WIND TURBINE RESCUE: EMERGING SKILL RETENTION ISSUES AND CHALLENGES

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The wind energy sector is becoming an increasingly important one for those involved in construction and with the increasing number of technicians employed in the industry, issues of occupational health and safety becomes of paramount interest. This paper explores the occupational health and safety challenges in the wind energy industry in relation to wind technicians' safe and competent use of a rescue and evacuation device in emergency situations whilst working at height. The study reported here evaluated the magnitude of procedural skill and knowledge retention over a three-month period after acquisition; the significant factors influencing procedural skill retention during safe rescue and evacuation; and the impact of cued recognition/recall methods on skill retention. Thirty trainees fully participated in the retention study at intervals of 28 and 90 days. The results suggest that refresher participants should undertake rescue and evacuation practice drills between three and six months after acquisition while fresher participants should undergo practice drills within the first three months. The contributing factors influencing the technicians' procedural rate of retention are the length of time after acquisition and practice, experience, feedback and it is advisable that cues be embedded within the training because with fundamental cues, there is increased retention of procedural tasks. This has implications for the wider construction industry where work at height in harness are carried out in isolated places.

Keywords: competency, rescue and evacuation, skill decay/retention, refresher and fresher, cued recognition/recall.

INTRODUCTION

Construction within the wind energy industry is hazardous and with the on-going growth and large numbers of turbines being built, issues of competency of qualified technicians become increasingly important as wind competes with other industries. With the growth of EU's wind energy and as the number of technicians employed in the industry continues to increase, issues of occupational health and safety becomes of paramount interest (EU-OSHA, 2013), and an integral part of the work life cycle. One obvious hazardous activity is working at height, which is often performed using harness equipment in remote areas. The management of wind farms must therefore take into account the competency of those technicians working on such structures as comparable to other industries.

Regulatory requirements such as Management of Health and Safety at Work Regulations 1999, (Reg. 8); and others identify the need for operational wind farms to have a secured and effective emergency response to incidents/accidents affecting

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persons on an onshore or offshore installation or engaged in activities in connection with it. Currently, there is no strategic incorporation of emergency response units and international consistency within the wind industry. Therefore, the initial response in times of emergency rescue and evacuation solely depends on the skills of the technicians and these skills make up part of their basic safety training.

The GWO, (Global Wind Organisation Standard, 2013) and RUK (RenewableUK, 2014) have been involved in developing a common training standard for the wind energy sector. These have resulted in the development of a standard for basic safety training which covers aspects such as first aid, manual handling, working at heights, fire awareness and offshore sea survival. Within the EU, the European wind turbine standard (BS EN 50308:2004) which is the current legislative development in the wind energy industry does not take appropriate account of offshore facilities, turbine erection, access hatch sizes and machinery guards to emergency escape lift requirements and lighting, though a revised update is being worked on which will ensure that safety is considered from the start of the turbines' life cycle.

The reliable and safe operation of a wind turbine rescue and evacuation device requires the use of a number of engineering safety features which is similar to other engineering devices and the significance of a wind technician to be trained, competent and respond to initial onshore or offshore rescue emergency situations cannot be over emphasized. Though 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. RUK standards) are likely to be regarded as a 'benchmark of good practice'. Within the wind industry, benchmark standards have been developed by the industry to address significant risks specific to the wind sector and these are supported by suitable third party accreditation systems like RUK Training Standards and GWO – Basic Safety Training.

The legislations relevant to Health and Safety training include but are not limited to the following: Health and Safety at Work etc. Act 1974, Health and Safety (First Aid) Regulations 1981 (as amended), Lifting Operations and Lifting Equipment Regulations 1998, Management of Health and Safety at Work Regulations 1999, Manual Handling Operations Regulations 1992 (as amended), Work at Height Regulations 2005, and Provision and Use of Work Equipment Regulations 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).

This paper explores the emerging skill retention issues and challenges faced by wind turbine technicians in procedural use of a standard rescue and evacuation device, (type RG9A – see Figure 2). Skill decay or retention is the progressive deterioration of knowledge and skill 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, Jr, *et al*, 2007). According to Tarr (1986) in Kim, *et al*., (2007), surveys have shown that personnel in technical jobs mostly perform procedural tasks. Procedural tasks are those that involve a number of coherent steps that may include any combination of cognitive and motor skills, (Stothard and Nicholson, 2001). Konoske and 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.

Consequently, the objective in relation to emergency rescue and evacuation was to study skill retention using cued recognition and recall processes and observe the skill retention path and impacts on the research participants who work at height. Retention which is the outcome of successful learning is typically evaluated by having the learner recognize, recall, repeat or reproduce skills they have acquired. Retention can be assessed both directly and indirectly, by employing recognition tests and priming paradigms respectively, (Schacter, 1992; Fischer and Yan, 2002). Though complex procedural tasks have been found in general to be more fragile, the importance of intrinsic cues in overcoming this problem was 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, which contributes to the recall of complex tasks.

Flexer and Tulving (1978) stated 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. Though different retention measures can yield different degrees of superficial retention, recall tests are usually of lower scores than the recognition tests (Farr, 1986). Therefore, this study designed its retention method by blending cued recognition and recall techniques using pictographic displays as the tool of assessment and monitor the rate of skill decay within an interval of one and three-months after acquisition, (Hancock, 2006; Meador and Hill, 2011).

The hypothesis is that after the initial skill and knowledge acquisition 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 decay in times of significant emergencies except where there is a support system available to the technicians.

RESEARCH QUESTIONS

This paper addresses the following questions:

8. What is the magnitude of procedural skill and knowledge retention over a three-month period after acquisition?
9. What are the significant factors influencing procedural skill retention during rescue and evacuation?
10. Does cued recognition/recall method influence the retention of skills?

METHODS

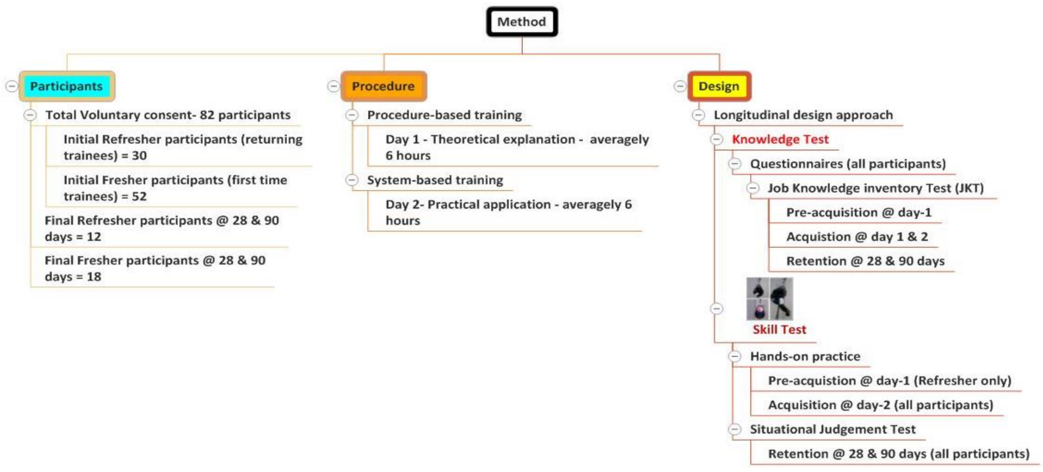


Figure 1: Method of data gathering using basic map explorer

The research participants were those registered to undergo the basic RUK/GWO approved height safety and rescue training and the study recruited a total of 82 wind technicians in three phases: 27 in phase-1; 26 in phase-2; and 29 in phase-3. The training involved procedure- and system-based training averaging 6-hours per day over two-day sessions with emphasis on emergency rescue, how to approach rescue situations in wind turbine generators (WTG) and competent use of rescue equipment.

The research implemented longitudinal design approach for data gathering (de Vaus, 2001) 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 evaluation from pre-acquisition to retention. The knowledge pre-acquisition test was administered before day-1 training session, while the two acquisition tests were after day-1 and day-2 sessions. Retention measures using JKT was administered online at intervals of 28 and 90 days.

Hands-on practical scenarios were used during skill pre-acquisition and acquisition stages using the automatic constant rate descender (CRD) RG9A (see Figure 2). Only refresher participants (returning trainees) were assessed during pre-acquisition stage because they have used this device in previous training sessions. Data for skill acquisition was collected for all participants (refresher and fresher) after day-2 training session. Skill retention assessment at 28 and 90 days was administered online using 'Situational Judgment Test' (SJT) (Lievens *et al*., 2008), with cued recognition/recall and pictographic displays by prompting the participants to correctly work out the step-by-step sequence and procedures of using the RG9A rescue device. 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 during rescue and evacuation.

JKT is a well-known method for assessing the effectiveness of, or need for training (Paulin, *et al*., 2002; Lievens *et al*., 2008). 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. SJTs are a type of psychological test which present the participants with realistic, hypothetical scenarios (Lievens *et al*., 2008) and requires the individual to identify the most appropriate response or to rank the responses in the order they feel is most effective and operational.

Figure 2: Automatic constant rate descender (CRD) RG9A

PRELIMINARY RESULTS

This research having been piloted, reviewed and amended is based on results of 30 research participants that fully participated all through the assessment period. This reflected an overall response rate of 36.6% out of a total of 82 initial research participants.

1. What is the magnitude of procedural skill and knowledge decay over a three-month period after acquisition?

The education sector has a history of setting 75% as the benchmark for passing score (McKnight, 1999). For the magnitude of procedural skill and knowledge decay presented in Tables 1 and 2, the refresher participants show an average of 15.9% and 22.7% decline in skill performance after 28 and 90 days respectively while the fresher participants show 18.5% and 29.6% decline in skill performance, (see Table 1). The magnitudes of knowledge decay for refresher participants were 8.4% and 10.5% after 28 and 90 days while the fresher participants were 18.4% and 21.4% respectively, (see Table 2). Result of refreshers' skill (65.9%) and knowledge (29.5%) decay at 24 months after training was based on the mean preliminary performance of refresher participants during pre-acquisition before undergoing the height safety and rescue training (see Fig. 3). Figure 3 estimates that at 24 months after acquisition, refresher participants will be performing at averagely 34% skill and 67% knowledge competency.

Table 1: Magnitude of skill decay over one and three month period – Skill assessment

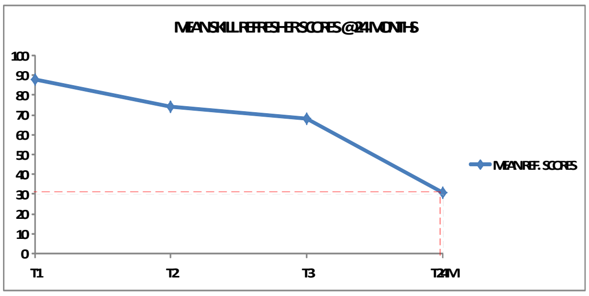
	Skill performance (%)		Magnitude of decay (%)	
Time	Refresher	Fresher	Refresher	Fresher
T_0	30	0		
T_1	88	81		
T_2	74	66	15.9	18.5
T_3	68	57	22.7	29.6
*T_{24M}	*30	*	*65.9	*

*T = extrapolated time at 24 months

Table 2: Magnitude of knowledge decay over one and three month period – Knowledge assessment

	Knowledge performance (%)		Magnitude of decay (%)	
Time	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



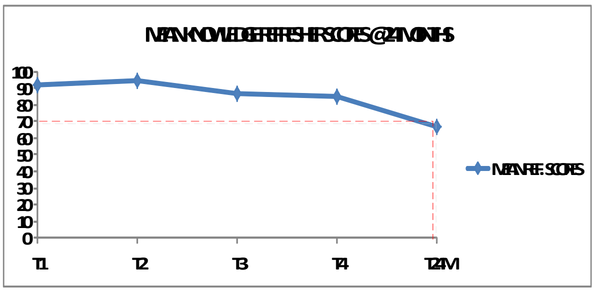


Figure 3: Estimated mean skill and knowledge competency plots for refresher participants at 24 months

2. What are the significant factors influencing procedural skill decay during rescue and evacuation?

Figure 4 show mean performance plots for skill assessments. Refresher participants display significant increase in performance scores from pre-acquisition to acquisition, peaking at 88% while fresher at acquisition show 81% competency. Analysis of skill structures plus control of environmental factors such as practice and familiarity allowed the prediction of special instances of near-perfect synchrony during acquisition, as well as predictions of various degrees of synchrony under differing circumstances, (Fischer, 1980). The refresher participants outperformed the fresher participants from acquisition to retention periods and these suggest the probable influence factor might be as a result of prior training and experience. Table 3 illustrate the mean relative effect of experience on performance scores for both refresher and fresher participants.

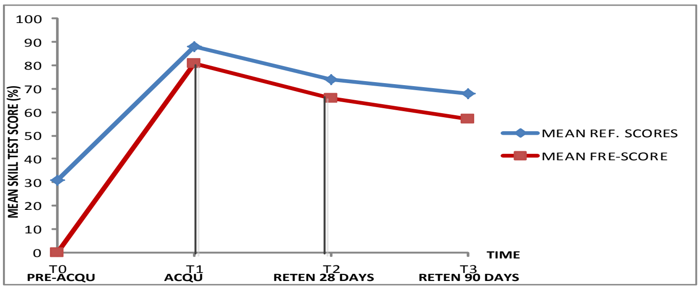


Figure 4: Mean score for skill assessment for refresher and fresher participants

Table 3: Experience of participants versus performance scores – Skill assessment

		Experience in Years					
Skill Test		0-1	2-3	4-5	6-7	8-9	10 +
Mean performance score %	**Refresher**		73.34 (4)	85 (2)	55 (2)		85 (4)
	Fresher	68.89(15)		62.22(3)			

(*) = number of participants within each group

Figure 5 and Table 4 both illustrate the mean performance scores for knowledge assessments. Figure 5 shows that development is relatively continuous and gradual, and the participants are never at the same level for all skills, (Fischer, 1980). Both sets of participants displayed steady increase in performance scores from pre-acquisition to acquisition averaging 95% and 98% respectively. Though this study demonstrate that at acquisition both set of participants can attain comparable levels of peak performance; over the course of retention, preceding trainings and experience of refresher participants (Table 4) seem to enhance their ability to retain knowledge longer than fresher participants. According to Stothard and Nicholson (2001), an individual's level of initial proficiency has a direct relationship with the level of skill retention.

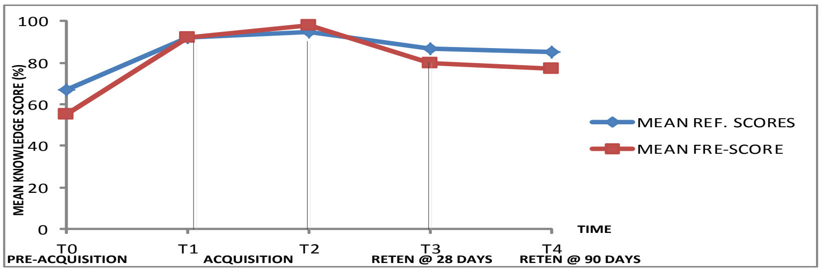


Figure 5: Mean score for knowledge assessment for refresher and fresher participants

Table 4: Experience of participants versus performance scores – Knowledge assessment

		Experience in Years					
Knowledge Test		0-1	2-3	4-5	6-7	8-9	10 +
Mean performance score %	**Refresher**		87.94(4)	93.75(2)	91.25(2)		87(4)
	Fresher	85.93(15)		87 (3)			

(*) = number of participants within each group

3. Does cued recognition/recall method influence the retention of skills?

The tests for retention typically involve using the recall test or recognition test. As shown in Figures 4 and 5, 'forgetting' for refresher and fresher participants occurred at different rates over the assessment period. Based on the proposed benchmark score of 75% and implementing cued recognition and recall methods of assessment, the refresher participants had average performance scores of 68% (skill) and 85% (knowledge) while fresher participants scored 57% (skill) and 77% (knowledge) at 28 and 90 days retention respectively. Overall, the refresher participants performed better than the fresher participants in both skill and knowledge tests. However, despite the influence of cued recognition and recall methods employed, it is considered essential that the absence of repetitive practice drills, experience and feedback seem to be contributing factors influencing the performance level of these participants.

DISCUSSION

The results identify that the magnitude of procedural skill and knowledge retention over a three-month period declined rapidly within 28 days after training and gradually toward 90 days. This result is comparable with the study of Wetzel, *et al*., (1983) which reveal that immediately after training and a four weeks interval, participants had a 21% drop in scores although Austin and Gilbert, (1973) observed a 16% loss of basic problem solving skills after 8 weeks. A common construct regarding this is based on the feedback the trainees receive during acquisition (Ramaprasad, 1983; Gibbs and Simpson, 2004; Sadler, 2010). When such feedback contains information about the magnitude and direction of performance errors, it directs the trainees towards ways of correcting the error and improving their performance while the infrequent or the total absence of feedback is associated with skill and knowledge loss, (Hurlock and Montague, 1982; Driskell *et al*., 1992).

Learning is characterised by an initial steep learning period that asymptotes to maximum proficiency, while forgetting is characterised by an initial steep drop in proficiency, which then levels off, dropping more slowly as time goes on (Stothard and Nicholson, 2001). According to Stothard and Nicholson, (2001), the major decay in skill occurs in the first few weeks/months after training, with smaller differences over time. Their findings which is comparable to the results of this paper claimed that instructors believed the drop in proficiency for a variety of skills was greater between time zero and two months, than between the sixth and eight month. Although, there are conflicting results from literature in the consideration of the rate of retention of cognitive skills, Arthur Jr., *et al*., (1998) have found that these skills are less prone to decay validating this research results. 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"*, thus substantiating the findings reported in this paper. 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 training and performance, the greater will be the skill loss. Other contributing factors to procedural skill decay of wind technicians could be associated to their peripatetic nature of work, practice, aptitude, equipment design and task difficulty. Sufficient learning leads to expertise (Stothard and Nicholson, 2001) and an expert organises their knowledge and skills qualitatively differently from a novice. Since safe working requires robust procedures, it is suggested that training and experience are the major contributing factors influencing procedural skill decay during rescue and evacuation.

Osborne *et al*., (1979), cited in Hagman and 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. The principle of encoding specificity states that cues for retrieval will be effective if and only if encoded at the time of learning (Tulving and Thomson, 1973). Applying this to skill retention, perceptual and cognitive cues are required to regain and perform learned skills (Bryant and Angel, 2000), and in the absence of such cues during recall, performance will suffer. A reflection of this is in increased retention of procedural tasks; with better retention of tasks with intrinsic cues and specific ordering (Hagman and Rose, 1983). Memory or job aides also help in performing and retaining skills while time limits can constrain the recall of a skill (Arthur *et al*, 1998). In addressing the proposal of procedural reinstatement, Bryant and Angel, (2000, pp. 29) stated that *"if training employed a job aid or checklist to aid learners in sequencing steps, that aid will be an important cue needed to reinstate the skill at a later time"*. Though this study validates the significance of cued recognition/recall methods, it also found that one of the major predictors of skill loss is task complexity which includes number of steps in a task, whether the steps must be performed in a set sequence and whether there is any built-in feedback that indicates the correct performance steps.

CONCLUSIONS

Using the proposed benchmark performance level of 75%, it is therefore expected that refresher participants should undertake rescue and evacuation practice drills within three to six months after acquisition. For fresher participants, it is recommended that they undertake an early refresher practice drill within 28 and 90 days after skill acquisition to restore their proficiency to a relatively acceptable level. Also, a 24-month retention timeframe is considered too long before technicians can embark on a full refresher training. It is therefore recommended that to keep proficiency within an acceptable limit, support systems (e.g. simulation practice drills or virtual reality training) should be available at regular intervals to the technicians after skill acquisition. However, if there are no support systems in place, the technicians have the tendency of forgetting how to use the device in the event of a 'live emergency' rescue and evacuation.

The most significant factors that influence the technicians' procedural rate of retention are considered to be the length of time after skill acquisition, experience, training, feedback and practice. The retention rates for the refresher and fresher participants are different, with the refresher trainees outperforming the fresher trainees at most levels of assessment. The impact of skill retention is more significant in skill (motor) than knowledge (cognitive) tasks. The longer the time interval between training and performance, the greater will be the skill loss.

Though cued recognition/recall method positively influences the retention of skills based on the participants' performance, it is advisable that such cues be embedded within the training because with intrinsic cues, there is increased retention of procedural tasks. Also, if simulation practice drill or virtual reality training is introduced, this will have the potential of increasing the technicians' retention rates over longer timeframe. Finally, skill decay is an obvious problem and with the low probability of rescue and evacuation happening, it is recommended that the proficiency of the technicians be kept at its optimum.

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