SKILL DECAY OF WIND TURBINE TECHNICIANS IN THE USE OF RESCUE AND EVACUATION DEVICE DURING EMERGENCY

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Abstract

The management of wind farms consists of the operation, maintenance and administration of wind farms either onshore or offshore. Therefore, management must take into account the competency of the technicians since they are the initial responders in times of emergency rescue and evacuation. The aim of this paper is to explore and establish the occupational health and safety challenges in the wind energy industry in relation to wind technicians' skill decay in the use of a rescue and evacuation device during an emergency. The study evaluated the effectiveness of the retention interval set by the training standards, the impacts of training on refresher and fresher trainees and their rates of 'forgetting' over a three-month period. Thirty trainees participated in the study with assessments at one and three-month intervals. While the performance level of all the participants improved during acquisition, there was observed decline in the performance level of the refresher and fresher trainees over a period of 28 and 90 days. In accessing the relative costs and benefits of sustaining procedural skills, it is considered that extra training will enhance retention regardless of whether it is during initial training or conducted as a refresher course afterwards. It is recommended that fresher trainees receive earlier refresher training to improve their proficiency. Although this project is on-going, these initial findings seem to be in conformity with previous skill decay research.

Keywords: acquisition, emergency rescue, retention, skill decay, wind technicians.

1. Introduction

The management of wind farms consists of the operation, maintenance and administration of wind farms either onshore or offshore. Within the last few years, the development and ownership of wind farms has experienced a global trend towards public utilities and independent power producers (IPP). Factors which have contributed to growth in the wind energy sector include financial confidence, innovation in technology, public and self-awareness, and legislative support from the local governments, (EU-OSHA, 2013). Planned and efficient wind farm management strategies can maximise both energy generation and operational performance and financial output of wind farms. With the growth of the wind energy, new dimensions of challenges will begin to emerge. As the number of technicians employed in the industry continues to increase, issues of occupational health and safety will become an integral part of the work life cycle. The introduction of new innovations in the industry in terms of working processes will also trigger new hazards which will require a combination of appropriate skills to deal with them, (EU-OSHA, 2013). The management of wind farms must therefore take into account the competency of those working on the structures as applicable to other industry.

There is a regulatory requirement that operational wind farm have a secured and effective emergency response to incidents/accidents affecting persons on an onshore/offshore wind farm installation or engaged in activities in connection with it, and which have the potential to require evacuation, escape and rescue, e.g., Management of Health and Safety at Work Regulations 1999, (Reg. 8); Maritime and Coastguard Agency (MGN 371)- Offshore

Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues – Annex 5; MCA – Offshore Renewable Energy Installations, Emergency Response Co-operation (ERCoP) for Construction and Operations Phase, and Requirements for Emergency Response and SAR Helicopter Operations; Search and Rescue (SAR) Framework Document for the United Kingdom of Great Britain and Northern Ireland; (Health and Safety Executive, 1997) etc. Currently, there is no strategic amalgamation of emergency response units within the wind industry. Therefore, the initial response in times of emergency rescue and evacuation will have to come from the technicians themselves. Such skills make up part of the basic training the technicians receive.

The GWO, (Global Wind Organisation Standard, 2013) has been involved in developing a common training standard for the wind energy sector. These has resulted in the development of a standard for basic safety training which covers areas such as first aid, manual handling, working at heights, fire awareness and offshore sea survival[1]. Within the UK, (RenewableUK, 2014), in consultation with members and key industry stakeholders, have developed industry training standards, such as working at height and rescue and marine safety training at national level in order to enhance the basic skills and knowledge of anyone working in the wind energy sector. These training standards by RUK have otherwise been formulated to make it compatible with that of GWO standards[2].

The aim of this paper is to explore and establish the occupational health and safety challenges in the wind energy industry in relation to wind technicians' skill decay in the use of a rescue and evacuation device during an emergency situation.

The hypothesis of the research reported in this paper is that after the initial training/acquisition received by wind technicians and due to the infrequent nature of practically carrying out on-the-job rescue and evacuation roles, there is a likelihood of skill and knowledge decay in times of significant emergencies except where there is a support system available to the technicians. One of the objectives of the research is to investigate and quantitatively demonstrate if wind turbine technicians are capable of retaining knowledge and skills learned within a 24 months period, being the current validity period before they undergo any retraining/refresher sessions and if cued recognition/recall test can impact on their rate of retention.

The significance of a wind farm technician to be trained, competent and respond to initial onshore/offshore rescue emergency situations cannot be overemphasised. Wind technicians are exposed to hazards and risks and as such it is expected that they be trained in safety and emergency procedures above these basic competency level which is set out by the regulating bodies. The basic competency level encompasses Health & Safety training for any employee undertaking a defined role or task on any wind project, and covers all life cycle phases, (RenewableUK, 2014). The scope and application primarily take into account the specific risks that the individual is exposed to in addition to any company or project requirements. The main legislation relevant to Health & Safety training covered by these guidelines includes but not limited to the following: Health & Safety at Work etc. Act 1974, Confined Spaces Regulations 1997, Construction (Design and Management) Regulations 2007, Electricity at Work Regulations 1989, Regulatory Reform (Fire Safety) Order 2005, Health & Safety (First Aid) Regulations 1981 (as amended), Lifting Operations and Lifting Equipment

[1] http://www.ewea.org/policy-issues/health-and-safety/gwo-standards/
[2] http://www.renewableuk.com/en/our-work/health-and-safety/training/index.cfm.

Regulations 1998 (LOLER), Management of Health & Safety at Work Regulations 1999, Manual Handling Operations Regulations 1992 (as amended), Work at Height Regulations 2005, Provision and Use of Work Equipment Regulations 1998 and Control of Substances Hazardous to Health Regulations 2002. It is therefore the legal requirement of employers to ensure that suitable information, instruction and training is provided to employees and others who may be exposed to risk, (RenewableUK, 2014). The Management of Health & Safety at Work Regulations 1999 clarify an employer's responsibility for ensuring employees are provided with adequate health & safety training and are deemed competent to perform the work they are required to carry out. In any situation whereby employees are exposed to new or increased risks, training must be recurrent periodically to take account of any new or changed risks to the health & safety of the employees concerned. Much of Britain's health and safety law originated in Europe and proposals from the European Commission may be agreed by member states that are responsible for making them as part of their domestic law, (Health and Safety Executive, 2003). To fulfil the requirements of the legislation, suitable and sufficient risk assessments and training-needs analysis (TNA) should be conducted and this involves the employer assessing training needs, prioritising training, delivering the training effectively and reviewing and assessing the effectiveness of such training.

There are no mandatory training schemes or standards that specifically apply to large wind projects in the UK, (RenewableUK, 2014). However, standards and schemes that have been developed and supported through industry consensus (e.g. RenewableUK standards) are likely to be regarded as a 'benchmark of good practice'[3]. Within the wind industry, benchmark standards have been developed by the industry to address significant risks specific or particular to the wind sector and these are supported by suitable third party accreditation systems like RenewableUK Training Standards and Global Wind Organisation – Basic Safety Training. There are some fundamental principles of occupational safety and health which are adopted by the ILO such as the Occupational Safety and Health Convention, 1981(No. 155) and its Protocol of 2002 which identifies the need for the adoption of a coherent national occupational health and safety policy, the Safety and Health in Construction Convention, 1988 (No. 167) which provides for detailed technical preventive and protective measures which are requirements related to safety of workplaces, machines and equipment used and work at height[4].

Therefore, this research explores the "skill decay" of wind turbine technicians in procedural use of a standard rescue and evacuation device, (type RG9A). A wind turbine safety, rescue and evacuation training program is a critical component of efforts to improve the reliability of technicians because skill decay in this area can lead to underperformance in times of rescue and increased likelihood of further accidents. Though past research has highlighted the significance of refresher training, there has been some debate concerning the appropriate content and frequency of such training, (Teachout, et al., 1993).

The concept of skill theory focuses primarily on cognition and intelligence as it deals with aspects of learning and problem solving. According to (Fischer, 1980), this concept deals with several key issues: the relation between organism and environment in cognitive development and the issues of sequence and synchrony. Fischer (1980) also stated that skills develop step by step through a series of 10 hierarchical levels divided into three tiers. These

[3] http://www.hse.gov.uk/risk/theory/alarp2.htm
[4] http://ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm

tiers specify skills of vastly different types: sensory-motor skills, representational skills, and abstract skills. Skill theory, therefore, provides a mechanism for predicting and explaining the development of skills in specific task domains, and it also gives a general portrait of how populations of skills change with development. This skill theory concept may be applicable to areas as diverse as language development, social development, and learning. According to (Watson & Fischer, 1977), skill theory should be able to predict the development of memory skills, and it has already been used as a tool for uncovering some new memory phenomena, such as a relation between recall success and skill level.

Skill is different from competence, ability, or capacity, skill is a concept that is context-based and task-specific, (Fischer & Yan, 2002). It is a unit of behaviour composed of one or more sets. Behavioural research has shown repeatedly that task factors have potent effects on most kinds of behaviour in people. The Health and Safety Executive (1999) guide highlights that people can cause or contribute to accidents or mitigate the consequences in a number of ways. Through a failure a person can directly cause an accident but however, people tend not to make errors deliberately. Such failures do occur by the way our brain processes information, by our training, through the design of equipment and procedures and even through the culture of the organisation we work for. With regards to organisation, the concept of organisational accident and the Swiss cheese model (Reason, 1990) is an accepted theory which influences safety science thinking. Designing tasks, equipment and workstations to suit the user can reduce human error, accidents and ill health and failure to observe ergonomic principles can have serious consequences for individuals and for the whole organisation.

Skill decay is the progressive deterioration of knowledge when they are not put into use over extended periods of time. As more time elapses, there comes more decay (Arthur Jr., et al., 1998, Arthur, et al., 2007). According to Tarr (1986) in (Kim, et al., 2007), surveys have shown that personnel in technical jobs perform mostly procedural tasks. Procedural tasks are those that involve a number of coherent steps that may include any combination of cognitive and motor skills. Konoske & Ellis (1991) noted that many procedural tasks can be viewed as an ordered sequence of steps or operations which are performed on a single object or in a specific situation to accomplish a goal. Reports by (Hurlock & Montague, 1982) showed better retention of continuous tasks. They stated that tasks with a meaningful organisation or coherence of steps tend to be remembered better. A well-organised task may include cues for the next step, allowing for recognition of the next step. Shields et al, (1979) found that soldiers tended to forget the steps in a procedure that were not cued by the previous step, for example, forgetting safety steps not intrinsic to the process.

Consequently, the objective in relation to emergency rescue was to study skill decay (retention) using cued recognition and recall processes and observe the skill decay path and impacts on the research participants. Retention, which is the outcome of successful learning, seems to be a straightforward concept, one that is typically measured by having the learner recognize, recall, repeat or reproduce what they have acquired. Retention of a subject matter can be assessed both directly and indirectly, by employing recognition tests and priming paradigms respectively, (Schacter 1992, Fischer & Yan 2002). Though complex procedural tasks have been found in general to be more fragile, the importance of intrinsic cues, in overcoming this problem, is illustrated by (Shields, et al., 1979). Healy et al, (1998) also reviewed studies that found both good and bad retention of procedural skills by putting forward the proposal of procedural reinstatement. Procedural reinstatement (Healy, et al., 1998), contributes to the recall of complex tasks.

The tests for retention typically involve using the recall test or recognition test. Previous literature highlight that recall and recognition tests are in various cases autonomous processes such that an individual's ability to recognise an event has no relationship to their ability to recall it (Flexer & Tulving, 1978). Different retention measures can yield different degrees of superficial retention, with recall tests usually of lower scores than the recognition tests (Farr, 1986). The aim of the research therefore was to design this study by blending cued recognition/recall techniques and pictographic displays as the tool of assessment and monitor the rate of skill decay within an interval of one and three-month after skill acquisition, (Hancock 2006, Meador & Hill 2011).

2. Research Questions

The following research questions will be addressed in this paper.

1. Is a 24 month retention interval too long?
2. What is the magnitude of procedural skill and knowledge decay over a three-month non-practice period and its safety implications?
3. Does forgetting over the three-month period occur at different rates for refresher[5] and fresher[6] participants?

Valid and reliable performance data will be needed to answer these questions.

3. Method

3.1. Participants

The research participants were those registered to undergo the basic RUK/GWO approved height safety and rescue training course- either refreshers or those attending for the first time (fresher). To achieve this representation, voluntary consent of the wind technicians was the standardised method of selection of those who agreed to participate. The study recruited 82 wind technicians/engineers in total over a three month period of data collection process, 27 participants in phase-1 from *22-26 July, 2013*; 26 participants in phase-2 from *9-13 September 2013*; and 29 participants in phase-3 from *30 September – 4 October 2013*. The research participants with varying years of on-the-job experience were representative of the wider population which the study may wish to extrapolate.

3.2. Materials

The research implemented a longitudinal design approach for data gathering in order to track changes over time and establish the sequence in which events took place. Questionnaires were designed based on job knowledge inventory test (JKT) (Teachout, et al., 1993). This was used for the entire knowledge appraisal, from pre-acquisition to retention measurements. Hands-on practical scenarios were used during the pre-acquisition and acquisition stages for the skill assessment using the automatic constant rate descender (CRD) RG9A, (see Figure 1). Skill retention assessment was conducted online using situational judgment test (SJT) (Lievens, et al., 2008), with cued recognition/recall and pictographic displays.

The rescue device (type RG9A) is designed for emergency situations where rapid evacuation is required, (see Fig. 1). It can also be used for self-rescue or for the rescue of others. CRD's can be used for single or repeat descents for 1 or 2 person loads. The mechanism can work in either direction, allowing each subsequent evacuee to use the alternate end of the rope during consecutive descents. The device is fitted with a handle which can be used to raise casualties a short distance. The handle parks away into the device hub for descent operation; this is

[5] Those returning for training
[6] First time learners

safety critical to avoid injury to the rescuer as the handle can freely spin when the device brake is not applied.

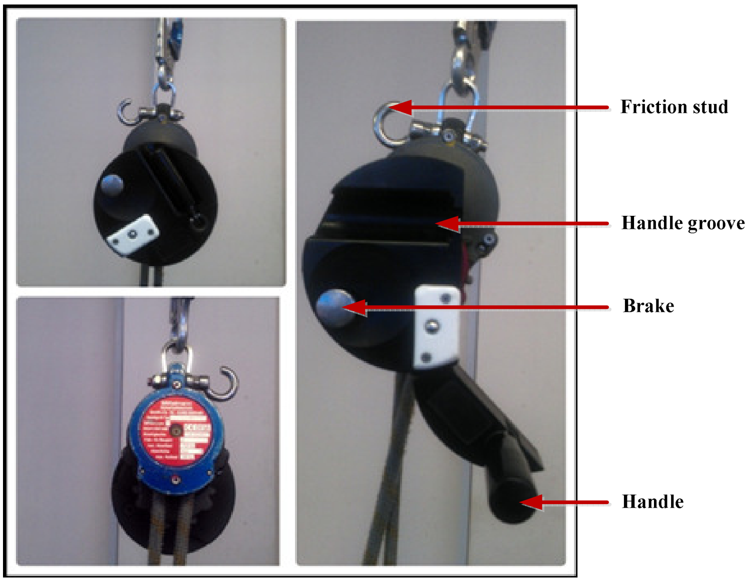


Figure 1: Automatic constant rate descender (CRD) RG9A

3.3. Design

One of the most commonly used and well known method for assessing the effectiveness of, or need for training is a job knowledge inventory test (JKT), (Lievens et al., 2008, Paulin et al., 2002). JKT is straightforward to develop and administer. They require individuals to answer multiple-choice questions related to on-the-job knowledge, skills, and abilities. JKT is very useful in the measurement of fundamental knowledge of technical information, (Teachout, et al., 1993) such as those used in the height safety, rescue and evacuation training course. Good JKT serves as a platform for providing an assessment of the degree to which the trainees possess the factual knowledge covered in a training course required to perform a task. They are useful as a job and training performance predictors and can also be used as criterion measures.

For initial skill assessments, hands-on practical scenario was used during the pre-acquisition and acquisition stages. The trainees were required to procedurally use RG9A device to perform hands-on rescue and evacuation of a casualty by taking turns alternately. This was a full task training where trainees were instructed to focus on the whole process of rescue and not parts of the task. The training/acquisition also involved group facilitation which was an important motivational factor in group and team-based training protocols and conditions as observed by (Bandura, 1986). The skill retention assessment was presented online as written description of realistic job situations using cued recognition and recall with pictographic displays. Situational judgment tests (SJTs) are a type of psychological test which present the participants with realistic, hypothetical scenarios and ask the individual to identify the most appropriate response or to rank the responses in the order they feel is most effective and operational, (Lievens, et al., 2008). All the research participants were required to evaluate the randomized written performance description and the associated picture by rearranging the correct sequence of procedurally executing the use of RG9A for rescue and evacuation. Situational judgment tests tend to determine behavioural tendencies, assessing how an individual will behave in a certain situation, and knowledge instruction, which evaluates the effectiveness of possible responses (Muchinsky, 2012). In contrast to most psychological tests, the SJT was designed as an assessment tool adapted to appropriately suit the individual role requirements of the wind technicians after the rescue and evacuation training.

3.4. Procedure

The assessment for wind technicians involved procedure-based and system-based training where each group received averagely 6-8 hours of intensive training over two sessions. The Day-1 session involved mostly theoretical explanation (procedure-based) of all the methods that make up the training requirements e.g. elements of a safe system of work, equipment selection and inspection, use of tools, risk assessment, method statements and emergency procedures. The Day-2 session covered practical application (system-based) of all the procedures with emphasis on emergency rescue, how to approach rescue situations in wind turbine generators (WTG) and use rescue equipment efficiently. All participants were trained in exactly the same way, with an average of four trainees to an approved trainer. With consent from the training providers, the knowledge pre-acquisition test was administered before the training session and the acquisition test after Day-1 training in collaboration with the training instructors. The second wave of knowledge acquisition test was administered at the end of Day-2 training. Retention measures using job knowledge inventory test (JKT) was conducted online at retention intervals of one and three-month bringing the sum total of assessment times to five sessions.

The pre-acquisition skill assessment was conducted using hands-on practical scenario based on performance in the use of RG9A for rescue/evacuation (refresher participants only). Data for skill acquisition was collected for all participants (refresher and fresher) after Day-2 training session. The acquisition assessment for skill was conducted after the participants had undergone training and attained some level of proficiency in the use of the rescue/evacuation device. This involved stepwise procedural performance of a rescue and evacuation process (lifting and lowering casualty) using the approved rescue device. Subsequently, follow-up of skill retention using situational judgement tests (SJT) was conducted online using cued recognition and recall with pictographic displays instigating the participants to correctly work out the step-by-step sequence/procedures of using the RG9A rescue device. The use of cued recognition and recall assessment with the aid of pictographic display better afforded the participants the opportunity to make use of their cognitive resources. Kanfer & Ackerman (1989) suggested that individuals have limited cognitive resources that are very important during initial skill acquisition.

4. Preliminary Results

4.1. Sample Characteristics

The preliminary analysis is based on a total of 30 participants that responded all through the three-month assessment (12 refresher and 18 fresher participants). This averages at 36.6% out of a total of 82 initial research participants. For most studies involving performance data expressed in error terms and that are positively or negatively skewed, such performance data undergo a square-root or log-transformation to reduce the skewness of the distribution. For these initial results, data presented have not been transformed.

4.2. Test of Normality

Interpretation of the test of normality using Shapiro-Wilk statistics was used to assess the normality of the distribution scores, (Shapiro & Wilk 1965, Razali & Wah 2011). The null hypothesis for this test of normality is that data are normally distributed. The null hypothesis is rejected if the p-value (sig) is below 0.05 of the distribution, which is statistically significantly different and not normally distributed. However, if the p-values (sig) are above

0.05, the null hypothesis is kept. The Kolmogorov-Smirnov test and the Shapiro-Wilk test most often give different p-values but the Shapiro-Wilk test is considered a more reliable alternative in the test of normality. The interpretation of skewness and kurtosis measures should be as close to zero as possible. The skewness and kurtosis z-values should be somewhere in the span of -1.96 to +1.96, however, data are often skewed and kurtotic. A small departure from zero is not much of a problem as long as the measures are not too large compared to their standard errors (SE), (Doane & Seward 2011, Cramer & Howitt 2004).

Table 1: Test of Normality (Refresher Skill)

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	**Statistic**	**df**	**Sig.**
Skill Test score T_0 pre-acquisition @ day 1	.172	19	.142	**.888**	**19**	**.029**
Skill Test score T_1 acquisition @ day 2	.189	19	.073	**.886**	**19**	**.027**
Skill Test score T_2 retention @ 1 month	.216	17	.035	**.886**	**17**	**.040**
Skill Test score T_3 retention @ 3 months	.199	12	.200*	**.903**	**12**	**.174**

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The normality of the skill test (refresher) scores for the data (see Table 1), and visual inspection of the histograms and normal Q-Q plots show that the sig-values for T_0 (.029), T_1 (.027) and T_2 (.040) are below the p-value 0.05 of the distribution. Therefore, they are statistically significantly different and not normally distributed and the null hypothesis of a normal distribution is rejected. The sig-value for T_3 (.174) is above the p-value 0.05, thus the null hypothesis is kept, indicating an approximately normally distributed data. The skewness and kurtosis values and measure of standard errors (SE) for the refresher participants are shown in the descriptive statistics as - skewness: T_0 = 0.675, SE = 0.524; T_1 = -0.738, SE = 0.524; T_2 = -0.320, SE = 0.550 and T_3=-0.209, SE = 0.637. The kurtosis values are: T_0 = 0.037, SE = 1.014; T_1 = 0.264, SE = 1.014; T_2 = -1.160, SE = 1.063 and T_3=-1.427, SE = 1.232.

Table 2: Tests of Normality[a] (Fresher Skill)

	Kolmogorov-Smirnov[b]			**Shapiro-Wilk**		
	Statistic	df	Sig.	**Statistic**	**df**	**Sig.**
Skill Test score T_1 acquisition @ day 2	.236	22	.003	**.900**	**22**	**.029**
Skill Test score T_2 retention @ 1 month	.139	19	.200*	**.937**	**19**	**.234**
Skill Test score T_3 retention @ 3 months	.259	18	.002	**.853**	**18**	**.009**

*. This is a lower bound of the true significance.
a. Skill Test score T_0 pre-acquisition @ day 1 is constant. It has been omitted.
b. Lilliefors Significance Correction

Assessing the normality of the skill test (fresher) scores for the data (see Table 2), and a visual inspection of the histograms and normal Q-Q plots show that the sig-values for T_1 (.029), T_3 (.009) both fall below the p-value 0.05 of the distribution. Therefore, they are statistically significantly different and not normally distributed and the null hypothesis of a normal distribution is rejected. The sig-value for T_2 (.234) is above the p-value 0.05, thus the null hypothesis is kept, indicating an approximately normally distributed data. The skewness and kurtosis values and measure of standard errors (SE) for the fresher participants (skill) are shown in the descriptive statistics as - skewness: T_1 = 0.816, SE = 0.491; T_2 = 0.048, SE = 0.524 and T_3= 0.072, SE = 0.536. The kurtosis values are: T_1 = 0.394, SE = 0.953; T_2 = -0.623, SE = 1.014 and T_3=-1.693, SE = 1.038.

Table 3: Tests of Normality (Refresher Knowledge)

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	**Statistic**	**df**	**Sig.**
Knowledge Test score T_0 pre-acquisition @ day 1	.189	19	.072	**.924**	**19**	**.134**
Knowledge Test score T_1 acquisition @ day 1	.270	19	.001	**.748**	**19**	**.000**
Knowledge Test score T_2 acquisition @ day 2	.257	19	.002	**.830**	**19**	**.003**
Knowledge Test score T_3 retention @ 1 month	.237	17	.012	**.923**	**17**	**.167**
Knowledge Test score T_4 retention @ 3 months	.256	12	.029	**.910**	**12**	**.214**

a. Lilliefors Significance Correction

The assessment of the normality of knowledge test (refresher) scores for the data (see Table 3), and a visual inspection of the histograms and normal Q-Q plots show that the sig-values for T_1 (.000) and T_2 (.003) fall below the p-value 0.05 of the distribution. Therefore, they are statistically significantly different and not normally distributed and the null hypothesis of a normal distribution is rejected. The sig-value for T_0 (.134), T_3 (.167) and T_4 (.214) are all above the p-value 0.05, thus the null hypothesis is kept, indicating an approximately normally distributed data. The skewness and kurtosis values and measure of standard errors (SE) for the refresher participants are shown in the descriptive statistics as - skewness: T_0 = -1.018, SE = 0.524; T_1 = -2.110, SE = 0.524; T_2 = -0. 522, SE = 0.524; T_3=-0. 753, SE = 0. 550 and T_4 = 0. .337, SE =0.637. The kurtosis values are: T_0 = 1.782, SE = 1.014; T_1 = 4.943, SE = 1.014; T_2 = -0. 918, SE = 1.014; T_3= 1.828, SE = 1.063 and T_4 = -0.731, SE =1.232.

Table 4: Tests of Normality (Fresher Knowledge)

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	**Statistic**	**df**	**Sig.**
Knowledge Test score T_0 pre-acquisition @ day 1	.132	22	.200*	**.953**	**22**	**.367**
Knowledge Test score T_1 acquisition @ day 1	.174	22	.083	**.872**	**22**	**.008**
Knowledge Test score T_2 acquisition @ day 2	.437	22	.000	**.603**	**22**	**.000**
Knowledge Test score T_3 retention @ 1 month	.197	19	.050	**.927**	**19**	**.152**
Knowledge Test score T_4 retention @ 3 months	.230	18	.013	**.870**	**18**	**.018**

a. Lilliefors Significance Correction

Assessing the normality of the knowledge test (fresher) scores for the data (see Table 4), and a visual inspection of the histograms and normal Q-Q plots show that the sig-values for T_1 (.008), T_2 (.000) and T_4 (.018) are below the 0.05 of the distribution. Therefore, these three values are statistically significantly different and not normally distributed and the null hypothesis of a normal distribution is rejected. The sig-value for T_0 (.367) and T_3 (.152) are above the p-value 0.05, thus the null hypothesis is kept, indicating an approximately normally distributed data. The skewness and kurtosis values and measure of standard errors (SE) for the refresher participants are shown in the descriptive statistics as - skewness: T_0 = 0.009, SE = 0.491; T_1 = -1.509, SE = 0.491; T_2 = -1.660, SE = 0.491; T_3= -0.383, SE = 0.524 and T_4 = -0.166, SE = 0.536. The kurtosis values are: T_0 = -0.481, SE = 0.953; T_1 = 3.077, SE = 0.953; T_2 = 1.687, SE = 0.953; T_3= -0.657, SE = 1.014 and T_4 = -1.581, SE = 1.038.

4.3. Results

1. Is a 24 month retention interval too long?

Figure 2 show the mean percentage performance scores for the skill assessment from pre-acquisition to retention. It highlights scores for both refresher and fresher participants. Both set of participants experience an increase in performance score from pre-acquisition to acquisition, peaking at 88% and 81% respectively. The development of skills is induced by the environment, and only the skills induced most consistently will typically be at the highest level that the individual is capable of. Analysis of skill structures plus control of environmental factors such as practice and familiarity allow the prediction of special instances of near-perfect synchrony, as well as predictions of various degrees of synchrony under differing circumstances, (Fischer, 1980). The refresher participants show 15.9% decline in performance level between the acquisition and 28-day retention, and 22.7% decline in performance level at the end of three-month. The fresher participants show 18.5% decline in performance level from acquisition and 28-day retention, and 29.6% decline in performance level at the end of three-month. Figure 2 show refresher participants outperforming the fresher participants from acquisition to retention periods which suggest the probable influence factor might be as a result of previous training and experience. The participants have an optimal level which indicates the best performance they can achieve and which is presumably a reflection of both practice and the upper limit of his/her processing ability.

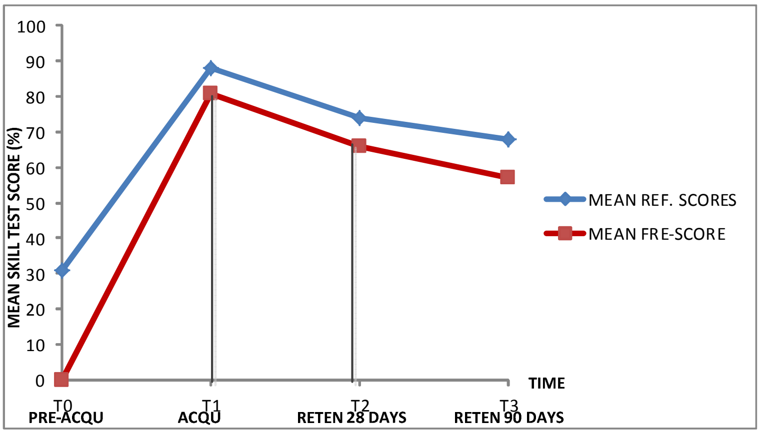


Figure 2: Mean score for skill assessment for refresher and fresher participants

Figure 3 show the mean percentage scores for the knowledge assessment across the assessment period from pre-acquisition to retention for both refresher and fresher participants. Both sets of participants display steady increase in knowledge score from pre-acquisition to acquisition averaging at 95% and 98% at acquisition. The refresher participants show 8.42% decline in performance level between the acquisition period and 28-day retention and 10.53% decline in performance level at the end of three-month. The fresher participants display an 18.4% drop in performance level from acquisition period and 28-day retention, and 21.4% drop in performance level at the end of three-month. Though this study reveals that at acquisition, both refresher and fresher participants can attain almost the same level of peak performance which in this case averages out at 95% and 98%, over the retention periods, the probable impact of previous trainings and experience of the refresher participants seem to enhance their ability to retain some knowledge longer than fresher participants. It shows that development is relatively continuous and gradual, and the participants are never at the same level for all skills, (Fischer, 1980).

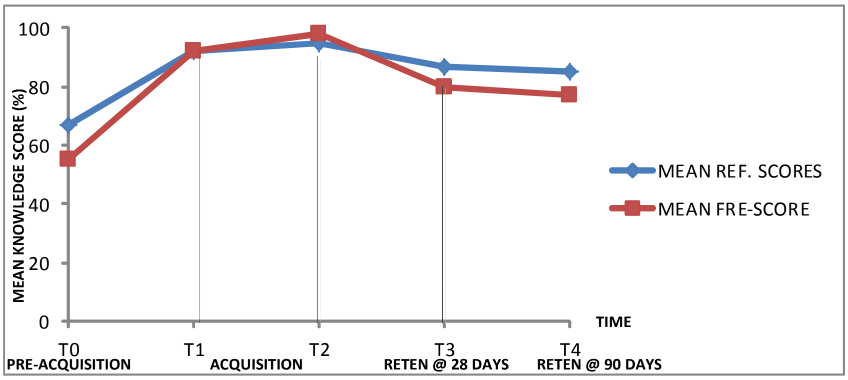


Figure 3: Mean score for knowledge assessment for refresher and fresher participants

2. **What is the magnitude of procedural skill and knowledge decay over a three-month non-practice period and its safety implications?**

The education sector has a history of setting 75% as the benchmark for passing score (McKnight , 1999). The magnitude of procedural skill and knowledge decay are shown (see Tables 5 & 6). The refresher participants show an average of 15.9% decline in skill performance score after 28-day and 22.7% after a period of three-month while the fresher participants show an 18.5% and 29.6% decline in skill performance level. The magnitudes of knowledge decay for refresher participants was 8.4% after 28 days retention and 10.5% after three months while that of the fresher participants are 18.4% and 21.4% respectively, (see Tables 5 & 6). Extrapolated results for skill and knowledge decay at 24 months was based on the initial performance of refresher participants assessed before undergoing the height safety and rescue training, (see Fig. 4).

Table 5: Magnitude of skill decay over one and three month period – Skill assessment

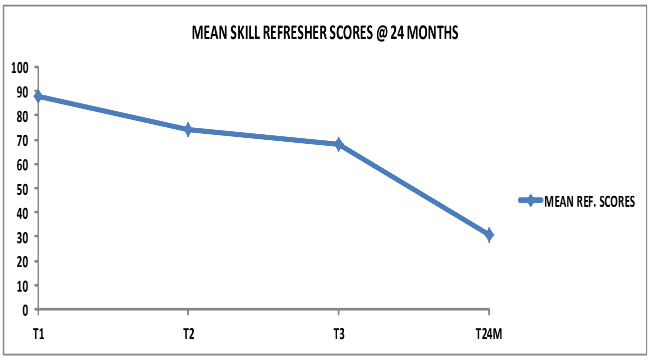
Time	Skill performance (%)		Magnitude of decay (%)	
	Refresher	Fresher	Refresher	Fresher
T_0	30	0		
T_1	88	81		
T_2	74	66	15.9	18.5
T_3	68	57	22.7	29.6
*T_{24M}	*30	*	*65.9	*

*T = extrapolated time at 24 months

Table 6: Magnitude of knowledge decay over one and three month period – Knowledge assessment

Time	Knowledge performance (%)		Magnitude of decay (%)	
	Refresher	Fresher	Refresher	Fresher
T_0	67	55		
T_1	92	92		
T_2	95	98		
T_3	87	80	8.4	18.4
T_4	85	77	10.5	21.4
*T_{24M}	*67	*	*29.5	*

*T = extrapolated time at 24 months



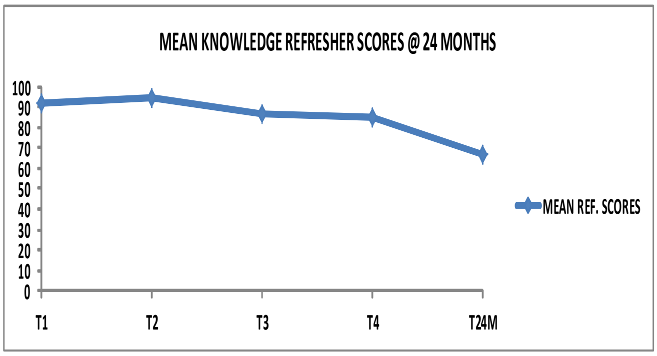


Figure 4: Extrapolated means for skill & knowledge score for refresher participants at 24 months

3. **Does forgetting over the three-month period occur at different rates for refresher and fresher participants?**

Figures 2 & 3 indicate that 'forgetting' for refresher and fresher participants occurred at different rates over the three-month period. The refresher participants over the course of the assessment session had a better performance level than the fresher participants in the skill and knowledge tests. Tables 5 & 6 also replicate the raw mean scores for both set of participants over the assessment period and the differential rates of decay.

5. Discussions

Firstly, the preliminary results show that skill and knowledge retention of wind technicians in the use of rescue device (type RG9A) for emergency rescue and evacuation declined rapidly within 28-day after acquisition and moderately towards the three-month retention interval. This result show some similarity with the works of (McKenna & Glendon, 1985), whose report revealed that less than a 25% of their trained personnel were skilful at performing the procedural task six months after training. Wisher et al., (1991), also found in their reports that knowledge about job decayed mostly within 6 months while skills decayed mostly after 10 months; though they did not quantify how much decay. Although (Marmie & Healy, 1995) recorded significant decline in retention rate from their studies within one-month and six-month retention test, they stated it was statistically significant. Another study by Osborne et al., (1979), cited in (Hagman & Rose, 1983) found that with uncued steps at the beginning and end of a process, as well as those addressing safety and those judged to be "difficult", they are least likely to be recalled. There are conflicting results from literature in the consideration of the rate of retention of cognitive/procedural skills. Some studies have found that these skills are less prone to decay (Arthur Jr., et al., 1998) however this is in contrasts to report by (Driskell, et al., 1992) who found that they deteriorate quicker than motor skills. Wisher et al., (1999) stated that cognitive skills "tend to be stable for long periods over time however people do exhibit forgetting". One of the main factors, whether direct or an intervening variable, is the time interval between training and performance. It is therefore not a surprise that the longer the time between practice and performance, the greater will be the skill loss. Studies have consistently found skill loss over time where performance decreases rapidly soon after training then occurring at an increasingly slower rate, which seem to be the case for this study, (Arthur Jr. et al., 1998, Wixted & Ebbesen, 1991). According to (Driskell et al., 1992, Wixted & Ebbesen, 1991), this pattern appears to be consistent across a variety of skills and tasks.

Secondly, the magnitude of skill and knowledge retention appeared to decline rapidly within the first three-month, though this is most significant in skill than knowledge. A common argument regarding this is based on the feedback the trainees received during acquisition. When such feedback contains information about the magnitude and direction of performance errors, then it directs the trainees towards ways of correcting the error and improving performance. The impact of skill decay or knowledge loss has also been associated with infrequent or the total absence of feedback (Hurlock & Montague, 1982, Driskell et al., 1992). The kinds of feedback provided to the trainees during acquisition affect retention, depending on the content of the information.

Thirdly, 'forgetting' over the three-month period occurred at different rates for refresher and fresher participants. The refresher participants tend to perform better on average than the fresher participants. This is shown in the mean scores for both skill and knowledge tests (see Figures 2 & 3, Tables 5 & 6), where the refresher participants outperform the fresher participants in both skill and knowledge retention tests. It should be noted that the degree of successful performance of an individual on any of these tests is largely dependent on the learning experience, or the type of practice and instruction received. Shields et al., (1979) identified amongst other factors accountable for most of the differences in retention that most task steps that are forgotten tend to be those that are not suggested by the previous sequence of steps or by the equipment. The initial level of learning which is obviously related to the amount of initial training is one of the most important factors in determining retention (Hurlock & Montague, 1982). An individual's level of initial proficiency has a direct relationship with the level of skill retention, and relation between recall success and skill level (Watson & Fischer, 1977).

6. Conclusions

In accessing the relative costs and benefits of sustaining procedural skills, extra training enhances retention regardless of whether it is during initial training or conducted as a refresher course afterwards. It is recommended that fresher participants receive earlier refresher training to improve their proficiency based on these results. At the moment, there is no consideration of this factor. These could be simulation-based, which has been found to increase the retention rates over a longer time frame. Feedback during the acquisition of skills which highlights the magnitude and direction of performance errors should be embedded in training as it is found to impact retention rate negatively when absent. Forgetting over a three-month period was also found to vary between the refresher and fresher participants. This effect can be related to the level of initial learning which is obviously related to the amount of initial training received by the refresher participants. Further work will have to be done to determine a desirable failure threshold for the trainees involved in the use of the rescue and evacuation device during emergency situations. This is amongst the pressing questions that the future investigation will be attempting to define.

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