale Q2 investigates whether the research subjects recognised the system environment based on the training. Both scales use a measure ranging from *Strongly disagree* to *Strongly agree*. Group VR showed that 58.8% of the whole subject group 'strongly agree's' with statement Q1, they were able to recognise hardware items during the test which have been learned during the training. In contrast, 20% of Group TR indicated 'strongly agree' for this measure however, 66.7% indicated that they 'agree' with statement Q1 whilst only 29.4% of Group VR 'agree'. The relationship between test group and item recognition on a self-rating scale showed to be significant (p = .048, two-sided, Fisher's exact test). Q2 shows a different distribution along the measurement scale. 76.5% of all VR Group individuals chose to 'strongly agree' with the recognisability of the system environment during the test, based on what they have learned one week prior in the training. In contrast, 26.7% of Group TR 'strongly agree' with Q2. The majority of Group TR 'agree's' with the statement, with 46.7% of all individuals. From Group VR, 23.5% 'agree' with Q2. This research found a statistically significant relationship between test group and the recognition ability of the system environment ($p < .000$, 2-sided, Fisher's exact test).

	Q1+Q2 self-rating performance measure	
	Group TR	*Group VR*
Q1. Disagree	0.0 %	5.9 %
Undecided	13.3 %	5.9 %
Agree	66.7 %	29.4 %
Strongly Agree	20 %	58.8 %
Total	100 %	100 %
Q2. Disagree	13.3 %	0.0 %
Undecided	13.3 %	0.0 %
Agree	46.7 %	23.5 %
Strongly Agree	26.7 %	76.5 %
Total	100 %	100 %

Table 10. *Q1+Q2 self-rating performance measure*

One VR Group participant that agreed with Q1 stated that he remembers how he saw the items in VR and what he did to get there and he explained that he did the same inside the real system and it worked. Another VR Group participant that indicated 'strongly agree' for Q1 mentioned that he recognised all the 10 items from the training during the test. Concerning Q2, one VR Group participant that indicated 'agree' explained that he agreed because he was able to recognise everything. One TR Group individual stated 'agree' for Q1 because he also recognised some other items from the training which were not asked in the test. The same individual indicated ‘agree’ also for Q2 and explained that he saw the environment form the pictures and he was aware of the environment. One TR Group participant strongly disagreed with Q2 and said that was because he had no idea where he would come based on the training and another TR Group participant that indicated ‘disagree’ for Q2 explained that he only used his own logic to recollect the items in the environment. Moreover, one Group TR research participant stated ‘agree’ for Q2 because he was only uncertain about the blower switch location. Q1 was agreed on by one Group TR participant with the explanation that he cannot strongly agree because “inside the system it looks different”. Another Group TR individual on the same matter explained that he recognised the pictures from the training but not the environment. Lastly, one TR Group participant was ‘undecided’ about Q2 because the environment looked different than he imagined it, especially upstairs inside the antenna. For a more detailed elaboration on the qualitative findings please see ‘Appendix 4.’.

Awareness state

Awareness state in this research functions as a support measure to performance accuracy in order to predict spatial awareness and memory recall. Awareness state was measured with a self-rating scale ranging from ‘guess’ to ‘remember’. Firstly, awareness state in relation to the frequency of recalled items (performance measure) was analysed for N = 32.

For item one, the majority of Group TR that has been able to recollect the item indicated their state of awareness as ‘know’, with 40% and ‘remember’ also with 40%. In comparison with that, the majority of Group VR that has been able to find item one indicated their awareness state with ‘remember’ with a total of 62.5%. For item two, 70% of all individuals from Group TR that were able to recollect the item indicated that they ‘remember’ the item location. Of Group VR, 50% of all individuals that were able to find the item mentioned they ‘remember’ and 50% ‘know’ the location. Concerning item three, it was mapped out that 58% of all TR Group participants that were able to find item three indicated that they ‘remember’ the item location. Furthermore, 46.7% of all right located items got assigned ‘remember’ by Group VR and the other majority of people (also 46.7%) that recollected item three right assigned ‘know’ to their awareness state. For item number four, of each individual that has been able to find it from Group TR, 33.3% indicated that they ‘remember’ the location, marking the highest percentage among the awareness scale. Comparing that with the VR Group, the most frequently indicated awareness state among all participants that were able to recollect item four is ‘remember’, self-indicated by 50% of the individuals.

Fisher’s exact test signified no relationship between the state of awareness and item one (p = .154, 2-sided) and also not between awareness state and item four (p = .489, 2-sided). However, a significant relationship was found between awareness state and item two ($p < .000$, 2-sided, Fisher’s exact test) and also between awareness state and item three (p = .004, 2-sided, Fisher’s exact test). For further qualitative findings on the awareness state please see ‘Appendix 4.’.

	Item recollection and awareness state		
Group TR Item 1	*Yes*	*No*	*Partially*
Guess	0.0 %	50 %	50 %
Familiar	20 %	33.3 %	25 %
Know	40 %	0.0 %	0.0 %
Remember	40 %	16.7 %	25 %
Total	100 %	100 %	100 %
Group VR Item 1	*Yes*	*No*	*Partially*
Guess	0.0 %	0.0 %	0.0 %
Familiar	0.0 %	0.0 %	16.7 %
Know	37.5 %	0.0 %	33.3 %
Remember	62.5 %	100 %	50 %
Total	100 %	100 %	100 %
Group TR Item 2	*Yes*	*No*	*Partially*
Guess	20 %	80 %	0.0 %
Familiar	10 %	20 %	0.0 %
Know	0 %	0.0 %	0.0 %
Remember	70 %	0.0 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 2	*Yes*	*No*	*Partially*
Guess	0.0 %	100 %	0.0 %
Familiar	0.0 %	0.0 %	0.0 %
Know	50 %	0.0 %	0.0 %
Remember	50 %	0.0 %	100 %
Total	100 %	100 %	100 %

Group TR Item 3	*Yes*	*No*	*Partially*
Guess	8.3 %	33.3 %	0.0 %
Familiar	8.3 %	33.3 %	0.0 %
Know	25 %	33.3 %	0.0 %
Remember	58.3 %	0.0 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 3	*Yes*	*No*	*Partially*
Guess	0.0 %	100 %	0.0 %
Familiar	6.7 %	0.0 %	100 %
Know	46.7 %	0.0 %	0.0 %
Remember	46.7 %	0.0 %	0.0 %
Total	100 %	100 %	100 %
Group TR Item 4	*Yes*	*No*	*Partially*
Guess	16.7 %	33.3 %	0.0 %
Familiar	25 %	33.3 %	0.0 %
Know	25 %	0.0 %	0.0 %
Remember	33.3 %	33.3 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 4	*Yes*	*No*	*Partially*
Guess	0.0 %	0.0 %	0.0 %
Familiar	7.1 %	0.0 %	0.0 %
Know	42.9 %	0.0 %	66.7 %
Remember	50 %	0.0 %	33.3 %
Total	100 %	0.0 %	100 %

Table 11. *Item recollection in relation to awareness state*

Confidence level

Confidence level marks the second self-indicated quantitative measurement in this research next to the collected awareness states of all participants. Firstly it is examined whether the confidence level stands in relation to the frequency of recalled items per group and secondly, in what relationship confidence level stands to awareness state.

For the statistics concerning awareness state and confidence level please refer to the appendices of this research report (Appendix 6.). In this research no clear relationship or pattern between confidence level and awareness state was found. Item one and item four showed statistically non significant results regarding the relationship of both variables while item two and item three indicated a significant relationship.

It is important to mention that for each item the individuals that were not able to recollect an item location at all were discarded from this analysis hence, each item analysis only considers the individual participants that mentioned a location, regardless whether wrong or not. Without indication of location the expression of a confidence level is not applicable.

For item one (N = 31), 20% of all TR Group participants that recalled the item correctly felt ‘certain’ about their answer while 25% of all VR Group participants felt ‘certain’. The majority of the people in Group TR that recalled item one felt ‘confidence’ about their answer (40%) and the majority of VR Group participants (50%) that gave the right location also mentioned ‘confidence’ as their confidence state. 80% of the people from Group TR that could not recall the item felt ‘moderate confidence’ while the individuals of Group VR that were not able to recall item one are spread out evenly across ‘moderate confidence’, ‘confidence’ and 'certain' (with 33.3% each). Item two was measured in relation to the confidence level with N = 31. It was investigated that 60% of all TR Group participants that recalled item two correctly indicated a confidence level of 'certain' while for Group VR, 100% indicated 'certain'. Moreover , 40% of Group TR that was not able to recollect the item rated their confidence level with 'moderate', which is also the majority. In contrast, the majority of Group VR that was not able to find item two correctly indicted their confidence level with 'low confidence' (100%). Item three was measured in relationship to the confidence level with N = 32 indicating that no individual was unable to recollect a location. 58.3% of all Group TR participants that were able to recollect the right item were 'certain' about their answer while 93.3% of all VR Group participants that gave the right answer indicated their confidence level with 'certain'. Moreover, also the majority of all TR Group participants that indicated the item location wrong were 'certain' about their answer with 66.7% while in contrast, 100% of all Group VR individuals that were not able to find item three correctly indicated 'no confidence'. Item four was measured with N = 30. The majority of Group TR participants that recollected item four correctly indicated an awareness state of 'certain' (45.5%) while all participants of Group VR that found the right item also indicated 'certain' with a majority of 53.8%. 66.7% of Group TR indicated 'moderate confidence' and was not able to find item four. No participant of Group VR was unable to find the correct item.

The relationship between recall of item one and confidence level is according to Fisher's exact test, not significant (p = .088, 2-sided). Also for item four (p = .095, 2-sided, Fisher's exact test), the relationship proved to be not statistically significant. However, item two (p = .002, 2-sided, Fisher's exact test) and item three (p = .018, 2-sided) showed to be of statistical significance. For further elaboration on the qualitative findings concerning confidence level, please refer to ‘Appendix 5.’ of this report.

	Item recollection and confidence level		
Group TR Item 1	*Yes*	*No*	*Partially*
No confidence	0.0 %	20 %	0.0 %
Low confidence	40 %	0.0 %	25 %
Moderate confidence	0.0 %	80 %	50 %
Confidence	40 %	0.0 %	25 %
Certain	20 %	0.0 %	0.0 %
Total	100 %	100 %	100 %
Group VR Item 1	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	12.5 %	0.0 %	0.0 %
Moderate confidence	12.5 %	33.3 %	50 %
Confidence	50 %	33.3 %	33.3 %
Certain	25 %	33.3 %	16.7 %
Total	100 %	100 %	100 %
Group TR Item 2	*Yes*	*No*	*Partially*

No confidence	10 %	20 %	0.0 %
Low confidence	0.0 %	20 %	0.0 %
Moderate confidence	20 %	40 %	0.0 %
Confidence	10 %	0.0 %	0.0 %
Certain	60 %	20 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 2	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	100 %	0.0 %
Moderate confidence	0.0 %	0.0 %	100 %
Confidence	0.0 %	0.0 %	0.0 %
Certain	100 %	0.0 %	0.0 %
Total	100 %	100 %	100 %
Group TR Item 3	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	33.3 %	0.0 %
Moderate confidence	16.7 %	0.0 %	0.0 %
Confidence	25 %	0.0 %	0.0 %
Certain	58.3 %	66.7 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 3	*Yes*	*No*	*Partially*

No confidence	0.0 %	100 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	0.0 %	0.0 %	100 %
Confidence	6.7 %	0.0 %	100 %
Certain	93.3 %	0.0 %	0.0 %
Total	100 %	100 %	100 %
Group TR Item 4	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	9.1 %	33.3 %	0.0 %
Moderate confidence	18.2 %	66.7 %	0.0 %
Confidence	27.3 %	0.0 %	0.0 %
Certain	45.5 %	0.0 %	0.0 %
Total	100 %	100 %	0.0 %
Group VR Item 4	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	23.1 %	0.0 %	66.7 %
Confidence	23.1 %	0.0 %	0.0 %
Certain	53.8 %	0.0 %	33.3 %
Total	100 %	0.0 %	100 %

Table 12. *Item recollection in relation to confidence level*

Qualitative performance measures (Q3+Q4)

This research has made use of supportive qualitative measures providing increased insight into the opinions and impressions of the participants. Question 3 and Question 4 were post experiment measures and were asked to the participants after the item recollection test was performed on the system. Question 3 asked the participants about their strategies to remember the hardware items during the week/during the training and Question 4 asked whether the participants feel that the training they have received one week ago prepared them well for the test. Due to the open nature of the questions the answers are often spread over both questions hence the table below (Table 13.) sorts out all findings and groups them by question. For the entire qualitative data gathered per participant please refer to the appendices of this report (Appendix 5.). The table below must be red with the consideration of an unequal distribution of participants among groups (Group TR = 15 participants, Group VR = 17 participants). 'Table 13.' also presents the kind of performance measure indicated per finding (total left row).

	Qualitative performance measures	
Q3	*Group TR*	*Group VR*
Performance measure memory recall strategy	8 participants indicated that they had no particular strategy to remember the items.	8 people stated that they had no strategy to remember the hardware items during the week.

Performance measure memory recall strategy	3 participants mentioned that they went over the items in their head.	7 people indicated that they visualised the environment again and went through the item locations cognitively.
Performance measure memory recall strategy	2 people indicated that they talked with another participant about the items after the training.	2 people stated that they had an actual strategy to remember the items. *See Appendix 5. for details
Performance measure memory recall strategy	3 participants mentioned that they tried to remember the location based on the function/meaning of the item.	1 person tried to remember by recalling units in relationship to the functionalities of the items and 1 person tried to focus on functionalities.
Performance measure memory recall strategy	1 person said that he focused on the location and not the functionality of the items.	3 individuals focused more on the visuals than on the functionalities.
Q4	*Group TR*	*Group VR*
Performance measure indicating spatial awareness	3 people indicated that they think the environment looks very different from what they expected.	4 people indicated that the environment looked different from the VR environment.
Performance measure indicating spatial awareness	1 person said that the environment was very similar to the environment portrayed during the training	10 individuals mentioned that the environment looked similar to the VR environment.
Performance measure indicating spatial awareness	8 people indicated that they tried to visualise the item location.	2 people indicated that they tried to recall item locations from memory.
Performance measure	2 people said that the counting explanation helped or that they tried to remember the counting.	4 people tried to remember the counting system.
Performance measure indicating spatial awareness	13 people showed very bad initial orientation for item 2 and 5 of them thought the item is located downstairs while in fact it is upstairs.	12 people go straight away to the location of item 2 showing very good initial orientation from which 11 find the right location instantly.

Performance measure	3 people said that the training provided did not prepare them well	No one from that group indicated that the training prepared them not well.
Performance measure	4 people mentioned that the training prepared them partially well.	3 people explained that they missed the reputation of training.
Performance measure	5 people mentioned that they think the training prepared them well	13 people indicated that VR training prepared them well for the test.
Performance measure	2 people mentioned in particular that they had problems remembering the items and the locations based on the training	13 people mentioned that VR can also hinder training. *See Appendix 5. for details
Performance measure learning mean	2 people explained that they liked the HWN. *See Appendix 5. for details	17 people indicated that they believe VR is a good training mean/mentioned positive points about it. *See Appendix 5. for details

Table 13. *Qualitative data measuring performance*

Overall it was apparent that participants from Group VR put more emphasis on visualisation and environment comparison between then virtual world and the real environment. Moreover, drastically more individual participants from Group VR indicated an opinion about the training mean mentioning positive points as well as negative points of VR for training while in contrast only very few people from Group TR spoke about the learning mean itself during the interviews. Further, Group TR participants overall were not satisfied with the environmental impression the traditional training provided of the real environment while in turn more than half of the VR Group participants indicated that they were able to recognise the system environment based on the training. Lastly, the main qualitative finding in this research is demonstrated by the amount of people indicating that the training prepared them well for the test. Almost all individuals of Group VR indicated the latter while in contrast only less than half of all TR Group participants mentioned that the training prepared them well for the test. For all qualitative findings please refer to 'Appendix 5.' of this report.

System comprehension

System comprehension measured through comprehension of item meaning, marks the second independent variable in this research. The following section provides the quantitative results looking at both groups, allowing to identify differences between groups in terms of system comprehension. All four items are listed separately below.

Item 1

Item one showed highly diverse results for both groups. 70.6% of all Group VR individuals were able to recall the item functionality while 6.7% of Group TR were able to do the latter. Moreover, 66.7% of Group TR was not able to provide the item meaning at all and 11.8% of Group VR was not able to explain item one. Fisher's exact test has proven to be significant (*p* < .000, 2-sided).

	Item 1 meaning recalled	
	Group TR	*Group VR*
Yes	6.7 %	70.6 %

No	26.7 %	17.6 %
Partially	66.7 %	11.8 %
Total	100 %	100 %

Table 14. *Item one meaning recalled*

Item 2

The meaning of item two was recalled by 23.5% of Group VR and 6.7% of Group TR. No recall was measured of 33.3% of Group TR and 11.8% of Group VR. The majority of both groups recalled the item meaning partially (Group VR: 64.7, Group TR: 60%). The relationship between item functionality recall and test group has not shown to be significant (*p* = .274, 2-sided, Fisher's exact test).

	Item 2 meaning recalled	
	Group TR	*Group VR*
Yes	6.7 %	23.5 %
No	33.3 %	11.8 %
Partially	60 %	64.7 %
Total	100 %	100 %

Table 15. *Item two meaning recalled*

Item 3

The functionality of item three was recalled correctly by 70.6% of all participants from Group VR and by 20% of all participants from Group TR. 13.3% of Group TR were not able to recall the item functionality and 5.9% of Group VR were not able to recall that. The majority of all TR Group individuals was partially able to recall the meaning with 66.7% while the percentage of partially recalled item functionalities for Group VR is lower (23.5%). According to Fisher's exact test, the relationship between test group and item functionality recall frequency is not significant (p = .010, 2-sided).

	Item 3 meaning recalled	
	Group TR	*Group VR*
Yes	20 %	70.6 %
No	13.3 %	5.9 %
Partially	66.7 %	23.5 %
Total	100 %	100 %

Table 16. *Item three meaning recalled*

Item 4

Item four has been recalled right concerning its functionality by 11.8% of Group VR individuals and 0% of Group TR participants. Group TR's majority recalled the item meaning not at all (86.7%) while the majority of Group VR recalled the item meaning partially with

47.1%. Only 13.3% of Group TR recalled the item partially. The relationship between recalled item functionality and test groups has been shown to be significant (p = .027, 2-sided, Fisher's exact test).

	Item 4 meaning recalled	
	Group TR	*Group VR*
Yes	0.0 %	11.8 %
No	86.7 %	41.2 %
Partially	13.3 %	47.1 %
Total	100 %	100 %

Table 17. *Item four meaning recalled*

Item comprehension and confidence level

The next paragraph deals with item comprehension in relation to confidence level. The measurements were of quantitative nature. Overall it can be said that confidence level showed in no case a statistically significant relationship with item comprehension. The findings show no clear relationship of pattern between the factors. Only the major findings are expressed in this section, for the complete quantitative findings please refer to 'Appendix 7.' of this report.

Item one was measured with N = 26 due to the fact that participants which were not able to report any item functionality are excluded from the analysis upon confidence level concerning their answer. Within all participants that indicated the item functionality correctly of Group TR, one participant indicated a 'Moderate Confidence' level marking 100% while in contrast more people from Group VR were able to recall the item functionality from which the majority (41.7%) indicated a confidence level of 'confidence'. A non significant relationship was identified by Fisher's exact test (*p* = .758, 2-sided). Item two (N = 28) was recalled by only one TR Group member correctly with a 'moderate confidence' level while several Group VR recalled the item most frequently with a confidence level of 'certain' (75%). Overall the confidence level 'certain' was indicated most often across both groups. According to Fisher's exact test, recalled item functionality and confidence level have a not statistically significant relationship (*p* = .246, 2-sided). Item 3 (N = 30) showed that 100% (3 people) of all Group TR people that recalled the item meaning right, indicated 'certain' in regards to their confidence level. For Group VR, the most frequently indicated confidence level of people that were able to recall the item meaning was 'certain' with 91.7% while the remaining percentage of subjects reported 'confidence' (8.3%). A performed Fisher's exact test mapped out a not significant relationship between item three comprehension and confidence level (*p* = .300, 2-sided).

For item four (N = 22), no individual from Group TR was able to recall the item meaning correct however of the people who did not recall it right the majority (50%) pointed out a confidence level of 'moderate confidence'. In contrast, one participant (100%) of Group VR that recalled the right functionality expressed a confidence level of 'certain'. For Group TR everyone who recalled the meaning partially either indicated a confidence level of 'moderate confidence' (50%) or 'confidence' (50%). For Group VR, the majority of people that recalled the functionality of item four partially is split between 'confidence' (42.9%) and 'certain' (42.9%).

Fisher's exact test suggested a not significant relationship of item functionality recall and confidence level (p = .059, 2-sided).

In summary it can be said that Group VR outperformed Group TR overall in spatial awareness. Group VR recalled 2.9 items on average while Group TR recalled 2.6. However, that difference proved not to be statistically significant. The quantitative *performance* measures indicated a higher recall percentage by Group VR for each item. Moreover, the self-rating measures (*performance measures*) on item recognisability (Question 1) and environment recognisability (Question 2) had shown that 'strongly agree' was selected most often for both questions by Group VR while Group TR selected most often 'agree' also for both questions. Concerning the supportive measure of *awareness state*, this research cannot be conclusive on its relationship with item recall *performance*. Two items showed a statically signifying relationship while two items showed a non significant relationship. The situation mapped out similar for the support measure *confidence level*. Two items provided statically significant proof of a relationship between *confidence level* and item recall *performance* while the rearming two indicated a non significant relationship. Eventually both support measures provided ambiguous findings. Additionally, a relationship between the two support measures can also not be identified in this research.

Looking at the qualitative *performance* findings, the major findings centring around the following facts; Group VR felt that the training prepared them better for the test in comparison with Group TR. Also, more participants of Group VR indicated that the real environment looks similar to the environment envisioned after undergoing the training. Lastly, Group VR seems more involved with the training mean in comparison with Group TR. In other words, Group VR mentioned the training mean remarkably more often than the other group, whereby positive and negative points were mentioned.

In terms of system comprehension and therefore *item functionalities recalled*, Group VR recalled 1.6 and Group TR recalled 0.4 out of four. For each of the four items, Group VR recalled the functionality better. Twice with considerable difference to Group TR (Item 1: 63.9% difference, Item 3: 50.6% difference). Furthermore, no significant relationship could be found between *item functionalities recalled* and *confidence level*. All four items showed no statistical significance and in addition to that, the present data provided no conspicuous data patterns or relations.

Conclusion and Recommendations

The following chapter represents the conclusions of this research and future recommendations. The conclusion stresses to answer the main research questions and sub research questions of this report. First all sub questions are answered leading to the main questions of this research being answered. The conclusion provides understanding of the influence of Virtual Reality training on *spatial awareness* and *system comprehension* found in this research.

Performance accuracy indicating spatial awareness

To understand the influence of VR training on spatial awareness, performance accuracy was investigated in this research using several measurements. Hence, the following sub question was subject to be answered: *Will the performance accuracy indicating spatial awareness be different when using Virtual Reality as training mean compared to the recall ability of individuals undergoing passive 2D presentation training, and if so to what extent?*

Looking at the quantitative data results, Virtual Reality outperforms the traditional way of training for each item in the test. In this research, the group that got trained by the means of Virtual Reality recalled 0.3 items more on average compared with the group of participants that was trained in a traditional way using a Power Point presentation and a 2D computer programme. Despite the fact that VR led to higher recall performance in each case, also the results of Group TR can be concluded as good. Both test groups recall most frequently 3 out of 4 items meaning that both trainings led to good learning outcomes. However and taking into consideration that those measures are solely of quantitative nature, a first indication for the fact that the performance of Group VR is indeed different than the performance accuracy of Group TR can be concluded from this research. The relationship between Virtual Reality and spatial awareness performance seems to be positive.

The quantitative measures can be enriched by qualitative data that was gathered during the experiment. More than half of GroupVR participants explained during the interview that they found the real environment (inside the system) similar to the environment experienced during the training. Multiple people from this group said that VR would help them understand how the system looked like which could be part of the reason for the good item recall result of Group VR.

In turn, only one person from Group TR mentioned explicitly that the environment looked like how it was imagined. Almost half of Group TR participants said that they cannot locate oneself and also not the items in the environment or that the visualisation they had about the environment was bad (see Appendix 5.). That indicates that better visualisation leads to better spatial awareness which is legitimate since visualisation is the key principle of building memory palaces for a better spatial awareness (Krokos, Plaisant & Varshrey, 2018). Moreover, 13 out of 17 people from Group VR and 5 out of 15 people from Group TR reported that they think the training prepared them well for the test. This finding underlines the quantitative outperformance of Group TR by the group that got trained in Virtual Reality.

In general, it was apparent that people from Group VR tend to talk more about the learning mean than people from Group TR. All Group VR participants (N = 17) mentioned at least once one positive effect of Virtual Reality. For example it was mentioned that VR provides a strong interactive experience, that the “glasses” helped to be immersed in the situation, that Virtual Reality helps to remember item locations or that the environment was very detailed and realistic which supported the memory during the training. In contrast to that, only two research participants from Group TR mentioned that they liked the traditional training mean (the 2D computer programme in particular). The positive points mentioned about the Virtual Reality training all describe important points that are contributing to the feeling of “being present” in the learning environment during the training.That feeling leads according to Krokos, Plaisant and Varshrey (2018), to a better memory recall performance due to the possibility of creating a strong memory palace through “being present”, using body senses such as position or movement. Hence, a starting point of evidence is made in this research, stressing the fact that Virtual Reality may lead to the creation of stronger memory palaces due to interactivity, immersion, experience and/or a realistic 3D environment.

On the contrary, also more than half of the people from Group VR expressed constraints in relation to the Virtual Reality training and said that VR can hinder training. Participants mentioned for example that especially the “downstairs” part of the actual system was more messy and crowded making it harder to find orientation. Other people explained that the numbering of item one was confusing and not helpful for remembering. One woman got very nauseous during her VR training and several participants could not deal very well with the usability of the Virtual Reality system itself. Overall it can be concluded that participants that were exposed to Virtual Reality as learning mean had stronger opinions about the learning mean compared to the participants that were trained by traditional learning means. It became apparent that the usability of the Virtual Reality system itself stands in between the learning and the user.

Usability issues were often described by the participants as hindering factors for learning. Those factors might be possible constraints to the effectiveness of Virtual Reality for spatial awareness in training. Almost half of Group VR indicated that in between the training and the test (7 days) they tried to visualise the environment and the items and walk them through cognitively. One person said, “i tried to replay the film again”. It seems that overall Virtual Reality activated a better “cognitive map” of the environment which can explain the better performance Virtual Reality training led to in comparison with traditional training.

Lastly it is interesting to mention that the self-rating performance measure confirmed the quantitative data as well as the interview questions; 77% of all Group VR individuals ‘Strongly Agree’ with the statement that the training provided, helped to recognise the actual system environment while in contrast the percentage of Group TR is with 26,7% much lower.

The answer to the guiding research question is yes, the memory recall performance comparing VR with traditional training mapped out to be different for both groups. At least in this research, Virtual Reality training converted into a better memory recall performance than the traditional training did.

Awareness state and performance accuracy for spatial awareness

The quantitative support measures *awareness state* was taken up in this research to investigate to what extent a self-indicated awareness state has a relation to *performance accuracy* indicating spatial awareness. The following question was to be answered by the experiment conducted in this research: *In what relation does awareness state stand to performance accuracy for spatial awareness ?*

Overall it is difficult to tell from the data collected whether or not there is an actual relation between self-reported awareness state and performance also due to the small sample, some significance testing outcomes might be not fully reliable. Two items showed a statistically significant relationship between the variables while the remaining two showed a nonsignificant relationship. Initially, awareness state was reported as cognitive support measure in this study aiming at explaining quantitative performance findings. At leat for this research, the measure of awareness state does not seem to stand in a (positive) relation with the item recall performance of the participants among both test groups. In other words, a better recall performance does not come with a higher awareness state and vice versa.

For example it was observed that 13 participants of Group TR had very bad initial orientation for item two hence, did not know where the location of item in relation to the entire environment is. However, once they started searching around most of them found the item location eventually and were able to recollect the actual item. The bad initial orientation indicates bad spatial memory and that the item location is not remembered or known nevertheless, most of those people (7 people) indicated ‘remember’ as awareness state. Overall it seemed that people could not indicate well which awareness state they are in.According to the observational data obtained, many people among both test groups seemed uncertain about self-rating their current awareness state of item recollection. Taking a close look at the observational data in relation to item two (see Appendix 5.) it becomes apparent that some people mentioned that they remember how the rack looks like on which the actual item is located (item memory) but they could not find the rack location (environment memory) which should have been the indicator for awareness state. As a conclusion from this experiment it can be drawn that there seems to be a difference in item location in relation to environment and exact item location in relation to the greater system part. In summery, that might be the underlying reason for the indication of 70% ‘remember’ by TR Group individuals that recalled item two eventually correct.

However, the sample size is too small to make actual inferences about the awareness state in relation to item recall performance. Hence, findings are too ambivalent even though some relationships are indicated, future research must investigate this relationship using a bigger sample size and possibly a different research method.

Confidence level and performance accuracy for spatial awareness

This research wanted to look at the confidence level in relation to spatial awareness as subjective supportive performance measure. The following question was to be answered: *What conclusions can be drawn from the relationship between performance accuracy and reported confidence level?*

In general no clear pattern was found in this research for *confidence level* in relation to *spatial awareness*. However, some main observations could be made. Despite the missing pattern overall, Group VR was more confident or even certain throughout all four items in their choice of recollecting the items. In general this research has found some influence of confidence level on item performance however not in relation to any group in particular. Group VR seems to be more often ‘confident’ and ‘certain’ however, this quantitative measure has underlying root causes (as for example the nature of the item) which might not be linked back to the difference in training mean only. Looking at the qualitative performance findings, Group VR had more initial orientation ability compared to Group TR however setting that in contrast to confidence level, Group VR was not more confident about the recollection of item locations.

Comparing the patterns found in this research of awareness level in relation to confidence level, the findings remain ambiguous supporting the outcomes of the research conducted for example by Duun (2004). Two items seemed to link confidence level and awareness state through a positive relationship with performance accuracy but two items do not. The patterns of both measures in itself are not clear and seemed to depend on the nature of the object recalled and/or other cognitive factors. Some items showed very unclear patterns of confidence level in relation to awareness state. People among both groups appeared uncertain about their state of awareness and confidence level. Moreover, it cannot be said whether both variables describe different constructs/concepts or e.g. whether one concept is part of the other as assumed by several scholars (Bolton & Bass, 2007).

One interesting finding for confidence level in relation to performance could be made for item two. Item two shows a more distinct pattern of confidence levels on performance. 100% which in that case equals (N = 14) of Group VR that recollected the item correctly were 'certain' about the choice they made. Group TR was 'certain' with 60%, showed 'confidence' with 10% and 'moderate confidence' with 20%. For that item it seemed that for people that trained in Virtual Reality, item recollection correlates positively with confidence level.

That finding can be supported by the observations. Group VR had much more initial orientation ability compared to Group TR. 12 people (out of 17) of Group VR went straight to the right item location, showing very good spatial awareness while appearing very certain. In contrast, 13 (out of 15) people from Group TR had very bad initial orientation of item two. It was not clear to those people where the item was located and only after searching around the item was found. That might be the explanation for the lower confidence levels while still, the overall recollection performance was good throughout the groups based on the successful item search of many Group TR individuals (however indicating low spatial awareness). Supporting that, it was observed that most people that had very bad initial orientation from Group TR indicated their eventual confidence level with 'Certain' due to the fact that once the item location was found (PDU rack) the item was seen quickly (circuit breaker). Hence the interpretation of subjective confidence level is referring to the "narrow" location of the item on the belonging hardware part instead of the overall location inside the system environment.

It can be concluded that confidence level had no consistent relationship with performance in this research. Several factors may have influenced that fact ranging from the misinterpretation of confidence level to the characteristics of the items or the individual inability to estimate one's confidence level.

Item functionality recall and system comprehension

Item comprehension was measured in this research to investigate an important part of training, the understanding of the learned items. Moreover, comprehension of objects marks one important factor in situation awareness too, next to spatial awareness. Hence, item comprehension is of essential importance for maintenance training. This research aimed to answer the following sub research question: *Does Virtual Reality training influence basic item meaning recall comprehension differently than traditional 2D training?*

Overall, Group VR outperformed Group TR in terms of item functionalities recalled. For each item, the participants that have received Virtual Reality training did better in recalling the functionality of the item. Group VR was able to recollect on average 1.6 item functionalities while on the contrary, Group TR only recalled 0.4 out of 4 item functionalities on average.

The most difference in item functionality recall ability was found for item one. Group VR recalled the functionality 63.9% better compared to the traditionally trained group. When looking at the qualitative data collected, several individuals from Group VR indicated that they felt they were busy with understanding how the VR system works so they were unable to listen to the item explanations provided during the training. Additionally, some people from Group VR explained that they expect the missing visualisation of the item explanations to hinder the learning comprehension. It appears in this research that participants were under the impression Virtual Reality on its own may be too distraction while in contrast, participants that got the VR training were better in recalling the item functionalities despite the fact that many assumed otherwise. Summing up it can be said that within the scope of this research, system comprehension seems to be influenced by Virtual Reality as training mean in comparison with traditional learning means.

Item functionality recall and confidence level

In regards to the self-reported confidence level of recalled item functionalities, this research could not identify a clear relationship or any pattern. For all four items, no statistically significant relationship between item recall ability and confidence level was found. Considering the observations taken during the test, it can be concluded that many participants among both groups were low in confidence even when the item functionality was correctly explained.

The following main research questions were defined for this research:

1. *Does Virtual Reality training influence spatial awareness differently in comparison with a passive 2D presentation training and if so, to what extent?*
2. *To what extent differs the learning effect in terms of system comprehension of virtual reality training from the learning effect of 2D presentation training?*

Question one can be answered with yes, in this research paper Virtual Reality training influenced spatial awareness differently in comparison with a passive 2D presentation training. Virtual Reality for training on radar systems led to 0.3 more recalled items in comparison to traditional training. Moreover, according to the participants Virtual Reality is very good to recognise the environment of the system, speaking for spatial awareness created. Moreover, the participants of Group VR had better initial orientation and found overall VR as learning mean helpful in remembering the item locations. Those factors indicated as well, a good spatial awareness.

In contrast, Group TR seemed to overall have more problems with navigation and spatial recall. Group TR did not agree as strongly as Group VR with the fact that the environment of the system was recognisable based on the training received. In summary, Group VR presented more positive indicators for spatial awareness than Group TR.

Question two can be answered with mentioning that overall Group VR performed better in terms of system comprehension in this research experiment. On average, individual participants from Group VR recalled 0.9 correct item functionalities more compared to Group VR. However the factors behind that matter remain unclear.

Future research shall repeat the study with a larger sample size and more accurate statistical and quantitative measures since the statistical testis in this paper cannot be relied on fully, more research must be conducted. First of all it would be of interest to conduct research to understand why some items in this research were easier to recollect than others and how the difference in system part location in the environment and location of the item on the system part itself play a role in that.

Secondly, after conducting this research it remains unclear how awareness state and confidence level as cognitive support measure come into play when recollecting spatial memory. A more in depth measure of the relationship between confidence level and awareness state may help to understand the process of recall performance better. Thus, this research paper agrees with the suggestion of Dunn (2004), to make use of the two-criterion signal detection model to add address this ambiguity more theoretical. To improve the experiment conducted in this research, it would be of interest to introduce more intervention groups measuring spatial awareness and confidence level at different times e.g. after three days post training, after one week post training and/or after one month post training. Moreover, the concepts shall be better explained to the participants and recalled locations shall be clear and unified for each participant.

Moreover, it would be interesting to look at the relationship between spatial awareness, and system comprehension closer and find possible connections. That could be enriched by adding level 3 of Endsley's (1989) model to the research: projection of future status. That level refers to the ability to understand how the object will react in the environment after a defined action within the environment happens. Together with spatial awareness and object comprehension, projection of future state builds the complete concept up *situation awareness* which is according to Endsley (1989) an important influencing factor for decision making in the environment. Making decisions is also for training in the defence industry highly important therefore this research may be extended from looking at spatial awareness and object comprehension only, to measuring *situation awareness* as a whole.

The limitations of this research also refer to the convenience in sampling. A more narrow target audience might result in different research findings. Measures such as the usability and user experience of the Virtual Reality training or personal characteristics and demographics of the participants might be reported for better validity and reliability of the research.

Discussion

The following section takes a closer look at the findings from this research in relation to literature and the views of other scholars on the matter.

Firstly, the main finding of this report is that Virtual Reality does prepare people better for tasks in the actual environment that require spatial awareness. That confirms the research of Brosci et al. (2015), stressing the fact that visualisation and orientation are key learning outcomes in technical training which can be supported by means such as Virtual Reality. This research can confirm the effective usage of VR for visualisation of the environment and orientation. Moreover, in the theoretical framework of this report it was described that it remains subject to further research to identify what kind of learning goals are suitable for Virtual Reality training, especially in a technical context (Mantovani et al., 2003; Yuviler-Gavish, Yechiam & Kallai, 2011). This research can conclude the positive effect of Virtual Reality training for learning objectives where spatial awareness and system comprehension are of essential importance such as for training in the defence sector.

Moreover, many research participants of the Virtual Reality group explained that they tried to visualise the seen environment and "go over it in their heads". That finding might be explained by the fact that the human brain creates so called "schemas", which creates a mental model based on experience the human has lived through. That schema is used to remember certain elements from this framework (Minsky, 1975). Minsky's (1975) explanation is very similar to the concept of memory palaces which was taken up in this research. Memory palaces are mental model's of a certain environment in which the position of objects inside that environment is spatially mapped and cognitively remembered. The mental mapping helps the human brain to remember the objects and locations (Krokos et al., 2016). For example Slater (2009) mentioned that being "present" in the virtual environment might be the cognitive factor contributing to the effectiveness of memory palaces. According to Freina and Ott (2015), "presence" is described as the feeling of being somewhere real. Madl et al. (2015) mention that body movement and navigation provide a feeling of "presence". Virtual Reality provides "presence" to its users which in turn leads to better learning and experience (Freina & Ott, 2015). This research used a sort of memory palace in the form of a 3D immersive Virtual World mirroring the actual environment which was in this research, a radar system. Hence, the feeling of "being present" in the virtual environment used for this paper was given, stressing that an effective memory palace was created. The fact that the Virtual Reality group performed better in recalling spatial memory might steam from the effective usage of a memory palace, confirming Minsky's (1975) and Krokos et al. (2016) view on mental models for remembering, in combination with a virtual world that is high in "presence".

When looking at the ambiguous findings of awareness state and confidence level in this research, the RK (R for remember and K for know) paradigm might play a role in that. First defined by Tulving (1975), the paradigm is used to assess memory retrieval based on a self-rating subjective measures. However, the difference between remember and know has been subject to differing interpretations which was also the reason for Gardiner (1988) to further define the RK paradigm (Dunn, 2004). The difference in interpretation might be the reason for ambiguous findings in this research. No clear pattern of awareness state could be indicated in relationship to recall performance. Moreover, two opposing views of RK are presented in literature. Some scholars see awareness state as different level of confidence, indicated by remember and know (Inoue & Bellezza, 1998). On the other side, researchers such as Tulvig (1975) or Gardiner (2001) define the RK paradigm as “qualitative different memory components”, representing different forms of memory recall. This research confirms rather with the latter view due to the fact that awareness state and confidence level showed no direct and clear relationship with each other in this research. Another reason for the possible unclear relationship between awareness state and performance recall may be the degree of attentional processing. According to Mania et al (2010), when visual imagery is needed to understand a simulated environment, stronger attentional processing is triggered compared to fully realistic looking environments. The higher level of attentional processing possibly leads to a different perception of ‘remembering’ when cognitive knowledge is tried to obtain in the realistic environment (Mania et al., 2010). Under the scope of this research, several people from Group VR indicated that the environment looked almost the same but “cleaner” than the actual environment which may have led to a higher degree attentional processing and as a result of that, to a different perception of ‘remembering’.

Taking a look at learning comprehension in terms of system comprehension, it was presented in this research that Virtual Reality led to a better system comprehension recall. That fact might also be linked to the memory palace theory (Krokos et al., 2016). However, in this study many individual participants of the Virtual Reality training reported that they were too busy with trying to remember the item location that they had problems also listening to the explanations given about the items (system comprehension). One possible explanation for this fact might be found in the theory of cognitive load. Cognitive load theory explains that information should be arranged in a manner that learning is supported without ending up in an overload of cognitive information (Kirschner, 2002). According to Kirschner (2002), two memories can be distinguished, the working memory and the short term memory. The working memory is used by the brain to translate information into long term memory which is needed to sustainably learn something. However, the working memory can only process up to 7 information at the same time and only 2 to 3 of those information simultaneously (Kirschner, 2002). During the Virtual Reality training conducted in this study participants were asked to remember 10 different items plus functionalities in one training session which might have been too much information load at the same time. Individuals reported that they were busy with remembering the locations but also with understanding the usability of the Virtual World itself. That indicates high mental effort which according to Kirschner (2002) and Paas and Merriënboer (1993) can lead to cognitive overload hindering learning.

Moreover, the usability aspect together with user experience of Virtual Reality is interesting to research especially when VR is used to deliver learning contents.

In this research Virtual Reality performed better than traditional learning. However, this study took an explorative approach to investigate whether there is an actual difference. What this study is lacking is a more in depth explanatory side of the matter. Therefore, it is beneficial to engage in reasoning for the positive effect of Virtual Reality training on spatial awareness and also comprehension of objects. One possible explanation might be provided by the Generative Learning Theory. That theory describes that incoming information are processed by selecting, organising and eventually integrating them in the right way to obtain only the relevant information (Parong & Mayer, 2018). During the VR training in this research the information provided were good to select, organise mentally (due to the concept of a memory palace) and integrate verbal with visual information. Hence, the Virtual Reality training may have been outperforming the traditional training since it provided the possibility of generating knowledge by deducting only the most useful information from the learning experience, generating meaningful knowledge (Parong & Mayer, 2018). The VR environment used in this research only displayed the most relevant environmental parts/system parts but looked other than that, rather clean and non distractive. Several research participants mentioned that it looked much cleaner than the actual environment labelling that a disadvantage of the VR training, while in fact it might have been a strength of the training. According to Naftaly & Rothman (2008) incorporating eventful but irrelevant objects in the learning environment might hinder learning therefore it is best to only include the major components of the lesson, possibly also making selection, organisation and integration of information easier (Parong & Mayer, 2018). Thus, the "cleanness" of the VR training in this research may have demonstrated great conditions for generative learning without distractions eventually leading to better learning outcomes compared to traditional learning means.

This research can conclude that Virtual Reality is suitable for learning scenarios where spatial awareness plays a centric role however, it must be further discussed to what degree immersive Virtual Reality is applicable or even needed for learning. When looking at especially training in the defence sector, next to training on the system and in the space also conventional scientific learning contents must be delivered e.g. applied physics or mechanics. Several researchers including Parong and Mayer (2018) suggest that Virtual Reality is not recommended as a medium for this kind of learning contents since immersion is not needed to learn more effectively. Future research must work on identifying the most applicable contents that shall be trained by the means of Virtual Reality.

In research it is presented that VR does increase learning motivation since it is yet still new and exciting to the majority of its users keeping the attention of the user high. Moreover, VR as a technology must be accepted by the end user as technology in the first place, but also as learning medium (Shen, Jung-tsung, Pham Thi Minh & Ting-Chang, 2018). This research can confirm that participants have been highly curious and fascinated when it comes to VR. Throughout the whole test group, a good user experience and motivation was observed. Hence, VR can keep the focus and attention of people high. Yet, i remains unclear how VR will perform in the long-term as learning medium and what it will do to learners motivation. In this research each participant from Group VR had a remark about the learning mean showing that individuals are cognitively engaged with the technology itself while on the contrary, individuals that trained traditionally with a Power Point presentation and a computer programme accepted the learning medium without substantial remarks about it.

Additionally, Virtual Reality in the future will gain even more popularity in the educational sector. A study by Shen et al. (2018) has proven that the experience created by immersive Virtual Reality leads to increased usage intention by the students, when facilitated right. This research can confirm that most test participants had a positive attitude towards VR as learning medium and believed in its instructional power enabling also self-steered learning. Fur future research, it might be wise to investigate whether there also is a consistent correlation between learning experience, motivation and actual better learning outcomes. This study has contributed to the scholarly knowledge about VR that it is a suitable learning mean for learning contents that requirers spatial awareness, good orientation and understanding of ones surroundings. This paper also provides evidence for the fact that VR is accepted as learning medium and technology.

The usability of Virtual Reality used in this research was overall good. Also participants that were not exposed to VR before were able to move and position oneself in the environment, two essential factors in VR usability. Usability can be a major determinant for the user experience but also for the learning effect (Wang et al., 2017). This research used a VR system where users can “drag” themselves around the environment with the controller. It represents one possible way of movement within an immersive virtual space. Participants in this experiment noted that the provided way of moving feels natural and allows to explore the environment to its full extend. Therefore, this research can contribute to VR usability research that “dragging” via the controller is a suitable way to obtain spatial knowledge from a 3D immersive environment. Nevertheless, this paper agrees with Shen et al. (2018), much usability and interaction research is to be done to optimise the interaction with the virtual world while technology-learner interaction remains stimulated.

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Appendix

Appendix 1

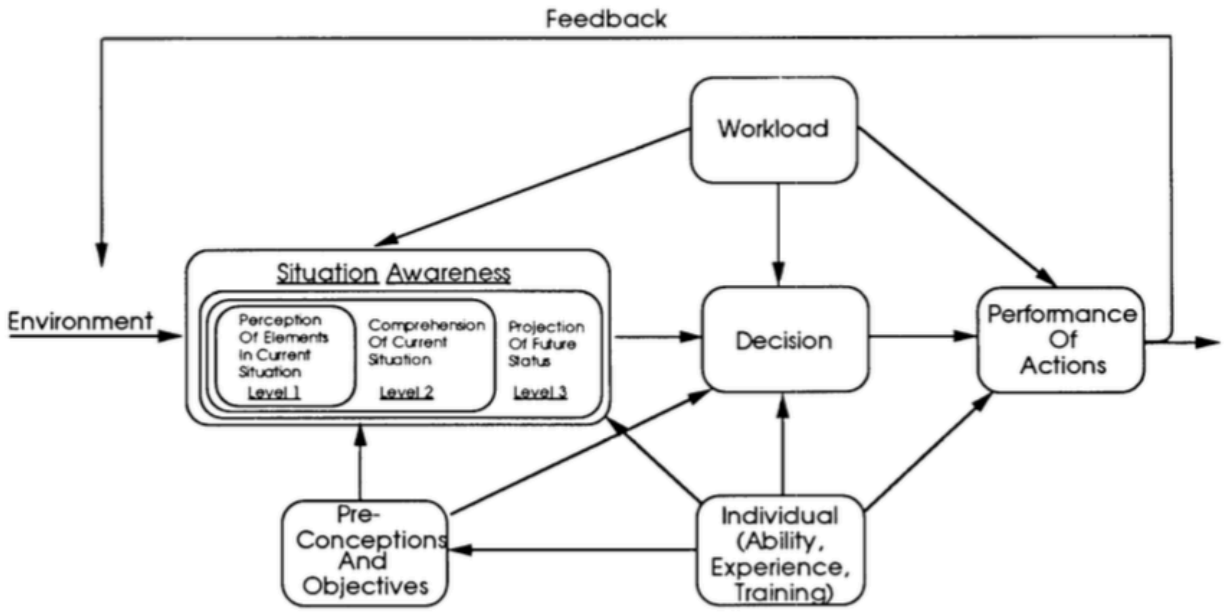
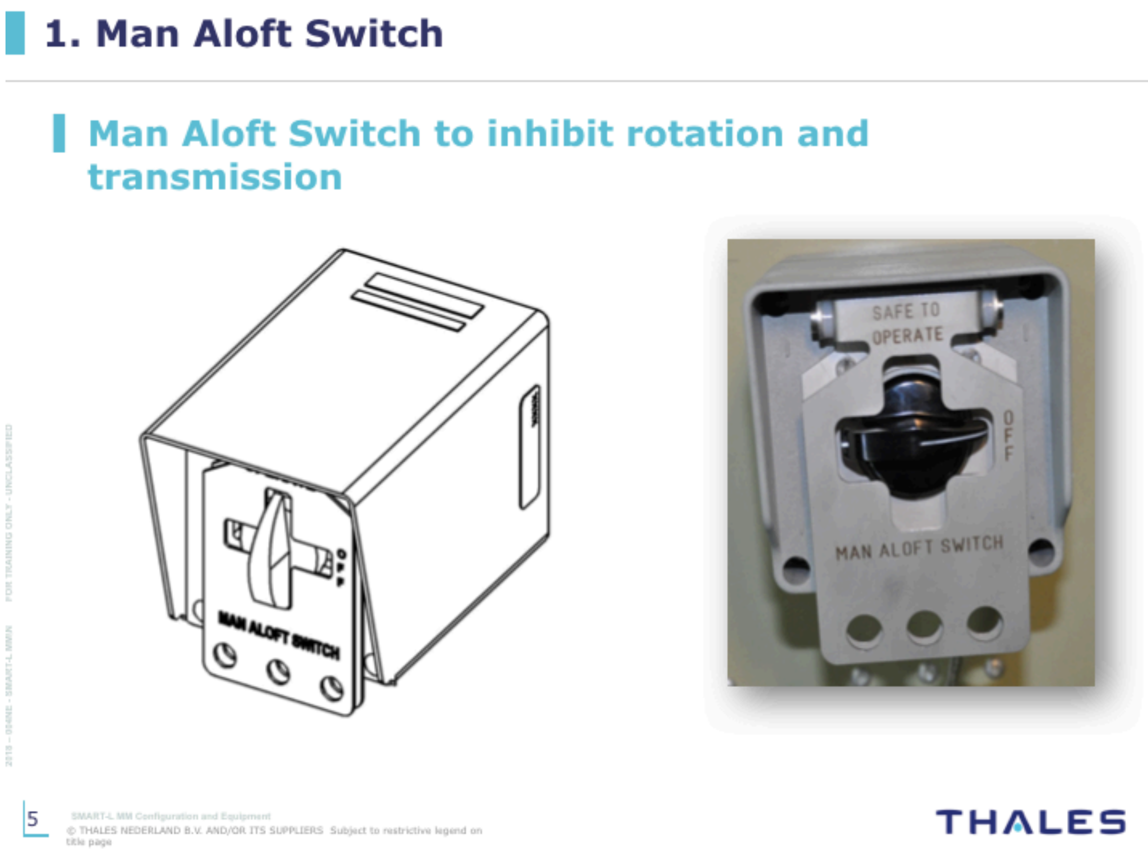


Figure 1. *Situation awareness in relation to decision making within environment derived from Endsley (1989)*

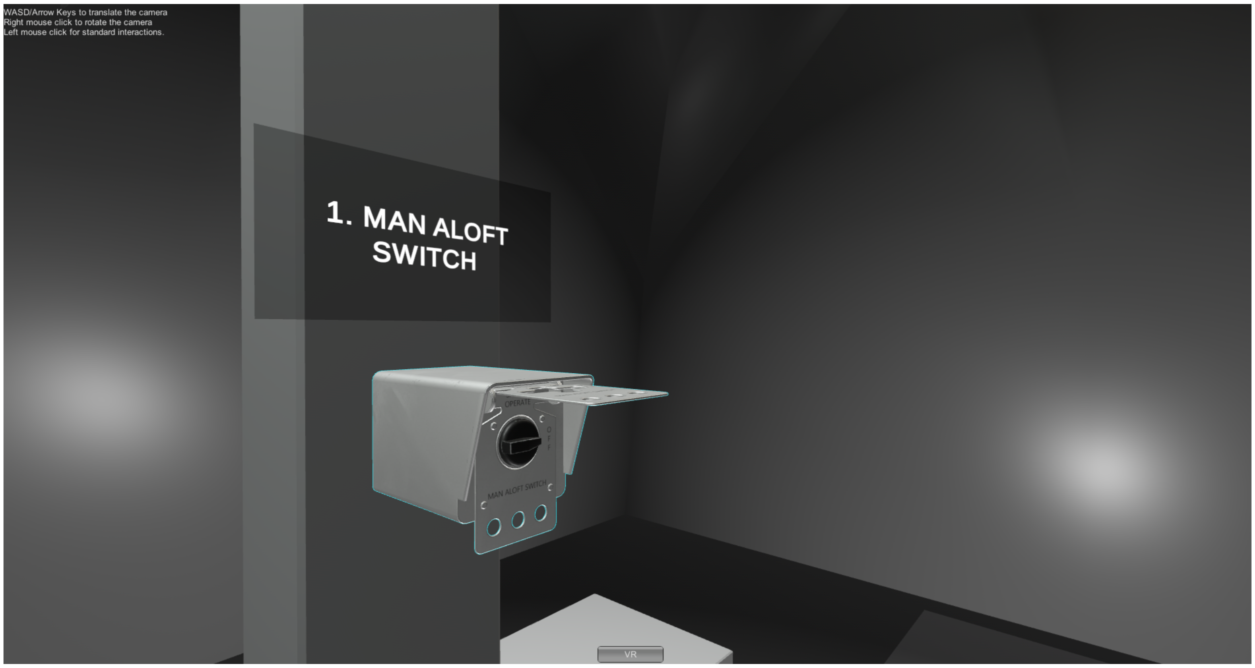
Appendix 2

Picture 1. *Example Item Hardware Navigator*

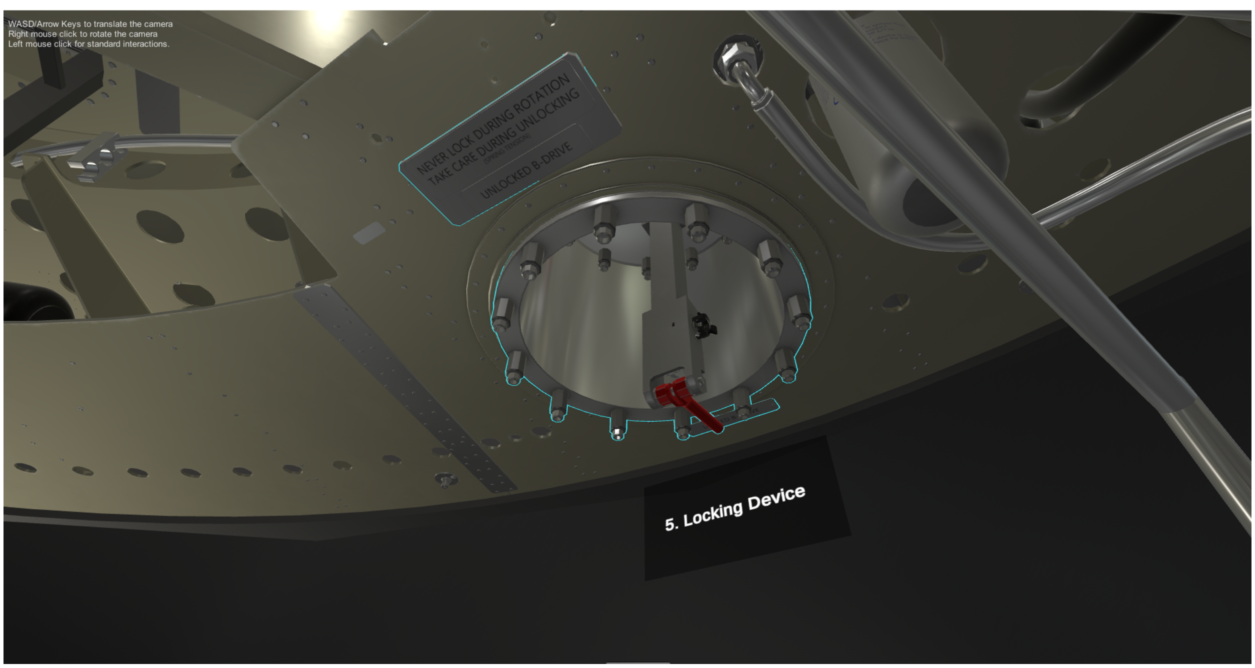


Picture 2. *Example Power Point presentation slide traditional training*

Appendix 3



Picture 3. *Example item from Virtual Reality training*



Picture 4. *Example item from Virtual Reality training*

Appendix 4

Observation Form – Thesis Meike Belter

Name Participant: **Group:** **Date:**

Item 1: TRXL 6 Number 6 of TRX-L Number 13

Initial Orientation/Navigation

Item location recalled: Yes - No - Partially

Awareness State (of spatial recollection)

Remember	Know	Familiar	Guess

Confidence Scale

No Confidence	Low Confidence	Moderate	Confidence	Certain

Picture 5. *Example of observation and interview sheet*

Appendix 5

Upon request available. Please contact:

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Appendix 6

	Item 1 awareness state and confidence level					
Group TR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	25 %	50 %	25 %	0.0 %	100 %
Familiar	25 %	25 %	50 %	0.0 %	0.0 %	100 %
Know	0.0 %	50 %	0.0 %	50 %	0.0 %	100 %
Remember	0.0 %	0.0 %	50 %	25 %	25 %	100 %
Group VR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Familiar	0.0 %	0.0 %	100 %	0.0 %	0.0 %	100 %
Know	0.0 %	20 %	40 %	20 %	20 %	100 %
Remember	0.0 %	0.0 %	18.2 %	54.5 %	27.3 %	100 %
	Item 2 awareness state and confidence level					
Group TR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	16.7 %	0.0 %	33.3 %	16.7 %	33.3 %	100 %
Familiar	0.0 %	50 %	50 %	0.0 %	0.0 %	100 %
Know	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Remember	14.3 %	0.0 %	14.3 %	0.0 %	71.4 %	100 %
Group VR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	100 %	0.0 %	0.0 %	0.0 %	100 %
Familiar	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Know	0.0 %	0.0 %	0.0 %	0.0 %	100 %	100 %
Remember	0.0 %	0.0 %	12.5 %	0.0 %	87.5 %	100 %

	Item 3 awareness state and confidence level					
Group TR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	50 %	50 %	0.0 %	0.0 %	50 %	100 %
Familiar	0.0 %	0.0 %	50 %	0.0 %	50 %	100 %
Know	0.0 %	0.0 %	0.0 %	0.0 %	100 %	100 %
Remember	0.0 %	0.0 %	14.3 %	42.9 %	42.9 %	100 %
Group VR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	100 %	0.0 %	0.0 %	0.0 %	100 %
Familiar	0.0 %	0.0 %	0.0 %	50 %	50 %	100 %
Know	0.0 %	0.0 %	0.0 %	0.0 %	100 %	100 %
Remember	0.0 %	0.0 %	0.0 %	14.3 %	85.7 %	100 %
	Item 4 awareness state and confidence level					
Group TR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	33.3 %	66.7 %	0.0 %	0.0 %	100 %
Familiar	0.0 %	33.3 %	33.3 %	33.3 %	0.0 %	100 %
Know	0.0 %	0.0 %	0.0 %	0.0 %	100 %	100 %
Remember	0.0 %	0.0 %	20 %	40 %	40 %	100 %
Group VR	*No confidence*	*Low confidence*	*Moderate confidence*	*Confidence*	*Certain*	**Total**
Guess	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Familiar	0.0 %	0.0 %	0.0 %	0.0 %	100 %	100 %
Know	0.0 %	0.0 %	50 %	12.5 %	37.5 %	100 %
Remember	0.0 %	0.0 %	14.3 %	28.6 %	57.1 %	100 %

Table 1. *Appendix, Confidence level and Awareness state*

Appendix 7

Item comprehension and confidence level

Each item might differ in number of analysed cases due to the fact that some people were not able to recall any item functionality and therefore the question about the confidence level concerning the item became not valid. Due to that fact all tables are also expressed in percentage and show the confidence level per ‘item functionality recalled’ category (Yes, No or Partially recalled) demonstrating all participants per category as 100%.

	Item 1 functionality and confidence level		
Group TR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	10 %
Moderate confidence	100 %	0.0 %	30 %
Confidence	0.0 %	100 %	20 %
Certain	0.0 %	0.0 %	40 %
Total	100 %	100 %	100 %
Group VR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	16.7 %	0.0 %	50 %
Moderate confidence	8.3 %	0.0 %	0.0 %
Confidence	41.7 %	0.0 %	0.0 %

Certain	33.3 %	0.0 %	50 %
Total	100 %	0.0 %	100 %

Table 18*. *Item one comprehension and confidence level*

	Item 2 functionality and confidence level		
Group TR	*Yes*	*No*	*Partially*
No confidence	0.0 %	50 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	100 %	0.0 %	55.6 %
Confidence	0.0 %	0.0 %	22.2 %
Certain	0.0 %	50 %	22.2 %
Total	100 %	100 %	100 %
Group VR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	0.0 %	0.0 %	27.3 %
Confidence	25 %	0.0 %	27.3 %
Certain	75 %	100 %	45.5 %
Total	100 %	100 %	100 %

Table 19*. *Item two comprehension and confidence level*

	Item 3 functionality and confidence level		
Group TR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	0.0 %	0.0 %	20 %
Confidence	0.0 %	0.0 %	10 %
Certain	100 %	100 %	70 %
Total	100 %	100 %	100 %
Group VR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	0.0 %	0.0 %	25 %
Confidence	8.3 %	0.0 %	0.0 %
Certain	91.7 %	0.0 %	75 %
Total	100 %	0.0 %	100 %

Table 20*. *Item three comprehension and confidence level*

	Item 4 functionality and confidence level		
Group TR	*Yes*	*No*	*Partially*
No confidence	0.0 %	12.5 %	0.0 %

Low confidence	0.0 %	12.5 %	0.0 %
Moderate confidence	0.0 %	50 %	50 %
Confidence	0.0 %	0.0 %	50 %
Certain	0.0 %	25 %	0.0 %
Total	0.0 %	100 %	100 %
Group VR	*Yes*	*No*	*Partially*
No confidence	0.0 %	0.0 %	0.0 %
Low confidence	0.0 %	0.0 %	0.0 %
Moderate confidence	0.0 %	75 %	14.3 %
Confidence	0.0 %	0.0 %	42.9 %
Certain	100 %	25 %	42.9 %
Total	100 %	0.0 %	100 %

Table 21*. *Item four comprehension and confidence level*

** from result section*